Practical Report for Alleviating Social Exclusion of Waste Pickers and Improving Community-based Waste Management Capacity through Conducting Environmental Education by Collaborating with Multi-Stakeholders in Khulna

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ABSTRACT
Khulna City has difficulty in proper waste management for want of waste management education and lack of multi-stakeholder involvement. "Waste Pickers" pick up valuable materials such as plastic bottle, metals, battery, etc. from waste dumping sites, separate them; circulate them in society. Despite they work in poor waste condition, society tends to exclude them. To alleviate the problems, JEEF and BEDS hunted a project "Develop a model case of the waste management in Khulna City, focused on the waste pickers and waste management education" from October 2015 to September 2018. We already presented project progress in "Waste Safe International Conference 2017". In this conference, we focused on Environmental Education (EE) on waste management for schools, income generation efforts of the waste pickers, brief of three years. In addition, we suggest future direction for improving the waste issues in Khulna City to realize the social inclusion of waste management collaborating with the related multi-stakeholders, by organizing the outcomes and lessons from the practical activity for three years.

WASTE PICKERS IN KHULNA CITY
Khulna is the third largest city in Bangladesh. Khulna has more than 1.5 million populations. According to Khulna City Corporation (KCC), every day 526 metric ton waste is produced in Khulna city. According to our baseline survey on waste pickers and interview to KCC, approximately more than 1,000 waste pickers are working in the primary, secondary and final dumping sites in and around Khulna city. In this project, we targeted 40 families of waste pickers who are working in the ward no. 17, 24 and Rajbandh final damping sites. Mainly, the waste pickers seriously face with the following issues.

(1) Unhygienic working environment; insufficient sanitation education and safety equipment such as mask, gloves, long boots, etc.
(2) Social discrimination and prejudice from the society.
(3) Frequently suffer from health problems such as itching, breathing, diarrhea, chronic diseases.
(4) Poor income generation.
(5) Lack of waste management in collaboration with the waste management stakeholders such as KCC, community people, schools, NGOs etc.

In these circumstances, in the first year, we formed multi-stakeholder based Waste Management Committee (WMC) involving KCC, Khulna University, Target Community representatives, Department of Education of Khulna Division, Department of Environment of Khulna Division, School Students-teachers, Doctor and Journalist etc. and they actively participated in various Waste Management activities; Formed Waste Pickers' Workers Cooperative Society Ltd. involving 40 waste picker families (government registration: No. 28/K), Conducted training on health and sanitation & literacy education program (30 times) etc.

PURPOSE OF THE PROJECT

The purpose of the project for three years is to make a model case of the social inclusion on the waste management collaborating with the related multi-stakeholders. We already presented the implemented contents of the first year's project on the Waste Safe 2017–5th International Conference on Solid Waste Management in South Asian Countries from 25-27 February 2017, Khulna, Bangladesh, so please refer to document 1. This time we especially focused on second and third year's activities such as environmental education program of schools and livelihood improvement of waste pickers.

Waste Pickers in Rajbandh final damping site of Khulna City

AT A GLANCE OF ACTIVITIES AND OUTCOMES

Second Year Activities and Outcomes	
(1) Conducted a Study Tour on Community Waste Management in Rajshahi.	Waste pickers of Khulna City visited Rajshahi and they exchanged opinions on waste management with the stakeholders of Rajshahi. Waste pickers of Khulna City also provided the sanitation training to the waste pickers of Rajshahi. The participants could raise their awareness for the role of the waste pickers in the society and for the importance of public sanitation.
(2) Developed environmental education materials and conduct activities on environmental education (including the teacher's training on how to conduct the environmental education activities) in the elementary & secondary schools including Waste Pickers, community.	40 schools practiced waste management issues and are still practicing. Students learnt the role of waste pickers and their importance, 3R – Reduce, Recycle and Reuse, to keep degradable and non-degradable waste separately at home. Waste pickers also participated in the school activities and they practiced the waste separation. Each school prepared action plans on waste management to keep their schools clean.
(3) Conducted cleanup activity including Waste Pickers.	Participatory based cleaning activities were conducted in 40 schools and in Nirala Residential area of Khulna city involving waste pickers, KCC, Nirala Janokallan Samiti, school teacher, students and general people, involving the waste pickers.

Visiting final dumping site in Rajshahi

Health and sanitation training to Rajshahi waste pickers

Meeting with Rajshahi City Corporation mayor



Environmental Education program together with waste pickers



Cleaning activities in schools and Nirala residential area

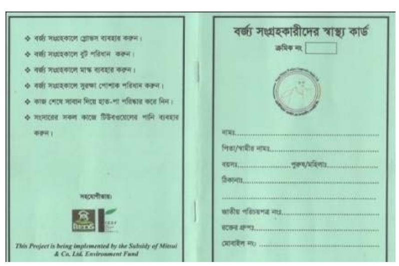



Developed Environmental Education (EE) materials
Left: Carta, Upper right: Flip card, Bottom right: Board game

Third year Activities and Outcomes	
(1) Conducted a pilot project on formal distribution channel of valuable waste for Waste Pickers cooperative.	Paper box making was introduced to the waste pickers as an alternative livelihood. Second paper was used to make paper box. Market chain was developed to sell the paper boxes. Waste pickers families increased their income at least 25% through making paper box.
(2) Held a policy meeting on how to involve waste pickers in waste management of Khulna City Corporation.	Involving more waste pickers in house to house waste collection and separating waste from different primary waste dumping sites was discussed with the Waste Management Committee members. Actually, KCC involved some waste pickers in their fecal sludge management plant and in cleaning roads. In addition, waste pickers were receiving health treatment facilities free of cost from KCC.
(3) Organized Waste Management Forum in Khulna to highlight the outputs of the project activities and on future direction of waste management of Khulna city	140 people participated in a Local Waste Management Forum and it spread the importance of the idea that waste management by cooperating with Waste Pickers, government, and local residents, etc. play an important role in creating the social inclusion. Department of Environment of Khulna Division, Department of Primary Education and Higher Education of Khulna Division, KCC, 40 Primary and Secondary schools, Department of Cooperatives participated in the Forum.
(4) Created an action guideline on waste management in the community society targeting at Waste Pickers by Waste Management Committee.	A guideline was created on an action guideline (draft) on waste management of Khulna City including the components of waste pickers, based on the activity's outcomes and lessons for three years.

Pilot project on formal distribution channel of valuable waste

Workshop for establishing formal distribution channel of valuable waste by Waste Management Committee and Waste Pickers



Environmental education in schools

Waste pickers are receiving health treatment facilities free of cost from KCC

Waste Management Forum 2018 with Khulna City People

FUTURE DIRECTION OF WASTE MANAGEMENT OF KHULNA CITY

From our project's outcomes and lessons, we think the future direction of waste management of Khulna city according to every stakeholder may be as follows. We will have to create a model city of social inclusion waste management, recognizing each role of the related organizations on waste management and collaborating together with each other. In order to realize the social inclusion waste management, it is considered that the environmental education will play more important role in near future.

- **KCC**: Ward base Action Plan, Green and Red cards for the household owners according to their performance on household garbage management, make policy to punish people who don't follow waste management system and throw/dump waste here and there cleaning activities, Provide opportunity to waste pickers to work in secondary damping sits, deployed waste pickers in waste separation process, etc.
- **Department of Education of Khulna division**: Cultivate waste management education leaders of school teachers, waste management education for students and ward people.
- **Department of Environment of Khulna division**: Make comprehensive or cross sectoral policy for effective and efficient waste management in division.
- **University**: Conduct different research activities, cooperate to prepare policies.
- **Waste pickers**: Should separate degradable and non-degradable waste through institutional format.
- **NGOs**: Support waste pickers for waste recycling business, cooperate education department, KCC, University, regular public awareness campaign in every ward through street drama, song.
- **Ward people**: Acquire the proper waste management through environmental education program and cultivate the community environmental leaders.
- **Media Person/Journalists**: Publish article on proper waste management.
- **Doctor**: Support to the health aspect for waste workers such as KCC cleaning persons, waste pickers, etc.

CONCLUSION

Many initiative efforts on social inclusion waste management involving the community society have been started in this project duration. However, it will take more time to reduce waste pickers' social discrimination. In this project period, it is considered that it is not always sufficient to change peoples' attitude to waste pickers and waste management to make Khulna city as a model of waste management.

In order to more enhance our project's effectiveness, we need to make a system for continuously and regularly using our developed educational materials on waste management in the society, collaborating with various multi-stakeholders. Then, we could more extend the concept of waste picker's role and the necessity of waste management education to the society through involving the multi-stakeholders, using the developed educational materials on the waste management and disseminating it to the citizens. In addition, the citizens should change their mind and attitude about society and waste, by considering not "private benefit" but "community benefit" such as building social capital in the waste management. In these circumstances, education sector such as environmental education will be key methodology to solve the waste issues.

We continuously try our best so that the future direction will be implemented by together with our organized "Waste Management Committee Members", such as KCC, Khulna University, Department of Environment and Department of Education of Khulna division, Waste Pickers, NGOs, Ward people, Journalists, Doctors so that Khulna city can be a model city of social inclusion on the waste management.

ACKNOWLEDGEMENT

This project is supported by the Subsidy of Mitsui & Co. Ltd. Environment Fund and is being implemented by JEEF and BEDS.

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COMMERCIAL AND HOUSEHOLD FOOD WASTE SEPARATION BEHAVIOUR AND THE ROLE OF LOCAL AUTHORITY – TOWARDS A SMART CITY

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ABSTRACT

This article explores some of the current strategies that have been undertaken by the Local Authorities aimed at increasing commercial and household source separation of food waste, evaluating their effectiveness, and any gaps that exist in public awareness. The study was conducted in Cork, which is Ireland's largest county and comprises of 8 Municipal District Councils. The research involved 568 commercial premises located within the 22 towns and 1362 households located within the 5 towns of county Cork with a population agglomeration >10,000 in each town. A varied approach has been taken to conduct this study, mainly: (a) door to door visit and re-visit to both commercial premises and householders; (b) distribution of leaflets through the local authority offices, and also through the waste collectors to commercial premises and householders; (c) advertising in the local Medias and (d) installation of equipment for source-segregation of waste.

1. INTRODUCTION

With the annual increase in waste generation and heavy reliance on land filling as a disposal method, it is just a matter of time before significant problems of space limitations, health, and environmental issues (i.e. climate change) impact on Europe and around the world significantly. Therefore, the European Union set out Legislation under the Landfill Directive (EU Directive 99/31/EC) on prohibiting the disposal of food waste to landfill. The process of separation of food waste at its generation source is identified as effective means in reducing the purchasing of unnecessary food and in reducing the amount of food waste sent to landfill. It can be reused as feedstock to downstream treatment processes namely composting, anaerobic digestion and ultimately to recover energy and replenish soil. In addition to creating opportunities for added value and jobs, the practice of segregating food waste will demonstrate to the householders the amount of food being wasted and result in a consequent reduction. For example, in USA alone, almost 45 billion kg of fresh vegetables, fruits, milk, and grain products is lost to waste every year. According to the Environmental Protection Agency, USA (EPA, USA), the disposal of this costs approximately $1 billion (Kosseva, 2011). In the United Kingdom, 20 million tons of food waste is produced annually and a major portion of this waste ends up in the landfill. Every tonne of food waste equates to 4.5 tons of CO_2 emissions, a greenhouse gas that has negative impact on the environment. Moreover, the estimated direct cost to producers of food that goes to waste globally is currently US $750 billion annually, a figure that excludes even wasted fish and seafood [FAO, 2011]. Therefore, every local authority must take the lead through proper consultation and communication in order to get all of the stakeholders working together to achieve the target of reducing landfill waste (Audit Commission, 1997).

A number of efficient measures have taken place in many European countries such as Austria, Germany, Sweden, The Netherlands and Spain (European Compost Network, 2013) to implement food waste regulations. Strong participation of both households and commercial premises in the initial act of source-segregation is the crucial factor that is found to be the common in all these countries. Therefore, it is important also to investigate the reasons behind participation in such schemes. Numerous articles have been published in scientific journals discussing the influence related to a variety of different factors within household and commercial premises that affect the participation rate in waste recycling schemes. Factors such as (i) demographic profile (Berglund, 2005; Dietz et al., 1998; Sterner and Bartelings, 1999; Vicente and Reis, 2008); (ii) the influence of local norms and environmental awareness (Hopper and

Nielsen, 1991; Widegren, 1998; Sterner and Bartelings, 1999); (iii) implementing incentives, such as pay by weight on residual waste (Bisaillon et al., 2009); (iv) regular collection of food waste; appropriate facilities in the local amenity sites to recycle food waste; (v) education and awareness raising through seminars, conferences, local medias (radio, newspaper, television) (Williams and Taylor, 2004; Austin et al., 1993; Spaccarelli et al., 1989) have been suggested as an effective strategy in order to increase recycling. However, a number of articles have described factors that are more important than others. Anna Bernstad (Bernstad, 2014) has suggested that the installation of equipment and existence of infrastructure is crucial and a more important for source-segregation of waste compared to the use of written information: such as distribution of leaflets among the households. Wan Azlina (Azlina et al., 2013) also suggested that good moral values and situational factors such as storage convenience and collection times encourage public involvement and increase the participation rates on source segregation of food waste. On the other hand, Tom Evison (Evison and Read, 2001) suggested that education and quality promotion and publicity on a regular basis are essential for the success of any recycling scheme. Authors also mentioned that local newspapers are not always the best means of informing the public, rather local authority environmental newspapers are more efficient in forwarding the policies and strategies to the public. Many also believe that public education about waste management and recycling should be initiated by the central government or national body rather than local authority. Very recently Moh et al. (Moh and Manaf, 2014) suggested that regulatory compliance in solid waste management, such as imposing fees or charges and mandatory household recycling could be given serious consideration for the implementation of food waste recycling within household premises. In addition to civic amenity sites, authors also suggested more recycling drop-off centres at public and convenient locations such as the family shopping malls. These should be provided with effective and efficient recycling collection services.

Therefore, the aim of this study is to investigate the role of the local authority to implement and increase the source separation of food waste within both commercial premises and households, and identifying any gaps that exist in public awareness. A brown bin adviser pilot scheme has been implemented to conduct this study, where brown bin advisers on behalf of the local authority deal with food waste recycling to commercial and household premises; and build a link between local authority and waste collectors, to successfully implementing recycling policy within a specific zone. In our knowledge, very little study has been done from the local authority point of view on implementing an approach towards successful campaign of food waste recycling. This case study has been conducted in 22 towns for commercial premises, and in 5 towns for household premises with a population agglomeration of >10000 in each town. All these towns are in Cork, a County that is located in the south-west region of Ireland, with a population of 518,128 and area of 7500 km^2.

2. METHODOLOGY

The present study was conducted by the Cork County Council through brown bin adviser scheme (Fig. 1) in 568 commercial premises located within 22 towns and 1362 houses located within 5 major towns in County Cork with a population agglomeration >10000. This study also included investigations of public and private civic amenity sites and waste collectors that collect kerb site waste located within the region. The interviewee's responses were documented and a database has been prepared and analysed.

Sampling population and frame

In this study, all the commercial premises that produce food waste have been targeted within all the major towns in County Cork and for the households, the towns which have population agglomeration more than 10,000 (Table 1). In households, the number of samples selected from each town was 6%, which is directly proportional to the size of the population in each town and also different estates in each town have been selected based on their standard of living which has been taken from Geo data. Waste collectors have been contacted on a regular basis through phone, email and post. Local authority also organised a number of meetings, seminars with the waste collectors and awareness events with the local businesses and tidy town volunteers (every town in Cork, there are few locals who are volunteers to make the town tidy, this is organized by the local authority). Local civic amenity sites have been visited by the brown bin advisers and the issues involved have been documented.

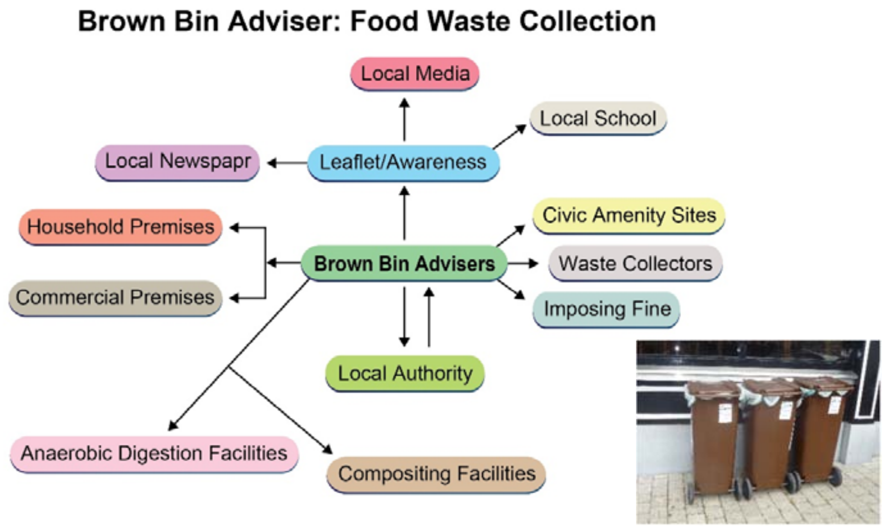

Figure 1 Flow diagram of methodology on the co-ordination of Brown Bin Adviser (inset: Brown Bins)

Questionnaire, data collection and analysis

A questionnaire was designed to determine the demographic status and intention of the respondent for the commercial premises (Supplementary Fig. S1) and for the households (Supplementary Fig. S2). A questionnaire which is designed for the commercial premises contained 10 points with their follow up details. Ultimate goal of these points to understand whether they are doing source segregation, if not then what are the next steps. Also relevant leaflets are handed to them. In relation to households, it was more advising how to use brown bin, who to contact, along with the leaflets that are provided from the brown bin advisers. Their experience and comments also have been documented and analysed. The data analysis was performed using the xl data sheets and using pivot plots. The identity of any respondent was not revealed in this study. However, this study is a cross sectional study, therefore, prevalence of the respondent's beliefs and intention would not be known. The validity of the answer given by the respondent could not be proven, therefore, assumptions will be made that the respondents are answering truthfully and all the data given is valid.

3. RESULTS AND DISCUSSION

Respondents' demographic information (commercial premises)

A total of 568 commercial premises (Fig. 2) in 22 towns within County Cork that produced food waste have been visited by the local authority as per this case study. After the first visit by the local authority advisers, average 53% premises participated in the brown bin scheme, which increased to average 81% after the second visit. However, hospitals, nursing homes and supermarkets are ahead in participating brown bin scheme from the beginning, as compared to the other types of commercial premises such as first food establishments or cafes (Table 2). First food establishments or cafes usually require more explanations, encouragement and occasionally multiple visits from local authority in participating food waste recycle scheme. In towns that are located in the remote areas, the majority of these premises were found to be reluctant to engaging a food waste collection service. It was noted that the participation rate was still less than 50% even after the second visit (Fig. 3). For ethnic commercial premises (such as Chinese, Indian), it was found to be very effective to issue letters; along with the visits; as they find it clearer, easier and reliable to understand through written communications. Among the restaurants, bars, shops – in approximately 30-40% of cases food waste is being taken by the local farmers to feed animals (i.e. dogs, pigs, hounds), which used to be the usual practice until 2001 in Ireland. However, to improve the security of food chain and to sustain food industry in Ireland, a ban has been introduced on feeding food waste to animal (EU Reg., 2014), unless individuals or company hold meat feeding license. However, this historic practice is also found to be one of the factors in delaying taking brown bin on board for the owners in commercial premises in Ireland. In this case the presence of brown bin adviser on the door has a huge impact on accepting brown bin scheme within these premises. Also follow up phone call after first visit is crucial to obtain maximum turnover during the second visit. Ultimately, reinforcing the importance of source segregation of food waste to the food producers will make a significant difference to the practice of food waste recovery. Also majority food producers find it more encouraging to do it once their peer business people practice it, and ask neighbour or colleague to use it. Fig. 3 shows types of premises

Table 1 Number of commercial premises that generate source segregated food waste at various towns in County Cork

Towns	Number of premises	Towns	Number of premises
Ballincollig*	44	Dunmanway	14
Bandon	37	Fermoy	30
Bantry	21	Kanturk	15
Blarney	7	Kinsale	45
Boherbue	2	Macroom	19
Carrigaline*	24	Mallow*	46
Carrigtwohill	4	Midleton*	40
Castletownbere	21	Millstreet	17
Charleville	15	Mitchelstown	29
Clonakilty	37	Skibbereen	23
Cobh*	40	Youghal	38

*Towns that is studied for households also (population agglomeration>10,000)

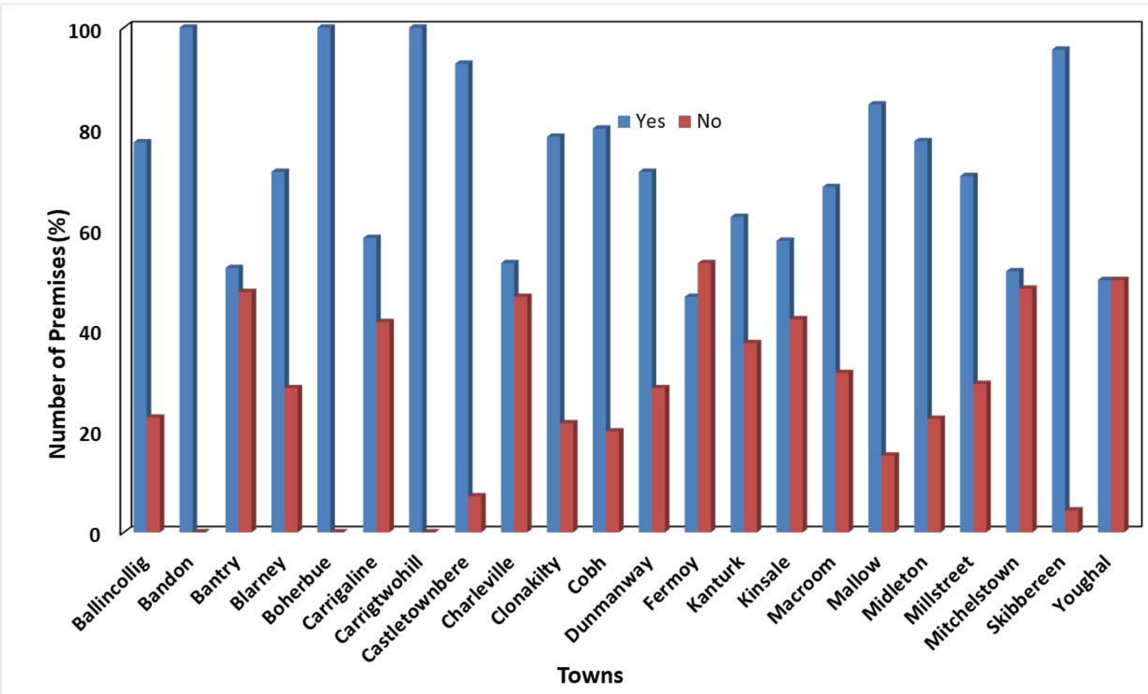

Figure 2 Brown bin status for the commercial premises at various towns in County Cork

Table 2 Types of commercial premises that are found to be compliant (%) after the first and the second visits by the brown bin advisers

Premises Type	Compliant after 1st visit (%)	Compliant after 2nd visit (%)
Bar (with food)	47	80
Cafe/Fast food	27	57
Canteen/Hostel	66	100
Hospital/Nursing Home	78	100
Hotel/Restaurant	40	62
Shop/Supermarket	54	89

that generate food waste in Cork. Cafes, fast food establishments, hotels and restaurants are found to be the major food waste producers in Cork, though rate of participation in the food waste recycling is slower within these premises compared to the other type of commercial premises, such as hospitals, bars, canteens.

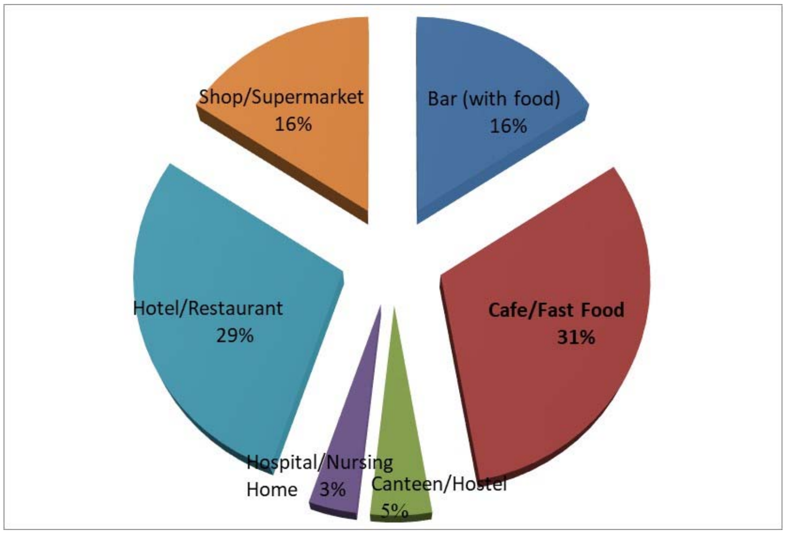

Figure 3 Commercial premises in County Cork that generate source segregated food waste

Respondents' demographic information (Households)

Brown bin advisers from Cork County Council have visited 1362 households located within the 5 largest towns in County Cork, and 29% of the households have been met by the advisers in face to face. Leaflets with contact details have been dropped to the remaining 71% houses in relation to the legislation and the procedure of food waste segregation (Table 3). After arbitrary re-inspection it has been observed that approximately 50% households participated in the brown bin scheme within 6 weeks of first visit. However, the majority households responded that appropriate collection of food waste would encourage food waste segregation at home. In particular, those households that are being provided with food waste bins and food waste being collected separately and more often than other waste, are viewed by respondents as the most encouraging approaches for them to separate their food waste at home. Furthermore, the existence of the food waste bins at home may also help increase household's perception about their neighbour's participation, which in turn encourage their

Table 3 Number of households is inspected by the brown bin advisers in County Cork

Towns	No. of Houses audited	% of Houses audited	Advising %	Leaflets only %
Ballincollig	347	6	31	69
Carrigaline	296	6	32	68
Cobh	247	6	28	72
Mallow	232	6	24	76
Midleton	240	6	28	72

involvement. On the other hand, providing composter units to each household are viewed to be less likely to be effective in encouraging food waste separation at homes. Hence, these views are strongly recommended by the public to the local authorities in order to increase participation in food waste separation. Typical questions from the households when brown bin advisers go to their door are: (i) confusion as to what to put and what not to put into the brown bin, (ii) how to clean the bin/caddy, (iii) concerns on lots of flies at home due to the food waste bin, (iv) need a wheelie bin as it is very heavy to carry, (v) will it cost any extra, (vi) problem of space for another extra bin etc. Therefore, appropriate training on preparing brown bin advisers or personnel from the local authority needed to ensure effective communication with the householders. It is also to confirm that the respondents involved with this research are in the lower, middle to higher income group, so that a community composition with homogeneous characteristics data can be generated.

Due to the presence of food waste bin at home, people also realise how much food is being wasted in a regular basis. In addition to recycling food waste, generating less food waste is also very crucial for the success of this scheme. Food for consumption goes through different phases, and there are losses at each phase. Losses occur during production and harvest (i.e. drought) stage, postharvest, handling and storage stage, packaging and processing stage, distribution and retail stage and finally consumer stages (i.e. households, restaurants etc). Introduction of food waste recycling scheme will have psychological impact and drive the consumers to reduce generating food waste. Moreover, consumers will buy durable and long lasting food items, reuse the cooked food, and will be forced not to buy unnecessary food. Also it promotes the practice of 'encouraging others attitude' on reducing food waste, or purchase exactly what consumers need. Due to extensive enforcement, 37% decrease in household waste disposed to landfill has been found in 2013 compared to 2012 in Ireland; and County Cork is following the same trend (EPA, 2013).

Civic Amenity Sites

Audits have been carried out on public and private recycling centres in County Cork aimed to review and evaluate both the site attendants and customers attitude towards food waste recycling. Location of the recycling centres are marked in Fig. 4, however, brown bin advisers visited four centres for this survey: 2 in Middleton, 1 in Cobh and 1 in Mallow. After visiting and talking to people within the sites, it has been realised that site attendants have an important role in encouraging and educating customers to segregate waste more efficiently at the respective sites. Moreover, longer opening hours, better signage and layout along with publicity, education and awareness campaigns would enable the public to use the site more efficiently. UK local authority has done a huge amount of work to improve the efficiency of local amenity sites, e.g. Lancashire County Council (William, 2004) has changed the name of the local amenity sites to Household Waste Recycling Centres that enhanced positive image of these sites within the society. Williams et al. also suggested the provision

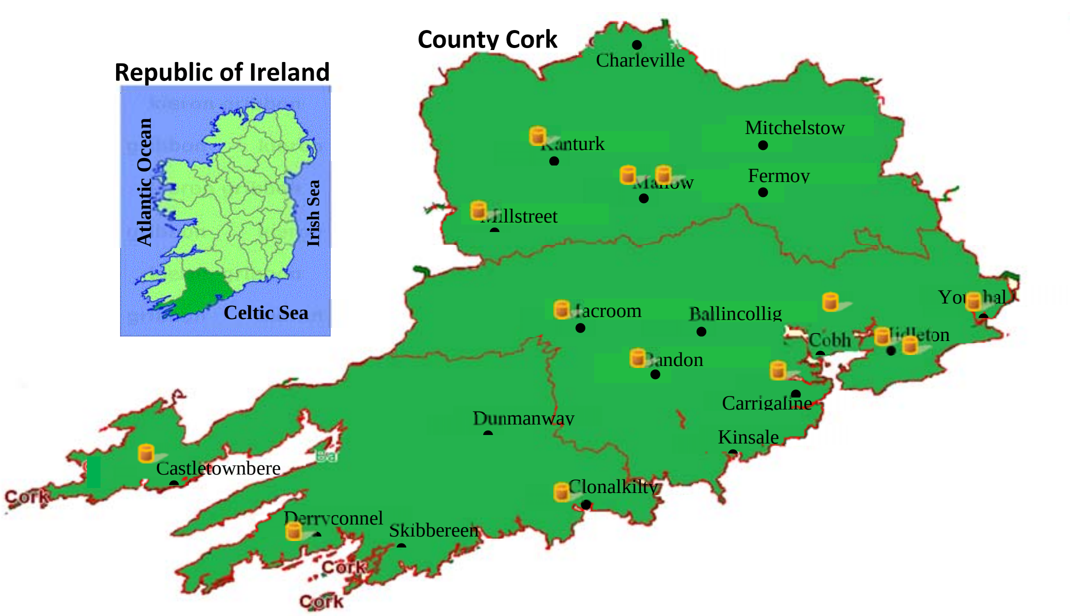

Figure 4 Public and private civic amenity sites are marked ( ) within County Cork; map of Ireland (inset). [Environ. map viewer, Local Authority]

of boxes or bin liners from the amenity sites that would facilitate pre-separation of the waste, and encourage source segregation of food waste. Table 4 details an EPA report, estimated household organic waste collected by Civic Sites in Cork. However, additional work is required and in progress to organize the Civic Sites in Cork to facilitate acceptance of source segregated food waste.

Table 4 Household waste collected at civic amenity sites in County Cork in 2013 (EPA, 2013)

Civic Amenity Sites	
Mixed residual waste (tonnes)	3,643
Organic waste (food and garden) (tonnes)	1,381
Total	5,024

Waste collectors

In County Cork there are 11 private collectors that are collecting kerb side waste at the moment and 6 of them sent out promotional materials to the customers on how to segregate food Waste, and are also collecting food waste in a regular basis. Others are in the process of organizing their route for food waste collection. Waste companies are dealing directly with their customers - both private houses and commercial premises. To facilitate the achievements set out in European Union (Household Food Waste and Bio -Waste) Regulations 2013, Waste Management (Food Waste) Regulations 2009, waste companies mentioned above produce and distribute advertising materials about new food waste bin system to inform both householders and commercial premises in relation to the time frame for the roll out of the service and educate them on using the brown bin properly to avoid contamination. Collectors will have to adhere to improved standards of service, incentivize households and business owners to segregate food waste and be much clearer about their charging structures. Local authorities must organize regular meetings and monitor the activity of waste collectors. Keeping formal and proactive relationships with the waste collectors are crucial on success of this scheme. An estimate of organic waste collected has been reported by EPA in 2013 (Table 5). However, it is expected that food waste collection will increase significantly in 2014 in Cork due to this awareness programme.

Table 5 Estimated Organic (Food/Garden) Waste Component of Collected Household Waste-2013 (EPA, 2013)

Area	Kerbside collections (in tonnes)	
	Mixed/residual collection (black bins/bags)	Organics collection (brown bins)
Cork County	54,282	234
Southern Region	240,404	16,593
National sub-total	737,782	83,389

Public Awareness

Public awareness is initiated by the Cork County local authority through brown bin advisers and through the Environmental Awareness Section. Brown bin advisers met both people in commercial premises, and households through door to door visits, organised 6 seminars in different locations under the banner such as ‘Stop Food Waste’, ‘What’s in your Bin’ in collaboration with Environmental Awareness Section. In some cases, assistance has been provided by respective tidy town committees, and local grocery shops such as ‘Supervalu’ (chain super market in Ireland) to conduct the awareness campaign. Cork County Council also sent the message to the public through local radio stations, posters, newsletters, newspaper adverts. It has been found that methods where residents are contacted and informed personally are significantly more effective than information delivered in more traditional approach (such as leaflets only, media etc). Similar trend also have been found by another study conducted by Read (Read, 2000). However, we have found that a common ground is created first by promoting the message through media, leaflets and posters (entrance of every town), followed by door to door visit – this ensured maximum efficiency, compared to any other method alone. Grodzinska (Grodzinska et al., 2003) suggested that public lack of knowledge was a serious barrier to the successful implementation of food waste recycling. Before residents fully acknowledge the waste problem in the County, they do not feel responsible for the waste they produce or feel compelled

Table 6 Case study on cost status within a small cafeteria before and after using brown bin

Bin Status	Before brown bin				After brown bin			
	Collection frequency / month	Vol. of Bin/L	Cost/ collection €	Total cost/ €	Collection frequency/ month	Vol. of Bin/L	Cost/ Collection €	Total cost/ €
General Waste	4	240	28	1344	1	240	28	336
Recycle Waste*	4	240	6	288	4	240	6	288
Food Waste	NA	NA	NA	0	4	120	9	432
Total cost / year (€)	1632				1056			
Cost saving/year (due to using brown bin) (€)					576			

*Recycle Waste: paper, card board, dried plastics, tins etc.

to participate in any schemes being provided. Knowledge about the availability of recycling programs and facilities is necessary for effective participation of the people in food waste recycling (Sidique et al. 2010). That's why the implementation of the scheme was accompanied by awareness program. Siddique (Sidique et al., 2010) also suggested that the effectiveness of the food waste recycling scheme relied upon improved understanding and higher participation by the people. Greater information and education programs and increasing the accessibility of recycling facilities are the best means of promoting positive attitude to recycling, and help to remove barriers preventing residents from food waste recycling. However, public awareness programs should not be a one off and must be continued after the initial implementation (Perrin and Barton, 2001). Since cost is one of the important factors in taking the brown bin on board, particularly for the commercial premises, it is important to explain by providing real life examples on cost effectiveness of using food waste or brown bin. In this work, a case study has been developed based on a small cafeteria located within Ballincollig in County Cork (Table 6). With the participation of the brown bin scheme a small scale cafeteria can save around €576 in a year. Providing this case study to the similar commercial premises was found to be very effective in encouraging participation in the source segregation of food waste.

Small community garden compost sites are another form of solution to recycle food waste efficiently. Encouragement from Local Authorities for such development can create positive attitude within the community on food waste recycling. Brown bin advisers visited a number of such places, where the owners of commercial premises are happy to participate (Supplementary Fig. S3a - S3e). They are larger than backyard composting sites but smaller than commercial or farm sites. These sites can retain their organic wastes for reuse in their community gardens or small urban farm settings. However, few complaints are common in community garden such as smell, attracting pests, smelly pools of stagnant water due to the poor drainage during the compost. However, there are a number of steps a community garden or urban farm can take to reduce compositing problems such as (i) understanding the composting process, (ii) turning to mix the materials to prevent odours, (iii) planning and implementing site and environmental control measures, including drainage and other infrastructures, (iv) implementing good management practices, (v) cultivating the local area through education and by sharing the benefits of compost with the neighbourhood; i.e. enrich the soil with organic material and microorganisms.

Challenges in food waste recycling

Based on the environmental model Source/Pathway/Receptor, challenges in relation to food waste recycling in Ireland starts from the food waste producer (Source), to waste collectors (Pathway), to destination of waste (Receptor). Challenges that are associated with the commercial premises are (i) lack of national awareness campaign, (ii) quantity of commercial premises involved to be educated, and lack of resources to educate commercial premises, (iii) unauthorised usage of food waste e.g. food for animals, (iv) regulatory requirements for composting, (v) space issue for bins, (vi) suitable collection times to overcome odour/vermin/volume issues. Moreover, continuous monitoring on the status of brown bin is also crucial, as it is natural that people are opening new premises, or closing the old one, or changing the ownership. In every case, it is important to do a follow up from the local authority, so those particular premises update their food waste recycling status. A pilot study has been conducted in this study (Table 7), where brown bin advisers have visited in two years gap to three towns. After visiting in 2014, good retention of brown bin has been found within the premises that have participated in the scheme in 2012, however, total number of commercial premises have been changed to more than double for both Ballincollig and Mallow towns, which is the effect of economic cycle of respective towns. Therefore, it is important for the local authority keep up to date on the status of new or old premises within particular region.

In the households, the challenges that are involved in Ireland at this moment are (i) lack of National awareness campaign, (ii) quantity of households involved to be educated and lack of resources to educate households, (iii) more usage of compost bins required, (iv) mixing of non food items with the

Table 7 Brown bin status in year 2012 and 2014

Towns	2012			2014		
	Total premises	Brown bin		Total premises	Brown bin	
		Yes	*No*		*Yes*	*No*
Ballincollig	20	12	8	41	22	19
Mallow	20	14	8	49	21	28
Millstreet	15	11	4	19	8	11

food waste. A mixing of plastics or other non food items in the food waste bin slows down the composting process in overall (Supplementary Fig. S4), that puts a significant impact in the overall brown bin scheme. Food waste with compostable bags and without non food items require less than 3 month to compost. On the other hand food waste mixed with non food items and or other than compostable bags require more than even 9 month to compost. Pictures of brown bin with and without compostable bags are shown in Supplementary Fig. S5. There are also challenges from the waste collector's side, such as resistance to the introduction of food waste bins-often paying lip service and "offering" instead of "arranging" segregated food waste collection. Challenges that are involved with appropriate facilities to take food waste (i) lack of awareness on home composting, (ii) lack of authorised facilities e.g. civic amenity sites/transfer stations/EPA sites accepting segregated food waste, (iii) more enforcement of checking waste loads to ensure food waste not included in general waste stream from areas where food waste regulations apply. These are EPA licensed facilities. When the new regulatory regime which includes pay by weights is introduced, it should be evident to everyone that this is beneficial both in environmental and financial terms (i.e. landfill levy will not be required for segregated food waste- it will only apply to waste going to landfills).

4. CONCLUSIONS AND RECOMMENDATIONS

Successful engagement of the public to participate effectively in the food waste recycling scheme is of major concern to the local authorities. Analysis of responses from the survey from the local authority in 22 towns for the commercial premises, 5 towns for the households, along with local civic amenity sites and waste collectors that are working within County Cork indicate that an integrated strategy is crucial to roll out brown bin within a community. This strategy should involve a dedicated team from the local authority who continue to visit and monitor the public and co-ordinate the activities of local authorities, waste collectors, civic amenity sites and public to implement the food waste regulations. In addition to organising appropriate infrastructure for recycling of food waste, or in other words improving the convenience for the households and commercial premises on source segregation of food waste, continuous awareness raising through education, leaflets and local and national media is crucial. It is anticipated that neighbour pressure and fines for non-compliance will result in increase roll out of food waste recovery. Cost saving case studies relevant with the type of commercial premises or households found to be effective for the food producers in participating food waste recycle scheme. The role of local authorities should include facilitating the development of appropriate facilities such as composting, anaerobic digestion etc within communities and to encourage communities to take ownership of these facilities and reuse the resultant material within the local area. Moreover, when they see the direct implementation and output of their food waste; that will increase the food waste recycling and make the overall process cost effective in the long run.

ACKNOWLEDGMENTS

Thanks to Dr. Mary Stack, Environment Awareness Section, and Ms. Sharon Corcoran, Environment Directorate in Cork County Council; Mr. Percy Foster from Cre-Composting & Anaerobic Digestion Association of Ireland and European Compost Network; and EPA, Ireland for their fruitful co-operation during this study. Also Cork County Council for funding this research.

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Recycling and reusing of lead from lead acid battery: A case study on Machkhali bazar in Bera upzila of Pabna district

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ABSTRACT

Lead-acid batteries are a common item in our daily lives. The application of lead-acid batteries is increasing day by day. The demand of lead-acid batteries has rapidly increased owing to their low cost and high availability. Lead acid battery is the most popular battery all over the world because of its recyclability, flexibility and casting efficiency. Once the lead of the battery is timed out, we have no option but to dump it because it has no use for us anymore, but the battery remains reusable which can be used for recycling. The recycling of this type of battery holds both economic and environmental benefits. In addition to this there can be considerable environmental impact during mining processes such as emission from smelting of sulfide ore, copper, nickel, and cobalt and this can be eliminated if recycling can be introduced. Battery contains toxic elements which has adverse impacts on environment and mankind. To decrease the negative impact the batteries can be recycled and reused instead of dumping. Battery reusing and recycling has combined effect on environment in Bangladesh either positive or negative. The study was undertaken considering root level recycling and reusing of battery. The most prominent battery recycling and reusing areas of Machkhali bazar in bera upzila of Pabna District were selected for this study. A survey involving approximately 20 batteries lead recycling shops were identified and 5 shops were surveyed.

Keyword: Lead-acid battery, lead, recycling, Reuse, toxic element, combined effect.

Introduction:

Use of lead acid battery in Bangladesh has increased day by day. As result, manufacturing of lead acid battery is increasing. Most of the lead used by these industries comes from recycling of lead acid battery. People use battery for various purpose like motor vehicle, IPS, electronic devices etc in our daily activities. Once a time, if the battery is expired by using, there have on options to use again but to dump it in the garbage.

Now, we have an options of recycling of lead that is again used in battery. Most of the lead consumed is derived from recycled and reused materials. The material that we obtain from the expired batteries is removed and recycled which reduces our raw material cost that are bring from aboard. The recovery of lead from damaged battery has the advantage that it is easier and far less energy dependent than the production of primary lead from ores. The recovery of lead decreases the lead dispersion in the environment and preserves the mineral reserves for the future.

Important characteristics of lead-acid battery include: an ability to work effectively in a wide temperature range; a powerful recover ability; low cost; low maintenance or maintenance free; a safety seal; powerful recover ability; a long life cycle in the usage stage; a low self-discharge rate. Bangladesh have become a significant mode of transportation in the past decade. Because of the development of electric van, automobiles, motorcycles the demand for lead used in lead acid batteries has been increasing rapidly with their advantages of low price, high-unit voltage, stable performance, and a wide operating temperature range, lead-acid batteries are used in rural telecommunication networks, electric power, solar and wind power energy storage systems and other areas.

Lead acid battery is generally consist of both sulphuric acid and large amount of lead which is not only erosive but also a good carrier for lead and lead particles. Lead is very high toxic metal which have adverse effects on environmental, human body and so on. This toxic substances are infiltrate into the soil, groundwater and surface water through landfill and also releases toxins into the air when they are recycling openly and creates contamination. Workers have risk of exposure lead and lead toxicity who are in industry for recycling of lead acid battery.

The main theme of this paper is to find out the actual present situation of reusing and recycling of lead from lead acid battery and enhancing the public awareness. To investigate the present condition a structured root level of survey is performed in five battery recycling shop in machkhli bera upozila of Pabna district. The survey procedure is decorated with proper planning described in Methodology section.

Objective:

Objectives of this study shows-

i) Two recycling process were found which are named Direct and Indirect recycling process in this study.

ii) Direct recycling process is not performed dangerous exposure to environment and health risks.

iii) To find out the actual scenario of reusing and recycling of lead acid battery and creating the public awareness.

Study Area:

Bera is an Upazila of Pabna District in the Division of Rajshahi, Bangladesh. The most prominent battery recycling and reusing areas of Machhkhali (raksha bazar) in bera upazila of Pabna District were selected for this study. The areas were selected in order to get an illustrative picture of the lead acid battery reusing and recycling activities in the study area. A survey involving approximately 30 batteries lead recycling shops were identified and some shops were surveyed. The survey was done in two steps. One was based on the reconnaissance survey of the area and others was talked with the shopkeeper’s.

Methodology:

In this study, both primary and secondary data has been used. The study is mostly depended on reconnaissance survey and primary data and information. It would also help to identify the system of recycling and also determine the impact of it. Secondary data collection includes necessary data collection, detailed information about the collection and ready to sell again etc. This information is collected from reconnaissance survey and the owner of these shops. After collecting data from primary and secondary sources, need to the analysis of data prepared a report and submitted to supervisor for necessary correction.

Survey observation and discussion:

Recycling Procedure of lead acid battery in the study area:

The study has found a working procedure of recycling the lead acid battery. Figure-1 showing the process below:

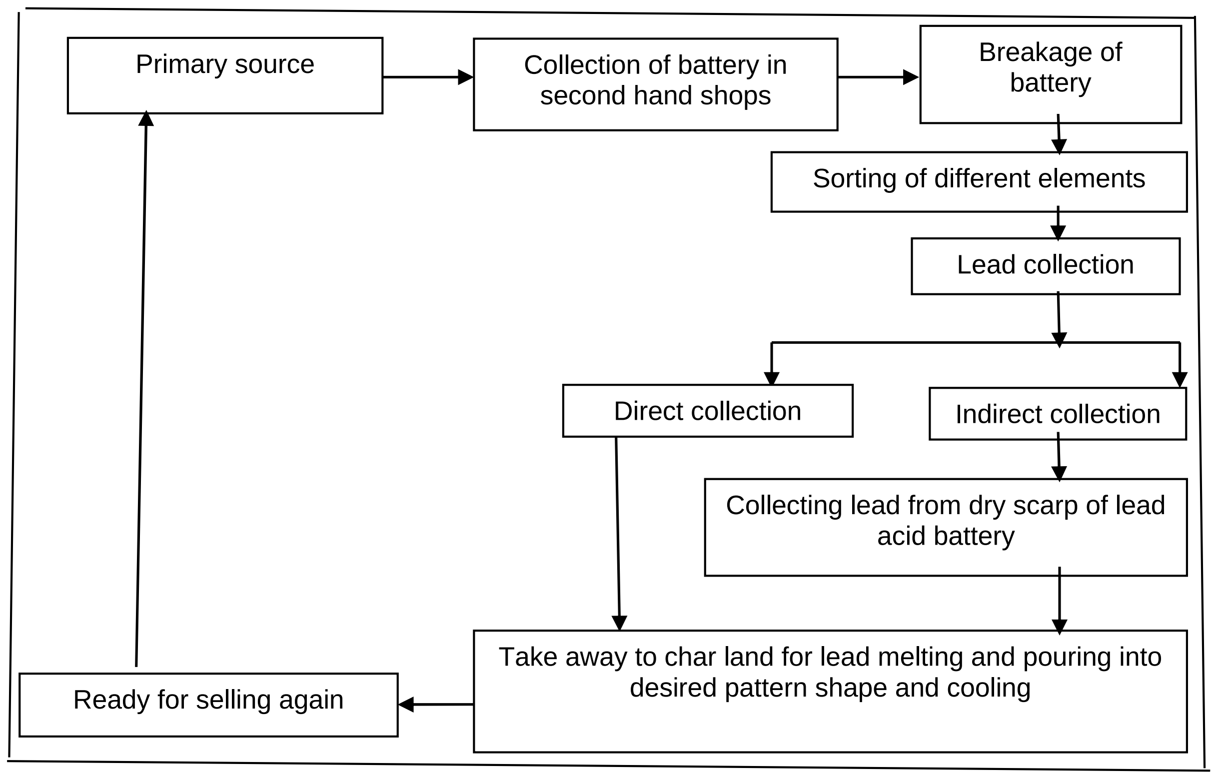

Figure-1:Recycling Procedure

Collection of battery:

They collect the battery from the secondary shops or to the battery dealers. The battery delars get the lead acid battery from local customers like house, office, hotel or restaurant mainly IPS battery and from drivers (private car, CNG, truck, easy bike, motor cycle, bus and pick-up etc.) who have willingness to sale their battery; comes into the battery shops and sells battery to the shopkeeper's. When a piece of lead battery is damped, damaged and becomes non rechargeable or not damaged badly enough to require; the owner can sale it to the secondhand battery shop or to the battery dealers in low price. They get batteries namely Rahim Afrooz Battery Ltd., Hamko, Volvo, Aftab Automobiles Ltd., Eastern Batteries Ltd., Haque Brothers (Carbide) Ltd., Platinum Power Trading, Tyre & Battery Bazar, Rolex Battery Co., Urmi Tyre & Battery Centre etc. Usually price of old lead battery is fixed for per kilogram.

Sorting process:

After collection the battery from different places of the country at first they stored in their own shops, After that they sorts the batteries various types like small size batteries or big size automobile bus, car batteries for obtaining mainly lead and separate other constituents of lead acid battery. They sorts these battery for doing other battery recycling procedure and their daily income.

Breakage of battery:

The batteries are manually broken up to separate out the acid and component parts. Then worker break the batteries with some instruments like sharp knives, hacksaw and so on. The owner of that battery recycling shop give salary depending on the size of batteries what they broken in the day. Workers get salary average range is 400-1000 taka per day according to number of per ton broken batteries .The salary of broken small size batteries is more than broken the big size batteries.

Lead collection:

The study has found two recycling processes which are named Direct and Indirect recycling process. Both in direct and indirect processes two steps has similarity which are collection and breakage of battery. Almost all parts of a lead-acid battery can be recycled in the manufacture of other plastic goods, including new battery casings. In many smaller recycling facilities in low- and middle-income countries, the plastic battery cases are often not recycled and may be dumped or burned.

- **Direct collection**

The direct collection process is done in non-sustainable manner produces lead oxide and dioxide and some other harmful gases has bad impacts on environment and human health. Workers collect lead directly from the damaged battery by separating all constraints of the broken batteris. They seperate the battery acid, lead and plastics. After that, the collected lead bring for melting.

- **Indirect collection**

The indirect collection processes is done by collecting lead from dry scarp of lead acid batteries. It’s a harmful process. Many women worker has done these in their yard openly. The scarp are dried in the sun put on polythene or dry cloths. Then they strike in the dry scarp with stick to separate the lead. The collected lead then taking for melting. Sometimes, they collect little lead by washing the batteries plastics. Then the wet lead dry on the sun and taking to melting.

Take away to Char for squeezing/ melting:

After collecting lead from unused broken lead acid battery worker taken the dry lead to the char of Jamuna river for melting. They have no developed plant to melting lead without any pollution. They didn’t melt lead local place because of its harmful effects and black toxic smoke. Because they have the idea about that the lead burning black toxic smoke and .the smoke is not good and that’s creates contamination of the local area. So, they take to the char land for protecting the local area from the toxic smoke for lead acid.

Giving desired lead plate pattern:

After melting the lead, the molten lead are poured into desired lead plate shape pattern. A few slugs are float on the surface of hot molten lead when it is poured then the slugs are removed by using specific object. Then waiting at a definite time unless the molten lead are cool. After the cooling the plate shape pattern replica are removed and the final product (lead plate) are obtained.

Supply:

The final shape product (lead plate) are again return to the battery recycling shop for selling to different battery dealers or industries so that they use the lead again to generate new lead acid batteries.

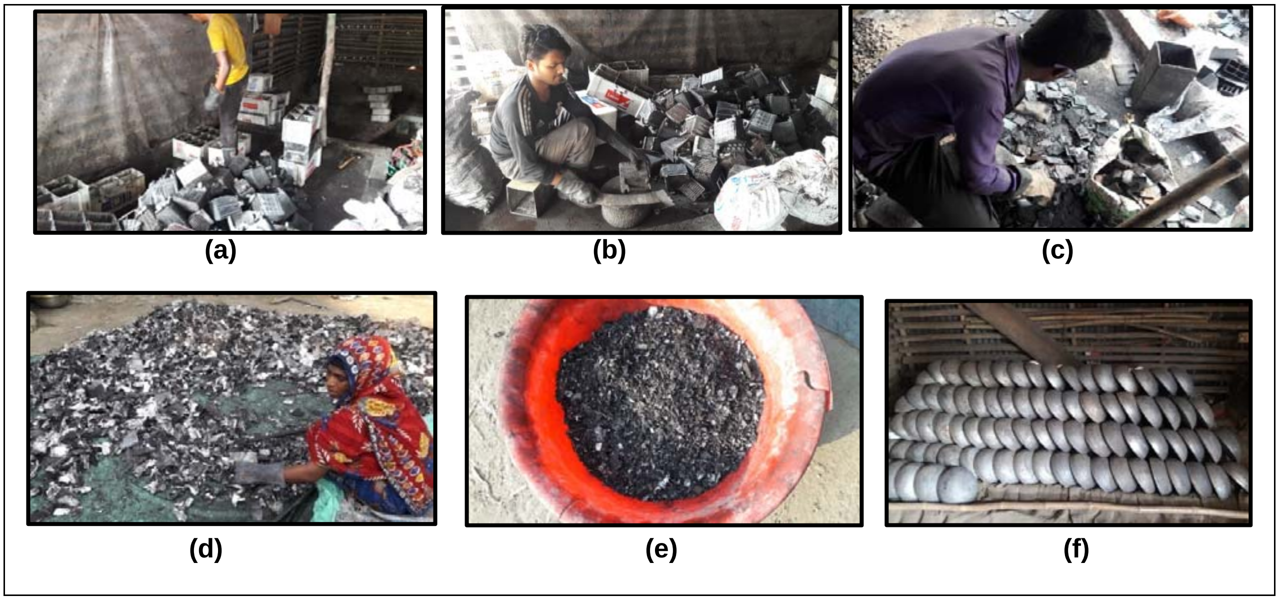

Figure-2: (a) Sorting process, (b) Breaking the batteries, (c) Collecting lead directly, (d) Collecting lead indirectly, (e) Collected leads, (f) Final product (lead plate) of unused lead acid battery and ready for selling.

Data Analysis:

Table-1: some information's of the shops

Shop name	Weekly Collection (ton)	Weekly lead plate sell(ton)	Types of automobile battery collecting maximum		Number of worker	Salary for worker who break battery	
			Large size battery	Small size battery		Large size battery(tk)	Small size battery(tk)
Mohona Battery Workshop	10-15	5-7	90%	10%	5	200-400	500-1000
Rohim Battery Workshop	10-20	5-10	95%	5%	7	450-500	500-950
Vai-Vai Enterprise	25-30	10-15	80%	20%	10	350-450	500-1000
Robiul Batteries	13-15	6-7	75%	25%	4	300-400	400-900
Nannu Enterprise	9-13	4.5-6	50%	50%	6	350-450	500-800
Hasan Battery Workshop	10-16	5-8	60%	40%	7	400-450	500-900
Azad Enterprise	20-25	9-12	70%	30%	8	350-450	500-1000

(1000kg = 1ton)

Table-2: some information's of the shops

Shop name	Number of male worker	Number of female worker	Worker dependency ratio on this shop	Age ratio of the worker		Worker education scenario	
				15-25(years)	25-40(years)	Educated	Uneducated
Mohona Battery Workshop	3	2	90%	2	3	_	5
Rohim Battery Workshop	6	1	100%	4	2	3	3
Vai-Vai Enterprise	7	3	100%	6	4	3	7
Robiul Batteries	4	_	95%	1	3	2	2
Nannu Enterprise	5	1	100%	3	2	6	_
Hasan Battery Workshop	5	2	100%	4	3	1	6
Azad Enterprise	8	_	100%	6	2	3	5

Effects of Lead Acid:

Positive effects:

Economically developed

The study area is situated besides the Jamuna river of Bangladesh. In few years ago this areas living situation, life styles was not good. The people who living in this area are just like a slum area and the area is under developed and they are fully dependent on boat, catching and selling fish and their daily income was also coming only this selected professions. They had no enough education system and not better school, college also there. But at present many people including male and female are works in recycling shop, they change their life standard day by day, they improve their life style and also many of them send to their children the school. The new school college also established day by day and people also started new business and many students also work their leisure hours in this battery recycling shop and they also contribute on their family. This battery recycling shop is one of the main source of the area which make it economically developed otherwise the area will faced with a dangerous crisis.

Employment

The study area have about 20-30 shops which are worked for recycling unused, expired battery. For the establishment of this manually recycling shop there were creating new job opportunity permanently and part time and its ratio is increasing daily. In each recycling shop, there were 7-8 male person and female person also working permanently and many others also works on their own residence. Thus the unemployment rate of the study area is decreased.

Working facility for women

In the battery recycling shop the working facility of women and women contribution also increasing. Because of the maximum women those are working this shop is nearest living, their residence is not so far from the shop and working safety, and other facilities ensured by the owner of the shop. Many women also work in their residence whose are also connected on this battery recycling shop. That's why the involvement of women to work enhancing in a speedy way. Poverty is reduced in a significant way.

Local development:

For the increasing of lead acid battery recycling shop, the local development is significantly change and its development is in extensively way on the study area. Besides the study area also developed remarkably. New NGO, Banks, mobile network tower, educational institutions (primary school, high school and college), good communication system, new high way road, grocery shops, medical pharmacy, and community clinic are also established on the study area.

Negative effect:

Effect on health

Lead used in batteries is toxic and causes a wide range of negative effects. In the study area, workers don't have idea about the adverse health effects. Most of the time they don't use any protection. The effects of lead are widely spread and that's affect all body internal circulation systems. The effects include loss of appetite with weight loss, constipation, abdominal pain or discomfort, nausea, vomiting and a metallic taste in the mouth. Diarrhea occurs occasionally. Lead exerts toxic effects in all parts of the nervous system. Initial signs include sporadic vomiting, loss of appetite, behavioral changes with aggression, irritability and agitation, headache, clumsiness and intermittent lethargy. This may progress to persistent vomiting, ataxia, convulsions, severe cerebral edema, raised intracranial pressure, coma and death. Lead may also cause visual impairment and reduced hearing. It may be mentioned here that If one gets expose excessively to lead it can cause damage to brain and kidney, impair hearing, and can led to various other associated problems.

Environmental pollution

Table-1: Different Types of pollution occur in the study area

Soil pollution	Water pollution	Air pollution
Recycling of spent lead acid batteries and disposal of process slag potentially contaminate soil with lead. Lead creates obstacles for plant growth and natural soil process including nutrient availability and microbial activity. For this reason, tree production is hampered. Spilling and leaking of acid from the batteries directly to the soil. Leaching of acid and lead salt due to improper processing which Create adverse impact on ecosystems (plants, animals, humans).	Lead also contaminate the ground water and surface water (pond and river). They dump the wastes of lead acid batteries directly into the water. Lead acid hampered the aquatic ecosystem of the study area. For this reason, production of fishes reduced day by day. Spilling and leaking of acid to water surfaces. Direct dilution of lead salts in water or through rain water when present in soil.	At each of these stages, lead fumes and dust are released into the air, contaminating both the workplace and the wider environment. The smoke which is created for melting lead hampered the growth of plants and reduces the plant fertile rate in the study area.

(a) (b) (c)

Figure-2: (a) Soil pollution, (b) Fill the river with wastes, (c) Water pollution

Dependable on this work

Dependable on this work: The maximum people on the study area are fully dependent on this recycling shop. The dependency ratio is 85-90%.In our survey we see that they are working in this shop maximum 8-10 hours in a day. Without this they are not doing in other profession because of lack of job opportunity, family conditions, educational conditions, lack of invest money and so on.

Fill the river

Some of them the wastes lead acid battery of the shops throw directly into the river, beside the switch gate of Jamuna river in the study area. Show a picture in the figure-2. For this reason, the water is contaminate and river fill up gradually.

Recommendation:

In our survey area they are working in open space in the nearest village market, their own residence area and besides their living free space. They are cut the batteries, separate the battery ingredients like plate, grids, lead raw materials etc in the open space. The people who are working on this recycling shop are not properly maintained safety as like wearing hand gloves, face protection, gum boots and other safety options. Although the safety materials are provided by the owner of the shop but very few worker wear safety items and they are also not enough cautious about working without safety materials. After the various steps such as cutting, shorting, curing and drying, plate preparation etc of lead acid battery recycling process different types of accessories are obtained. This accessories include kamina vent plugs with co-injected O ring, vent plugs double lids, VRLA valve plugs, vent plugs ,hold down adaptors, pole protector, cord handle, elbow fitting etc. They cannot gather this accessories in a fixed place, they throw the elements around the nearest place. It's harmful to throw the wastes of lead acid batteries in the garbage. Needs to forbidden the pour battery acid onto the ground or into a drain in the study area. Increasing awareness so that they don't take lead acid batteries to a landfill and also don't store batteries outside, unprotected from the weather. The use of automated, enclosed processes with pollution control devices can reduce these emissions of dust and lead fumes. With adequate technology, training (working and increasing awareness) and regulatory frameworks and support battery recycling can positively contribute to the conservation of natural resources, energy savings, a reduction of toxic gases and the development of the area.

Conclusion:

Recycling process of lead from lead acid batteries is not a simple work which can be done in small enterprises in an area. Constructing, commissioning and operating a modern environmentally sound recycling plant is a very expensive. Not only does the initial capital investment, but there is an ongoing, and essential, huge cost to cover environmental and hygiene control systems. Any modern recycling plant must have a fixed and high throughput of used lead acid batteries. The popularity of recycling of lead acid battery is increasing and the catastrophic health implications of lead exposure, it is increasingly important that safe and efficient recycling exists. While recycling of lead from lead acid battery is successful, the current methods is inexpensive and potentially hazardous smelting process in the study area. To minimize safety risks and environmental contamination it is essential to follow systems where informal recycling operations operate and fewer environmental and safety regulations are in place, the health are severe, leading to recycle lead being classified as the most polluting industrial process. Offer a method which has some manners to minimize the release of contaminants. Since secondary lead recycling from spent lead acid battery is expected for lead metal alternative resource and positively affect economic growth, the term of environmental issue due to this processing activity must be strictly concerned. Despite lead smelting route which commonly used give significant impact on the environment issue toward emission was a major drawback. Local governments should focus on an environmentally safe collection of used lead acid batteries and delivery the lead plate to an environmentally sound smelter. This is highly regulated and practiced at the state, national and international levels.

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Paper ID: 007

Identification and Assessment of Ecosystem Service and Disservice of Ward no. 11, 12 and 13

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Abstract

This paper aims to create mapping of ecosystem services and disservices by identifying and assessing ecosystem service and disservices of a locality which would be helpful in future zoning and disaster mapping. Ecosystem services and disservices are directly and indirectly related to every context and activities of human life. So proper maintenance and monitoring is a must for creating healthy eco-friendly living area. So for this study three wards 11, 12, and 13 of Khulna city was considered as the study area. Analysis of this paper is completed on the basis of questionnaire survey, existing condition survey and the Habitat Suitability Index (HSI) calculation. Some recommendation will provide on existing condition for creating better ecosystem on the basis of analysis.

Keyword- Ecosystem, Disaster mapping, Eco-friendly, Services and disservices, Human Suitability Index

Executive Summary

Khulna is the third largest city of Bangladesh. At the past time (till 2005) a large portion of economic contribution of Khulna was came from the Khalispur area of Khulna City. It was because Khalispur area had the largest and maximum amount of Jute mills of Bangladesh, the newsprint mill, power house mills. But currently due to some reason the most mills are now shut down and this khalispur area of Khulna city is like a blind part now. People still live in this area but this area lost its vibe. But due to shut down of those mills there is low focus to these area and less people lives in this area. So this may cause some environmental issues. As now in this area the mills are like a left old land without any maintenance and this causes economic harm as well as environmental harm also. Without maintenance, the barren lands and mills became the zone of crime and free zone of drug taker. This causes social insecurity and at the same time the drug and smoke harms the environment indirectly. The unmaintained old buildings also become a risky element as it has the chance to collapse. The unmaintained land and mill areas may also become a place for water logging as well as mosquito breeding, air pollution and odor which also cause environmental problem of the area as well as ecosystem disturbance. Ecosystem is a very major factor in case of proper and healthy life with good environment. In a good environment all the living being can live well and perform their activities perfectly. So ecosystem disturbance should always need to be measured at all the area and should be under control. To maintain the ecosystem services and disservices and future scope for future zoning and disaster mapping of the khalispur area the ecosystem services and disservices must need to be assessed first. To get a view of ecosystem condition, instead of working on the entire khalispur zone this study selected some specific wards to get the view of ecosystem conditions in a précised level. While selecting the wards some factors were considered.

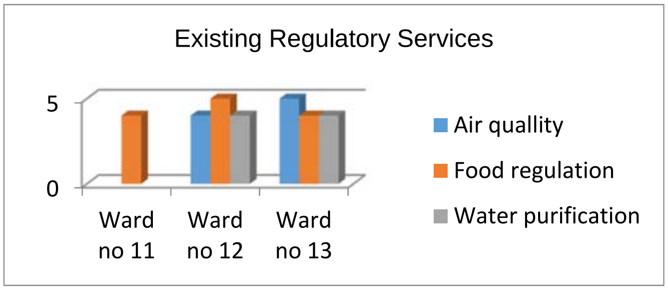


Fig: Existing Regulatory Services *Source: Field survey, 2018*

The ward 11, 12 and 13 was selected as the study area. These three were selected under considering the issue that the ward 12 and 13 have almost all the shutdown mills.

So these will give an overall view regarding the mill area and the ward 11 is not consist of mill area. Instead ward 11 have residential area, jhill area, mosques and also parks. By assessing over these three wards this study will provide the overall condition and also help to find the solution of the identified problems. So through this study it can be helpful to solve solution, understand ecosystem services and disservices and also analysis will help to find the exact situation critically. Filed survey, existing condition analysis and index calculation will help to analyze the result of the ecosystem assessment of the area. According to field survey data analysis the result of existing regulatory services at ward 11, 12 and 13 is show in the chart where all 3 ward have better food regulatory system. But Ward 12 and 13 have better air quality also.

In the chart of Disservices it is also found that in ward 13 water logging is the most problematic issues where ward 11 have only major disservices in the form of pollutants. The dumping sites are more visible in ward 12.

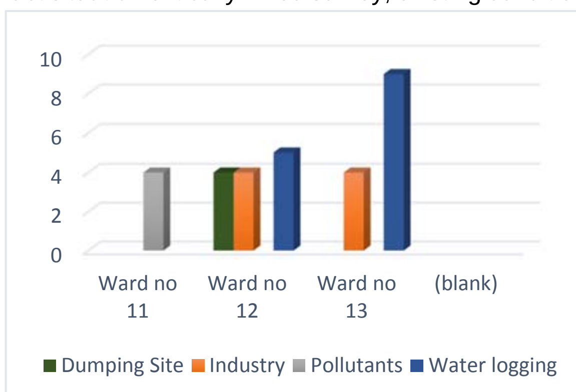


Fig: Comparison of Disservices *Source: Field survey, 2018*

Open dumping sites are always a problem for human as well as for the entire environment.

Through Habitat Suitability Index (HSI) the environmental impact was assessed from the perspective of pond. HSI is a geometric mean of

Ten suitability indices: **HSI = $(SI_1*SI_2*SI_3*SI_4*SI_5*SI_6*SI_7*SI_8*SI_9*SI_{10})^{1/10}$**

SI value	Criteria	Ward no 11	Ward no12	Ward no 13
		Jhil Pukur	Khalishpur Thana Pond	Newsprint Mill Pond
SI_1	Location	1	1	0.01
SI_2	Pond Area	1	0.8	1
SI_3	Pond Drying	0.9	1	0.5
SI_4	Water Quality	1	0.33	0.33

SI value	Criteria	Ward no 11	Ward no12	Ward no 13
		Jhil Pukur	Khalishpur Thana Pond	Newsprint Mill Pond
SI_6	Fowl	0.67	0.67	0.67
SI_7	Fish	0.33	0.01	0.01
SI_8	Ponds	0.96	0.64	0.32
SI_9	Terrestrial habitat	1	0.67	0.33
SI_{10}	Macrophytes	0.01	0.68	0.7
HSI=		0.52	0.44	0.25

Three significant ponds representing three location of ward no11, 12 and 13 have been valued by calculating Habitat Suitability Index (HSI). The Three significant ponds were Jhil Pukur in ward 11, Khalishpur Thana Pond of ward 12 and Newsprint Mill Pond of ward 13. From HSI result the Ponds of this area have a worse condition. Only Jhil Pukur has a value of 0.52 which is categorized as 'below average'. The other two ponds have a value of 0.44 and 0.25 which are categorized as 'poor'. Among them Newsprint Mill Pond which is situated inside Newsprint Mill was under the worst condition. That is because the mill has been shut down for a long time.

So from this study the existing condition of ward 11, 12 and 13 was assessed and the existing problems were identified in a detailed way. Some suggestions are also provided on the basis of the problems.

Introduction

Being an important part of nature, ecosystem always have some activities and natural resources which follows a cyclic process to perform well. (Andrew & P.Costa, 2016). Ecosystem is the process which is very essential for an area or locality. A service and a disservice are the components of these ecosystem. In the past, people often unable to understand of the significance of ecosystems and were randomly considered as public property, and so used without any control. (A.Sandifera, Ariana, & Bethney, 2015). For instance, a study was perform to evaluate the marine ecosystem in the Polish exclusive zone of economy, in the Baltic Sea which concentrates mostly on benefits, such as mineral and biological resources, climate regulation, recreation and erosion control, and only to a lesser extent outlines disservices (TP, 2008). The latter it can be include rise of sea level, storms and sea floods, erosion and abrasion, blooms in form of toxic components, eutrophication, pollution, parasites and diseases, and salt wedge intrusions in the form of groundwater.

An 'ecosystem' is an arrangement of plants, animals, micro-organisms and the natural environment, existing together as a unit in a very complex and dynamic way and dependent on one another (Haines-Young R, 2009). As service and disservice both are related to each other, they should be evaluated in some extent. Ward no 11, 12 and 13 of Khulna city were selected as study area as representatives of the thirty one wards of KCC. Hence, ecosystems are at the same time dynamic and discontinuous systems with interactions and connections which are progressing both in spatial and temporal (Pomeroy & J., 1988). They represent ecological processes and the resources they provide can be expressed in terms of goods and services. Ecosystem processes can be considered value-neutral, whilst their goods and services are considered to have a value to society. Being a part of Khalishpur residential zone, this area has been expected to be well organized. Thus it is imperative to assess the situation, as it is important issue at present world.

Objective

To identify and assess ecosystem service and disservices of a locality (ward no 11, 12 and 13) and managing eco-system services and disservices.

To identify the future scope for future zoning and disaster mapping

Limitations

Proper access to the services was a major limitation of this study. So, nearby and moderate access to the service has been assessed. Hence, people of all communities were not interested to participate and share their opinion. Thus this study may lack of proper participation of people and their valuable opinion.

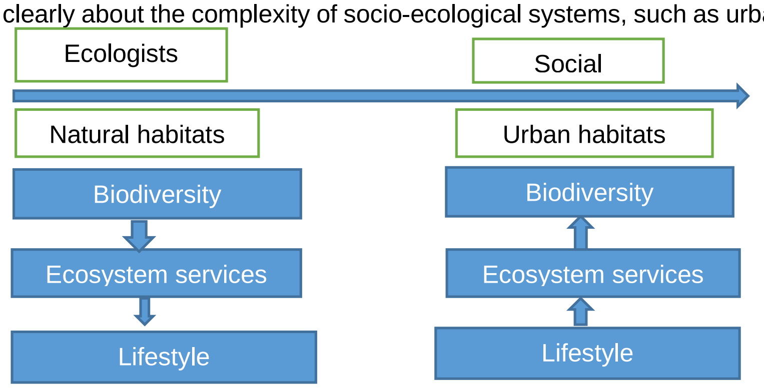
Literature Review

Ecosystem

Ecosystem which is a natural community. It interacts with organisms and their physical environment. (Assessment, Millennium Ecosystem, 2003). An ecosystem represents a dynamic community which encompasses populations of plants, animals, microorganisms and the non-living environment which interacts together as a functional unit. The factors of environment are soil type, position of any element in the landscape, climate and availability of water, determine the presence and distribution of ecosystems ((USEPA), 2009). The ecosystems main inputs are daylight, soil, nutrients and water, while wastes are from one portion of the system and energy form other portions of the system. A main output is biomass (or carbon-based life) which is restoring itself. An ecosystem performs through continuously cycling energy and materials which indicates living organism's growth, reproduction and then death (Haines-Young R, 2009) . This energy and materials which is cycling through living organisms, has grown in response to a mixture of disturbances (fires or floods), stresses (droughts or diseases) and ecological interfaces (competition or predation) over millions of years. Recently, the changes noticed in the rate of recurrence and intensity of these disturbances and stresses raises issues about the aptitude of species and ecosystems which is important to persist and adapt (Assessment, Millennium Ecosystem, 2003).

Ecosystem services & disservices

In the earlier years the ecosystem services has been broadly used concept which have shown the variety of benefits of biodiversity in the sector of human welfare (e.g. in relation to health, social networks, economy, cultural history, landscape and agriculture). Ecosystem services or more broadly, environmental goods related issues can be discussed widely while emerging over three decades ago and it was developed especially during late 1990s ((USEPA), 2009). Among various ecosystem services (Haines-Young R, 2009), the ecosystem services can be understood as a concept which is the bridge between biodiversity and lifestyle (Figure 1). The linkage can be addressed from two different perspectives; Thinking based on natural sciences traditionally takes the ecosystems as a departure point and focuses on natural habitats, whereas social sciences tend to start from social phenomena, such as lifestyle, and focus on urban environments. Both approaches are needed, while understanding clearly about the complexity of socio-ecological systems, such as urban ecosystems. (Fischer J, 2006).



Provisioning, regulating, cultural, supporting or other ecosystem services were explicitly or implicitly described in most studies and assessments which describes with a focus on ''goods'' produced by green and blue areas, while ''bads'' are usually noted only briefly or left without any attention (Assessment, Millennium Ecosystem, 2003).

Figure 1: Relation between Natural and Urban habitat

Human activities disturbs the ecosystem functions in most disservices. There are only a few studies that explicitly build on the concept of ecosystem disservices.

This simplified diagram illustrates the main linkages between biodiversity and lifestyle from two different perspectives. Natural scientists, such as ecologists (left), typically see biodiversity as the basis of ecosystem services which, in turn, make certain lifestyles possible. This approach based on social science (right) which usually indicates lifestyle as a driving force which utilized as a specific kinds of ecosystem services and, in turn, certain kind of biodiversity to be maintained (Fischer J, 2006).

Components of ecosystem services

Ecosystem services are the diverse benefits, obtained by people from ecosystems. In 2005, the Millennium Ecosystem Assessment ecosystems and their resulting services were categorized and identified the links between these facilities and human cultures, and the direct and indirect feedback loops (Folke C, 2004).The Millennium Ecosystem Assessment framework identified ecosystem services within four categories; Provisioning services, Cultural services, supporting services, Regulating services.

These types also helpful while understanding the complexity of dependencies, feedbacks and trade-offs between services and human beneficiaries, and can provide useful information for decision making.

Biodiversity's contribution to ecosystem services

Provisioning services

- Food
- Genetic resource
- Nutrients
- Fresh water

Cultural services

- Spiritual and regional values
- knowledge system, place sense
- Education and inspiration
- Recreation and aesthetic values

Regulating services

- Invasion resistance
- Pollination
- Climate ,Disease and Erosion regulation
- Natural hazard protection
- Water purification

Supporting services

- Primary education
- Provision of habitat
- Nutrient cycling
- Soil formation
- Produce of oxygen
- Water cycling

Figure 2: Examples of ecosystem services (Ecosystem and habitats)

Although such analysis may be intensive to information which takes an approach looking for multiple benefits and that is expected to reduce the threats of compromising the structure, function and services of ecosystems. It also increase the choices for retaining resilience (Folke C, 2004).However, the potential for modified ecosystems to provide a full range of ecosystem services over the long term may be limited if ecological or other thresholds are reached.

Indexes for Calculating Sustainability of Ecosystem Elements

Indexes calculated denote the sustainability of any elements to analyze. There are also some indexes that can be used to analyzing the ecosystem elements. Habitat Suitability Index is one of them.

Habitat Suitability Index

The Habitat Suitability Index (HSI) was developed by Oldham et al. (2000) (Oldham, Keeble, & M.Swan, 2000). HSI scoring systems were originally developed by the US Fish and Wildlife Service as a means of evaluating habitat quality and quantity. An HSI is a numerical index, between 0 and 1. 0 indicates unsuitable habitat, 1 represents optimal habitat.

HSI scoring can be useful in:

- Evaluating the general suitability of a sample of ponds for great crested newts
- Comparing general suitability of ponds across different areas
- Evaluating the suitability of receptor ponds in a proposed mitigation scheme.

The HSI is a geometric mean of ten suitability indices:

$$\mathbf{HSI = (SI_1 * SI_2 * SI_3 * SI_4 * SI_5 * SI_6 * SI_7 * SI_8 * SI_9 * SI_{10})^{1/10}}$$

The ten suitability factors have been described in brief in a diagram eventually-

a) Factor 1: Geographic location (SI_1)
Sites should be scored according to the zone in which they occur. This scoring can be carried out either in the field, or as part of a desktop exercise.

b) Factor 2: Pond area

Pond area is the surface area of the pond when water is at its highest level (excluding flooding events) during spring and other time of the year the measurement result of the springtime area should still be evident from vegetation types. Pond area should accurately be measured. As it can be tough reading off SI scores from graph, pond area should be rounded to nearest 50 m. It can be particularly difficult to read off SI scores for very small ponds, ponds smaller than 50 m2a score of 0.05 should be used.

c) Factor 3: Permanence

Pond permanence should be deduced from local knowledge and on personal judgments. A landowner may know how often a pond dries. For example, a pond that is already dry by late spring is likely to dry out every year, etc.

d) **Factor 4: Water quality.**

Water quality valuation is subjective and based primarily on invertebrate diversity. Hence, water quality should not be confused with water clarity. Sometimes clear water can be devoid of invertebrates, and turbid ponds can support a wealth of invertebrates. There is no quick and simple invertebrate index of water quality. Yet, some species are water quality indicators.

e) Factor 5: Shade

Estimate ratio pond perimeter shaded to, at least 1m from the shore. Shading from trees also includes buildings but should not include emergent pond vegetation.

f) Factor 6: Fowl

It is the impact of water fowl upon a pond. At high densities, when waterfowl are encouraged to use a pond, by provision of food, the birds can remove all aquatic vegetation, pollute water and persistently stir sediments. 'Waterfowl' includes most water birds, such as ducks, geese and swans. Moorhens should be ignored because almost every pond has at least 1 or 2.

g) Factor 7: Fish Local knowledge and own observations can help to collect information about fish. But, stickle back (which can be significant predators of great crested newt larvae, when present in large numbers) are unlikely to be deliberately introduced to a pond, but may arrive through other means. Netting is useful in detecting smaller fish, such as sticklebacks, or the fry of larger species.

h) Factor 8: Pond count

This is the number of ponds occurring within 1 km of survey pond. The survey pond itself would not be counted. Ponds on the far side of major barriers, such as main roads, should not be counted.

i)Factor 9: Terrestrial

Terrestrial habitat score is about understanding of habitat quality. Good terrestrial habitat offers cover and foraging chances and includes meadow, rough grassland, hedges, scrub and woodland. Terrestrial habitat should be considered only on the near side of any major barriers to dispersal (e.g. main roads or large expanses of bare habitat).

j) Factor 10: Macro phytes

Estimate the percentage of the pond surface area occupied by macro phyte cover. This includes emergent, floating plants (excluding duckweed) and submerged plants reaching the surface.

Study Area

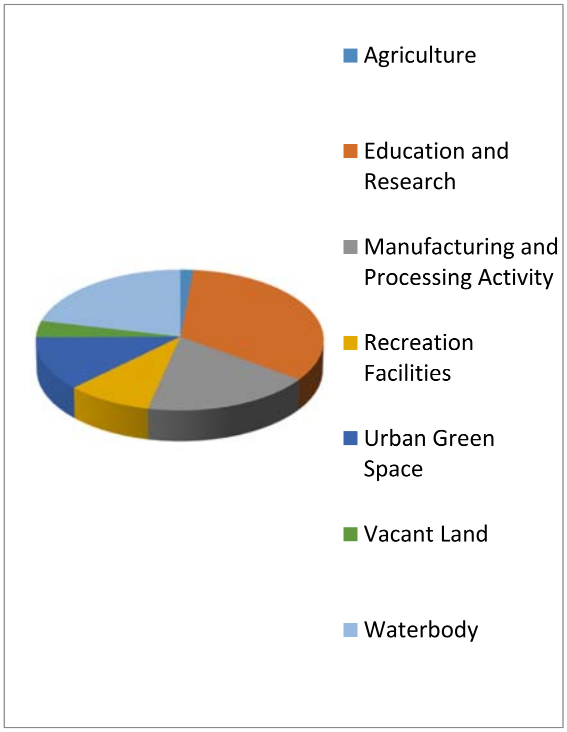
Ward no 11, 12 and 13 of Khulna City Corporation were selected as the study area. It is located between 22°50' and 22°52' north latitudes and between 89°31' and 89°34' east longitudes. This is a part of Khalishpur Thana. These ward comprised Khalishpur residential area.

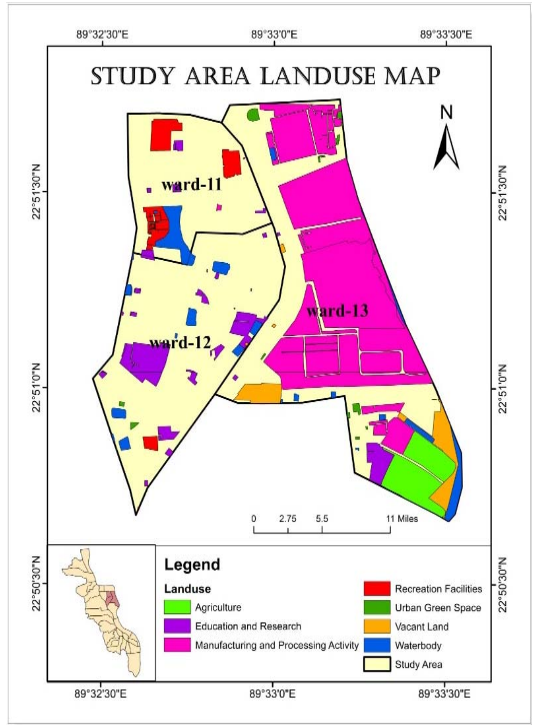
About Study area components with diagram

Table 1: Demographic Information of Study Area

Source: (BBS, 2011)

Ward No	Population	Area	Density per sq.km
11	27140	0.36491	74374.5033
12	72800	0.65905	110462.0287
13	27920	1.11957	24938.1459





Source: Map generated by author, 2018

Figure 2: Land use Percentage of Study Area

Figure 3: Land use Map

Detail Methodology

The project has followed a particular framework of methods. The detail methodology of the study is described here.

Conceptualization

At first conceptualization of ecosystem service and disservices was performed. Various type of ecosystem services and disservices were found and a list of them were created through different case studies. A clear concept about ecosystem service and disservices was achieved after this section.

Selection of study area

After conceptualization ward no. 11, 12 and 13 of Khulna City Corporation were selected as study area. Then the land use of the study area were analyzed and land use map with all the service and disservices were generated through ArcGIS.

Generation of buffer area of ecosystem services

The ecosystem service and disservices were buffered at 50m distances and buffered areas have been located into the study area. Thus for the proper utilization of public opinion priority buffer zones were declared in the map. In the map high priority zones denote more intense location of ecosystem service and disservice in one place. On the other hand low priority zones denote less intensity of ecosystem services in one place.

Preparation of a questionnaire
After that a questionnaire was prepared to assess the opinion of the local people about ecosystem service and disservices situated in their locality. The questionnaire included all the relevant and necessary questions about use and satisfaction of the services.

Survey of the study area
After preparing a questionnaire carried out a survey to the study area (ward no 11, 12 and 13). Three types of survey were performed.

- **Questionnaire survey:** A questionnaire survey was performed at the study area. 25 respondents attended in individual questionnaire survey.
- **Existing condition survey:** The surveyors observed the existing condition of provisioning, supporting, regulating, cultural services and disservices and filled up the checklist.
- **Focus group discussion:** Focus group discussion was performed by the community group of the locality in the common places of the study area.

Analysis and recommendation
Finally the public opinion and existing situation were analyzed and some measures have been recommended. Recommendations also valued the demand and lack of the local people.

- **User Opinion:** User Opinion were analyzed through valuation of questionnaire survey.
- **Existing Condition:** Comparative analyses were done through the crosstabs with two different variables of existing situation between three wards.
- **Index Calculation:** Habitat Suitability Index (HSI) was calculated regarding three significant ponds from three wards for comparison between them.

Analysis & Findings

This part comprises analysis of the surveyed data. People opinion and surveyed condition were analyzed here and at last an index (HSI) was calculated.

Public Opinion

The result from public opinion survey is shown here through some chat with the comparative analysis and its source is from field survey 2018.

Comparative Existing Condition Analysis of the services between wards:

How long they have experienced the services	Most significant service in the area	Satisfaction level of services

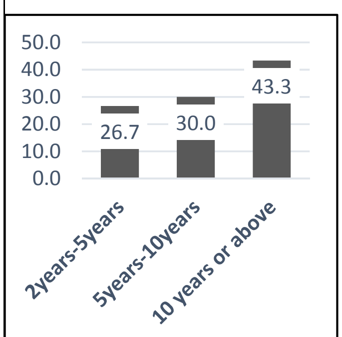
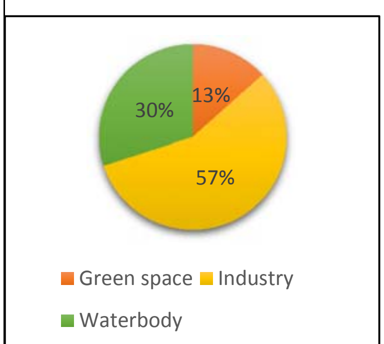
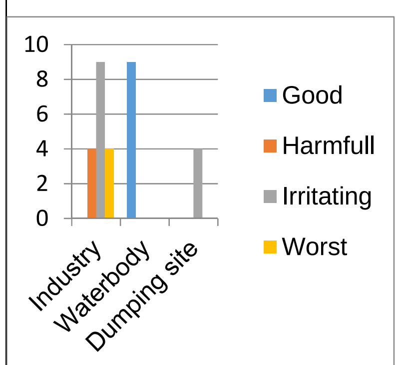

		

fig4.1:Timeline of experiencing the services at the study area people	**fig 4.2: Most Significant service in the locality**	**fig 4.3: Level of satisfaction for available services**

How long they have experienced the services	Most significant service in the area	Satisfaction level of services
Almost all the dwellers are there permanent dwellers. A very large amount of people of the study area was living there for a long time which is 10 years or more than 10 years. Up to 40% people are experiencing the services 10 years or above.	As khalispur, industrial center of Khulna, a large amount of industrial contribution was came from herr. But now most of the industries of this area are shut down and left like a barren land. Another is water body. There are enough amount of water body and there is a large lake called Jhil Pukur serves a large amount of people. Last significant existing service is green space because presence of satisfactory amount of trees and vacant lands in the area.	According to public opinion survey, almost all users are satisfied with the water body facilities of the area, but they are very much dissatisfied with dumping site service. Most of the location of the area have no specific dumping site which causes odor and health issues in the area. Another dissatisfaction arises from shut down industries, due to those industries left without maintenance people are facing environmental issues like water logging issues, fear of building collapse as well as they are facing security issues and fear of crime.

Regulatory services

Source: Field survey, 2018

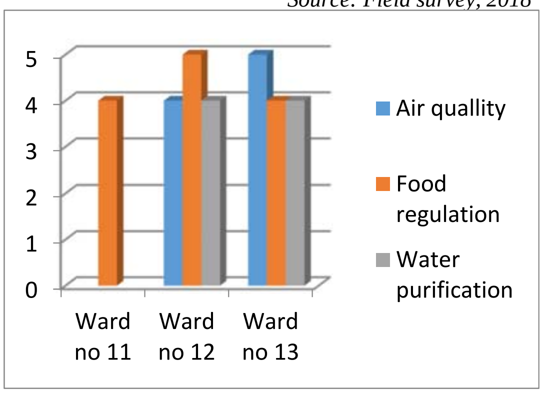
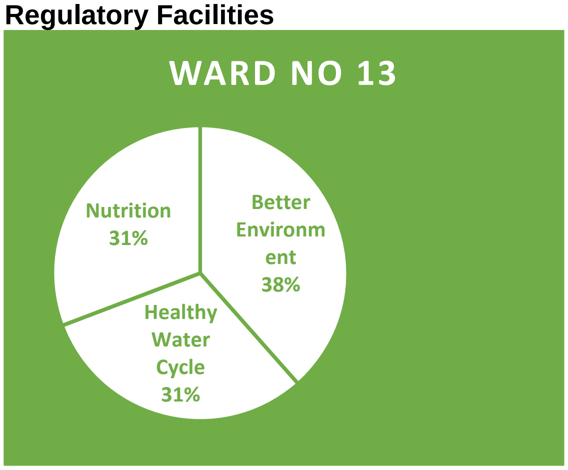


Figure 4.4: Existing Regulatory Services

The study area comprised some of regulatory services of food, air and water. In the area there is a good source of vacant and some agriculture land. Where ward 13 having the best water purification system, ward 12 have the better food regulation property. The reason of having best purified water in ward 13 was having a lot of industrial site, it had a good number of trees as well as ponds present there. Ward 11 has only food regulation system in a moderate number. Also, ward 12 and 13 had a balance in the regulatory system but ward 11 had a poor condition. The ward 12 and 13 have an attractive result in case of air quality analysis and it is because as the ward 12 and ward 13 is the planned industrial area which have sufficient number of trees. Tree are the best air purifier and environment balancer.

Regulatory Facilities

Source: Field survey, 2018



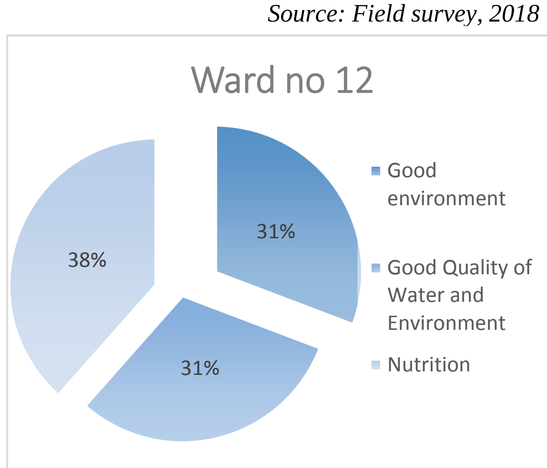


Figure 4.5: Comparison between wards regarding Regulatory facilities.

Provisioning Services

Source: Field survey, 2018

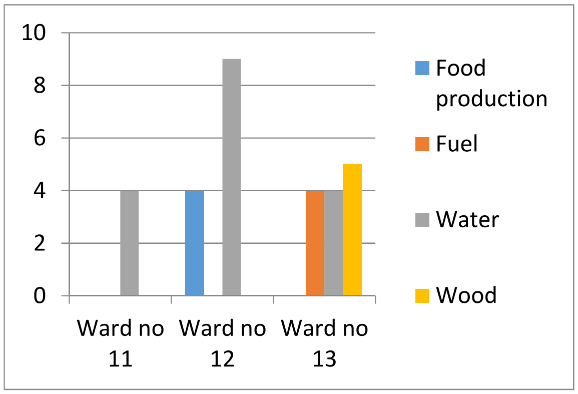


Fig 4.6: Comparison of provisioning services between wards.

Supporting services

Source: Field survey, 2018

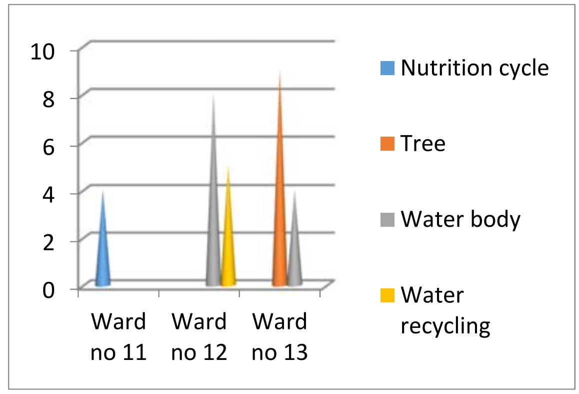


Fig4.7: Comparison of supporting services between wards.

Provisioning Facilities in Map

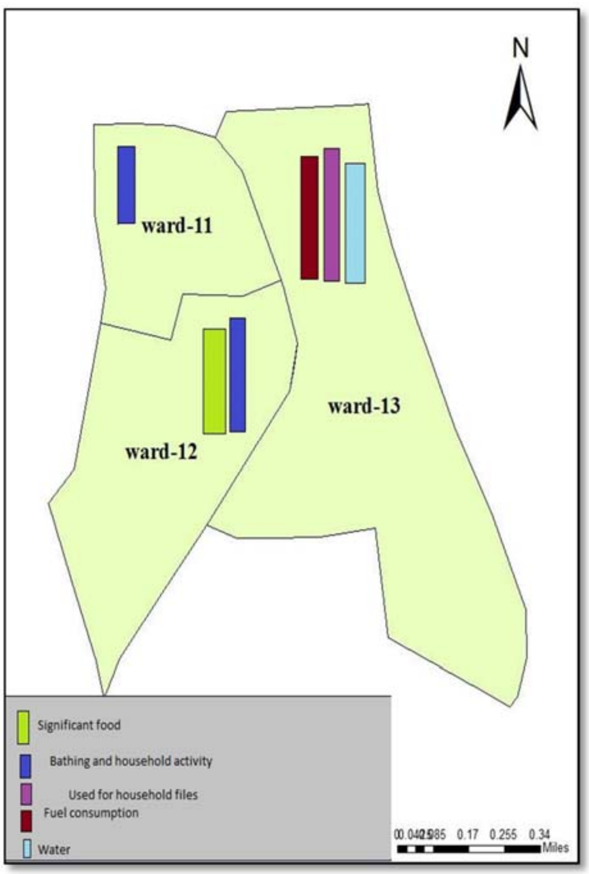


Fig 4.8: Provisioning Facilities

Supporting Facilities in Map

Map Prepared by- Author

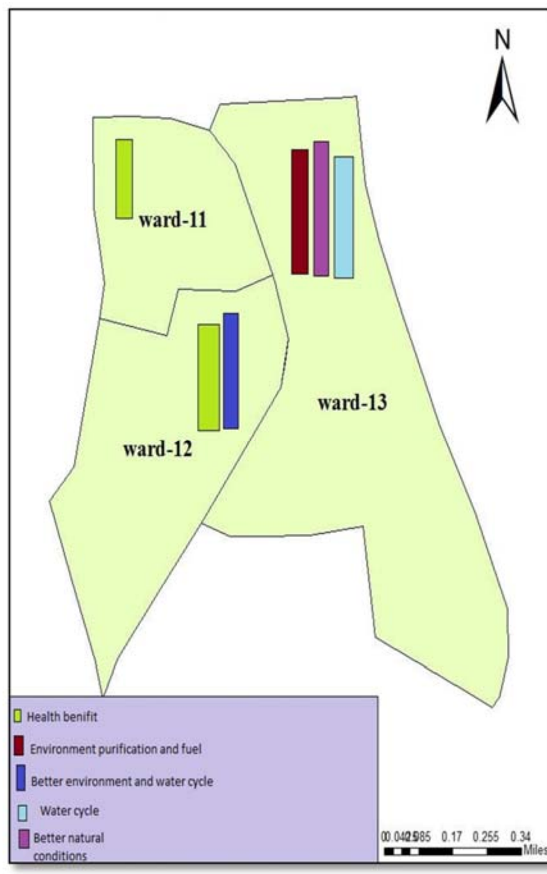


Fig 4.9: Supporting Facilities

Significant Services
As an industrial center of Khulna city a large amount of industrial contribution was came from khalispur area of Khulna division till 2005 (source: field survey). But now most of the industries are shut down and left like a barren land and creating security issues. This is the scenario of ward 13 as it has mainly the Jute mills and power houses are inside ward 13. There is also some industries inside the ward 12 Like Hardboard mill, People's Jute mills.

There is 31% of industries in ward 12 where 100% in Ward 13 .But ward 11 do not have any industries

Source: Filed survey, 2018

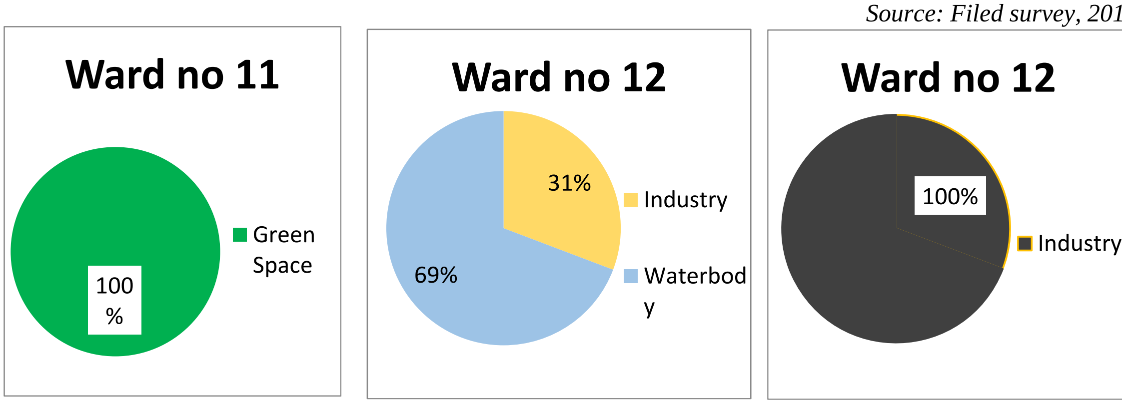


Fig 4.10: Comparison of significant services between wards.

and its most significant services are green space.

Cultural services

Source: Field survey, 2018

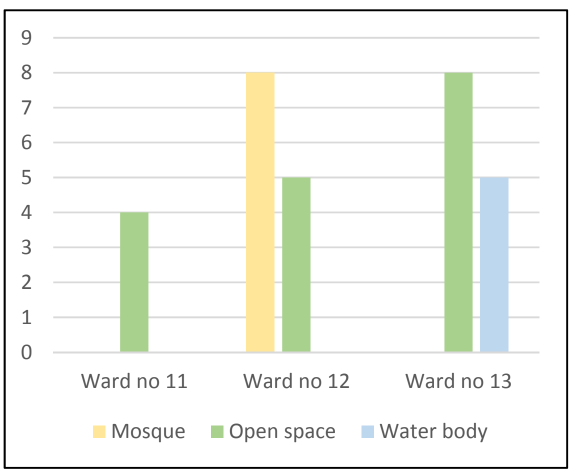


Fig4.11: Cultural Facilities.

Cultural Facilities

Source: Field survey, 2018

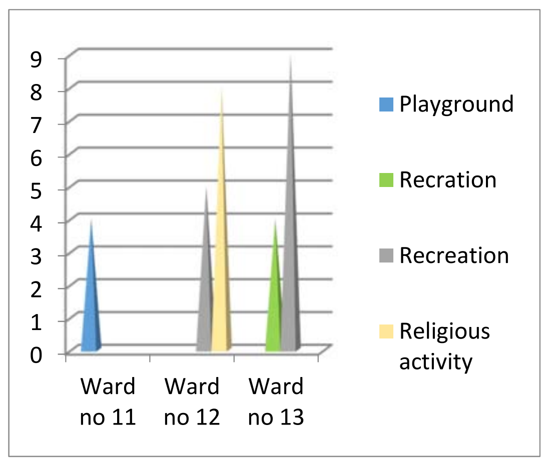
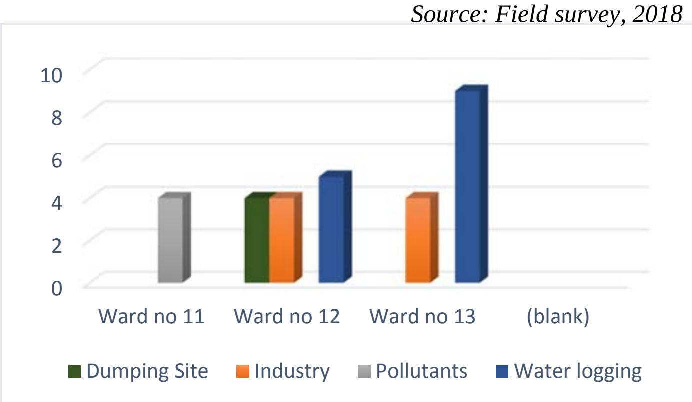


Fig4.12: Cultural Facilities.

Disservices:
In case of environmental analysis of any area all areas have some disservices parallel with the services. Comparing between wards, ward 13, 12 have water logging problem which is the important disservices as this cases scope of mosquito breeding .Mainly this problem is due to no maintenance of shut down industries. Another disservices at ward 12 and 13 which is the industries. Actually this might be the environmental issues, security issues as well. So this is why industries became the disservices. Ward 12 has dumping sites which are open dumping sites and creates air pollution and odor to the nearby area. Better service if it is running but as it is shut down it is left without any maintenance which creating environmental issues, security issues as well. So this is why industries became the disservices. Ward 12 has dumping sites which are open dumping sites and creates air pollution and odor to the nearby area.

Ward 11 has one disservice which is pollutants .But basically almost all area all places have pollutants.

Source: Field survey, 2018



As per bar chart result and field survey .In the study area ward 11 is having less disservices which is quite good .This become possible because there is no industries inside ward 11 .

Fig4.13: Comparison of Disservices

Index Calculation (Comparison of Habitat Suitability Index (HSI) between wards**)**

Three significant ponds representing three location of ward no11, 12 and 13 have been valued by calculating Habitat Suitability Index (HSI).

Table 2: Habitat Suitability Index (HSI) of the ponds

Source: Field survey, 2018

SI value	Criteria	Ward no 11	Ward no12	Ward no 13
		Jhil Pukur	Khalishpur Thana Pond	Newsprint Mill Pond
SI_1	Location	1	1	0.01
SI_2	Pond Area	1	0.8	1
SI_3	Pond Drying	0.9	1	0.5
SI_4	Water Quality	1	0.33	0.33
SI_5	Shading	0.75	0.5	1
SI_6	Fowl	0.67	0.67	0.67
SI_7	Fish	0.33	0.01	0.01
SI_8	Ponds	0.96	0.64	0.32
SI_9	Terrestrial habitat	1	0.67	0.33
SI_{10}	Macrophytes	0.01	0.68	0.7
HSI=		0.52	0.44	0.25

The Three significant ponds were Jhil Pukur in ward 11, Khalishpur Thana Pond of ward 12 and Newsprint Mill Pond of ward 13. From HSI result the Ponds of this area have a worse condition. Only Jhil Pukur has a value of 0.52 which is categorized as 'below average'. The other two ponds have a value of 0.44 and 0.25 which are categorized as 'poor'. Among them Newsprint Mill Pond which is situated inside Newsprint Mill was under the worst condition. That is because the mill has been shut down for a long time.

Findings and Recommendation

Key Findings

Key findings of the study were some significant findings that were found through the analysis and observation. Key findings were-

- Ward 12 the most balanced ecosystem area among the 3 of them
- Ward 13 had the worst condition because of having shut down industries
- The area consisted of huge number of water bodies as well as support services.

- Presence of good amount of trees in this area due to being a planned industrial area
- The most significant service was industry which is now shut down.

Recommendation

Finally some measures have been recommended to meet the gap between service and disservices of ward no 11, 12 and 13 area of Khalishpur Thana.

- ✓ Increasing more security to the mills
- ✓ Need proper maintenance to the industrial section of the areas and mills.
- ✓ Provide more dumping site
- ✓ Dustbins need to be covered as it cannot spread odor
- ✓ Proper maintenance to the existing water bodies especially in rainy season.
- ✓ People demanded of tube wells and dustbins on their site. These should be provided for better health care.

Conclusion

Ecosystem services and disservices play vital role in every context of human life. They keep relation with various activities of human. So to know ecosystem services and disservices and try to maintain the proper balance of the ecosystem services is very important factor. By this research and identification of service and disservices the concept of ecosystem is cleared with the analysis result of existing condition. Whether people use the service or not, it (ecosystem) is the element which affects people's life either positively or negatively. Though some services provide damage to the people and those services demand to protect them and ensure the proper use of those services.

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PLASTIC POLLUTION SOLUTION BY FEEDSTOCK RECYCLING: REDUCING IMPACT OF PLASTIC POLLUTION ON WEATHER

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ABSTRACT

Plastic demand and usage are increasing noticeably worldwide. According to the statistics in 2016, 335 million metric ton of plastic is being produced globally. This huge amount of plastic is not completely recycled or degraded. Only approximate 9% of plastics are being recycled and 12% is incinerated. The rest 79% of plastic is being built up in landfill, marine and other places. Plastic pollution has a destructive impact on weather. Sea Education Society scientists studied plastics in the Atlantic and estimated that 100,000 marine animals die each year from suffocating on or ingesting plastic bags. The aim of our research is to convert this huge ton of waste plastic into crude oil which can be used in engine and turbine for power generation. For our experiment we collected Polypropylene (PP) as waste plastic from local waste shops. These waste plastics were then taken into a vessel (pyrolyzer) and were heated at 400^0C-500^0C. The produced gas was condensed and collected in a container. The whole process took around 50 minutes for pyrolysis of 50 gm of PP. The results showed that 10% PP were converted into crude oil. But our research demonstrates that by further modification of the overall process we can achieve 90% efficiency.

Key-word: *Plastic, Pollution, Weather, Pyrolysis, Crude oil.*

INTRODUCTION

Plastic materials are becoming inseparable part in todays life, due to their lightweight, durability, and energy efficiency, coupled with a faster rate of production and design flexibility; these plastics are employed in entire gamut of industrial and domestic areas; hence, plastics have become essential materials and their applications in the industrial field are continually increasing. [1-6] However one has to accept that Every blessing can have a negative side. Plastics are relatively cheaper and being easily available has brought about use and throwaway culture. Plastics waste management has become a problem world over because of their non-degradable property. A majority of landfills, allotted for plastic waste disposal, are approaching their full capacity. Thus, recycling is becoming increasingly necessary. [7-12]

It has proved so useful to humans that since the 1950s we have produced an estimated 8.3 billion metric tons of the stuff. However, the victim of this success appears to be much of life on Earth. And humans, one day, could find themselves among them. For some 79 per cent of the plastic produced over the last 70 years has been thrown away, either into landfill sites or into the general environment. Just nine per cent is recycled with the rest incinerated. With more than eight million tons going into the oceans every year, it is estimated there will be more plastic than fish by 2050 and 99 per cent of all the seabirds on the planet will have consumed some. It is thought the sea now contains some 51 trillion microplastic particles – 500 times more than stars in our galaxy. It is found all over the planet, with 300 billion pieces in the once-pristine Arctic and a remote island in the Pacific, the uninhabited Henderson Island, one of the Pitcairns, believed to have the highest concentration of plastic pollution in the world. Killing off sea creatures is bad for humans because we consume so much of it ourselves. Some 92.6 million tons were caught worldwide in 2015.Given plastic degrades to pieces small enough to pass through the stomach into the flesh of fish and other animals, we are already eating some of the plastic we have thrown into the sea.[13] Around 73,000 tons of plastic waste end up in the sea everyday through the rivers Padma, Jamuna and Meghna in Bangladesh. Bangladesh also produces 3000 tons of plastic waste every day. A very little portion of the waste accumulates in the sea though. The remaining waste along with that coming from China Nepal and India accumulate in domestic rivers, canals and other places polluting the land and cause serious threat to environment and human health. In Bangladesh 6.5 million tons of plastic waste is currently generated while 3000 tones are being added to that daily. [14]And, of course, just like other animals that plastic is likely to be finding its way into the tissues of our bodies with potentially harmful consequences. [15] Each year more than 100 million tons of plastic are produced worldwide. Though plastics have opened the way for a plethora of new inventions and devices it has also ended up clogging the drains and becoming a health hazard. [7-12].At the same time, waste plastics have created a very serious environmental challenge because of their huge quantities and their disposal problems. Waste plastic pyrolysis in liquid fuel (gasoline, diesel oil, etc.) or chemical raw materials not only can effectively solve the problem of white pollution, but also can alleviate the energy shortage to a certain extent. Recycling of waste plastics is expected to become the most effective way. Waste plastics' recycling, regenerating, and utilizing have become a hot spot of research at home and abroad and gradually formed a new industry.The increase of petroleum and petrochemical prices opened the ways for industries to invest in decomposition of plastic wastes to petrochemicals [16,17]. Today, plastic landfills are as valuable as petroleum mines. Models for reaction's kinetics for optimal pyrolysis conditions of plastic waste mixtures have been proposed by researchers. Literature abounds in the recycling of these traditional wastes to petrochemicals [18-20] and many industries are sustained and developed based on decomposition of natural and synthetic polymers [19,20]. Most plastic can be recycled to make fuel oil by waste plastic pyrolysis plant. Pyrolysis is a process in which waste plastics can be heated to high temperature about 180℃）, then oil gas will come out, the oil gas through cooling system, that is condensers and top cooling pipe, was cooled down, and then oil gas turn to liquid oil, that is fuel oil. It can be used to engine, generator, and so on. This fuel oil not only can solve the waste management problem, but also solve the plastic pollution problem. The plastics include polystyrene [21,22], poly (vinyl chloride) [22,23], polypropylene [22-24], PE terephthalate [23], acrylonitrile-butadiene-styrene [23], and PE [21-23]. In some cases, plastics were copyrolyzed with other materials such as waste motor oil [23]. With regard to fast pyrolysis of PE, pyrolysis of LDPE [21], HDPE [25,26], and various mixtures [22] was reported.

This combined advantage has inspired us to design and develop a machine which can efficiently convert plastic to suitable form of fuel. In this paper the objective is to develop a machine which can convert plastics to some useful form of fuel and a method is suggested to convert waste plastic to useful fuel. This study includes the production, characterization, and evaluation of alternative diesel fuel from pyrolysis of PP waste plastics. Comparison of our pyrolyzed oil with conventional petroleum-derived diesel fuel was a further objective, along with a comparison to Petro diesel standards.

MATERIAL AND METHOD

Materials and Process Description

The plastic used in this experiment was used waste plastic box and container (PP) for domestic purposes. Waste plastics were cleaned with detergent and clean water for removing foreign materials such as mud and oil. Washed out waste plastics were dried and cut into small pieces in the range of 0.5 inches to 2 inches by using scissor.

Experimental Set up

We had customized three types of experimental set-up for our purpose. All the set up contained a closed chamber with a thermocouple, valve, pressure gauge, Gas exit line, Condensing part and oil collection jar. The effective weight of the total set-up varied between 4kg-4.5kg. The reactor with plastic was heated with gas up to 550°C. Here it is necessary to mention that the thermocouple was used through the wall of the stainless-steel pyrolysis chamber to measure the temperature. Therefore, the temperature mention may vary in some amount as compared to conventional system. We didn't use any inert gas to evacuate the chamber because the oxygen remained there produced CO_2 is heavier than the air so this would emit before the pyrolyzed gas or oil would come out. There was no output at low temperature range and the process was carried out between the temperature ranges of 330°C and 490°C in the reactor for about one hour and thirty minutes. The vapor products of pyrolysis were carried out through condensing part. The condensers were cooled by water and the condensed bio-oil was collected into the collector. The noncondensed gas was flared to the atmosphere and the char was collected from the reactor after completion of pyrolysis cycle. The process flow diagram is shown in figure-1

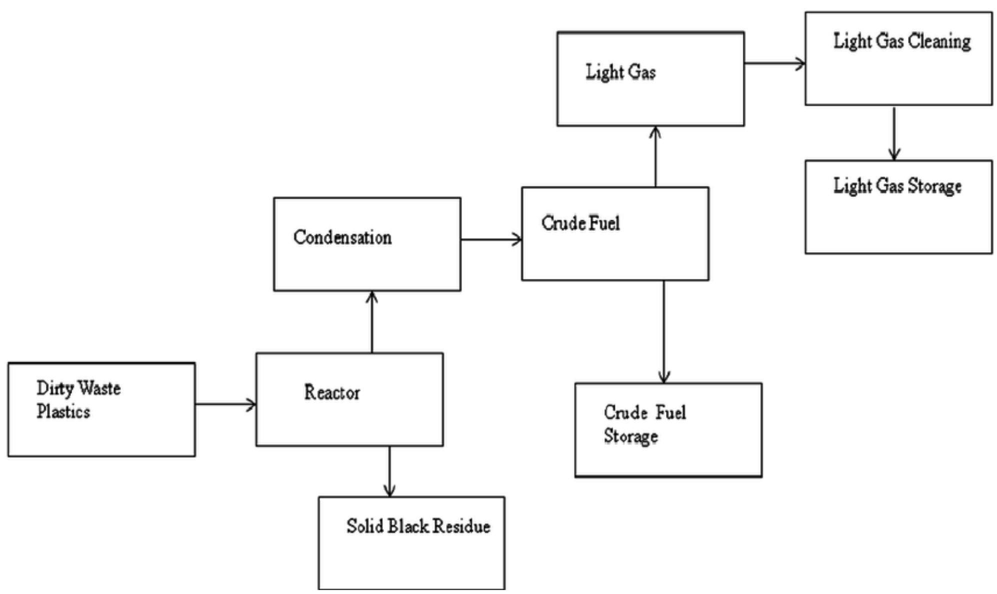


Figure 1: Whole process flow-chart

RESULT AND DISCUSSION

Efficiency of Experimental Set-up

For the first type of set up, at higher temperature(344^0 C) the leakage occurred at the joint of the pressure gauge and the container and only small portion of oil come out at the end of the test run. 2^{nd} modified version of the set up gave better result than the previous but at higher temperature(370^0 C) gas leaked through the cover. Finally the third version gave the best result of this experiment.It worked till the last and gave the maximum result.(figure-2 & 3)

Figure 2: Three Experimental Set-up

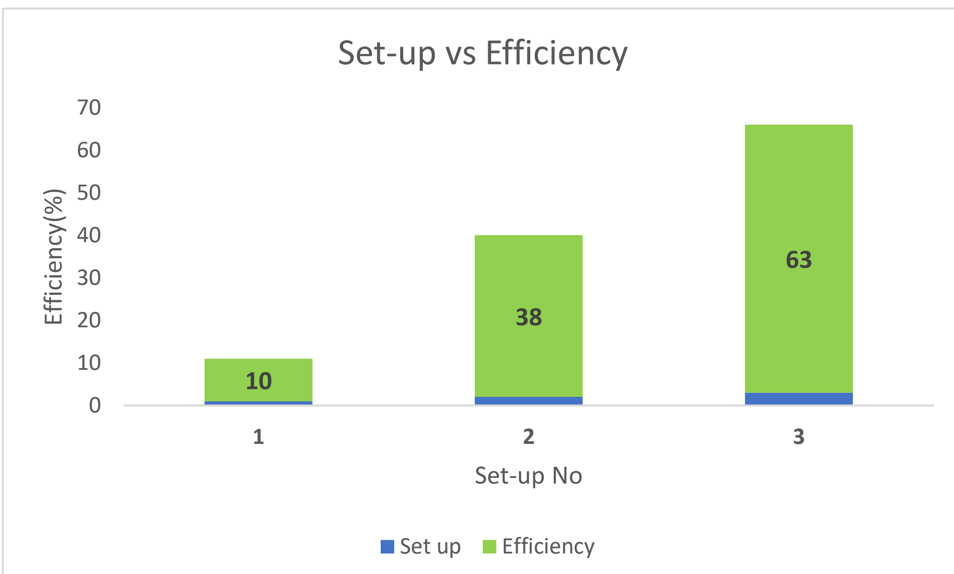
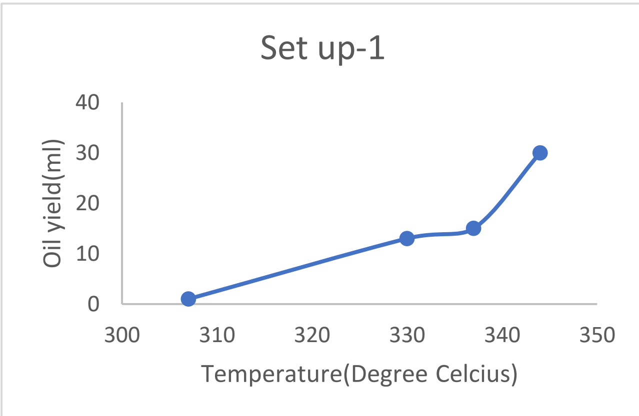


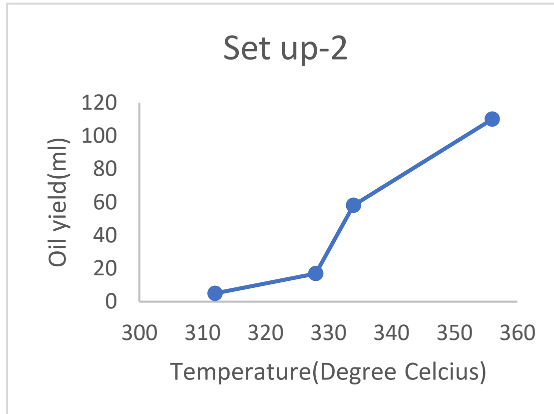
Figure 3: Relation Between Set-up and Efficiency

Effect of temperture on oil yield

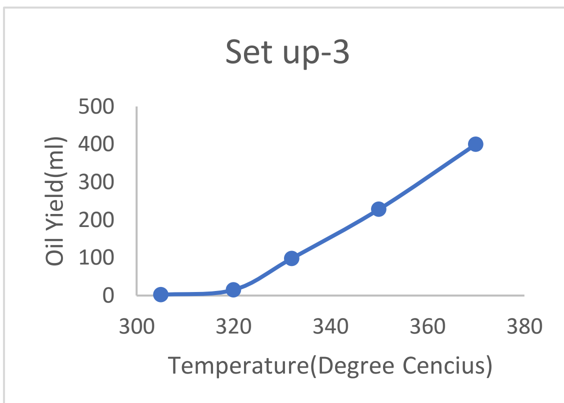
The products are separated into gas, oil, and char residue by pyrolysis of waste plastic. For all the set up, oil yield increases with temperature and it is 400ml at 370^0 C (from set-up 3,figure:4). The gases produced through plastic pyrolysis consist principally of hydrogen (H_2), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), ethane (C_2H_4), and butadiene (C_4H_6), with trace amounts of propane ($CH_3CH_2CH_3$), propene ($CH_3CH{=}CH_2$), n-butane ($CH_3(CH_2)_2CH_3$), and other miscellaneous hydrocarbons.



(a)



(b)



(c)

Figure 4: Effect of temperature on product yield;(a), (b), (c)

Analysis of Waste Plastic Pyrolysis Oil

Physiochemical Analysis: The waste plastic has high volatile content 77.03% by weight which is suitable for pyrolysis conversion of organic solid wastes to liquid product. The comparison of characteristics between waste plastic pyrolysis oil obtained at 420°C and other fuel are shown in Table-1

Table 1 Characteristics of waste plastic pyrolysis oil.

Analysis	Waste Plastic pyrolysis oil	Waste Tyre derived pyrolysis liquid	Typical fuel oil(furnace oil)	Commercial automotive No. 2 diesel
Density(kg/m^3)	760-770	940-970	880-950	820-860
Flash point(^{0}C)	32.5	≤32	66-93	52-96
Fire point (^{0}C)	~42	~42	≥76	≥68
GCVs	42.96	40.80-42.90	43.00-45.00	44.00-46.00

Density: Density is one of the most important characteristics for determining the quality of crude. Density governs the viscosity of the fluid along with the calorific value. If density increase, viscosity of fuel also increases so high viscosity fuel resulting in larger fuel droplets. If fuel droplets are large that result in incomplete combustion of fuel. So, efficiency decrease. If fuel density is less, fuel mass will also be less for same volume. If less mass of fuel is transferred to engine for combustion, the stoichiometric ratio is affected and the fuel-air mixture becomes lean, which means recued combustion. Therefore, too low or too high density of fuel oil is not desirable. It is clear from figure:5 that the density of WPPO is 0.756 gm/cc which is close to the density of kerosene, diesel, and gas oil. So, the conventional fuel such as diesel oil, kerosene oil, and gas oil may be replaced by plastic pyrolysis oil.

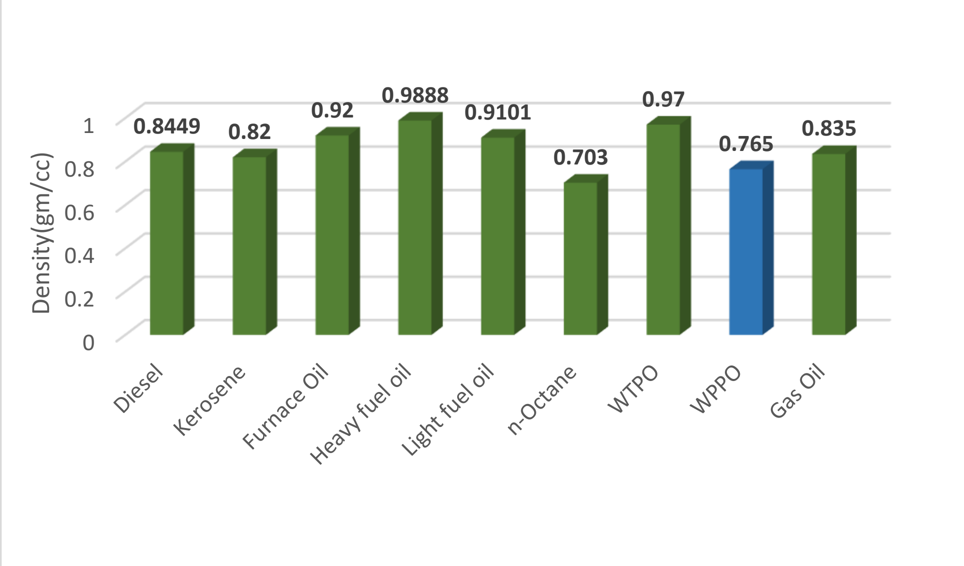


Figure 5: Graphical representation of density of different types of fuel.

Flash Point: The Flash Point of a volatile chemical is the lowest temperature at which it can ignite in either liquid or vapor form. In general, chemicals which have a flash point that is higher than the environment (e.g. room temperature) will be at low risk of catching fire. We measured flashpoint of the fuel using Cleveland open-cup method. The flash point of WPPO was about 32.5°C. A low flash point indicates the presence of highly volatile materials in the fuel that is a serious safety concern in handling and transporting. The flash point of furnace oil, diesel, and kerosene is higher than WPPO (figure-3.5) which indicates that these have low risk to handle. By removing lighter components (such as naphtha/gasoline) the flash point of WPPO will be increased.

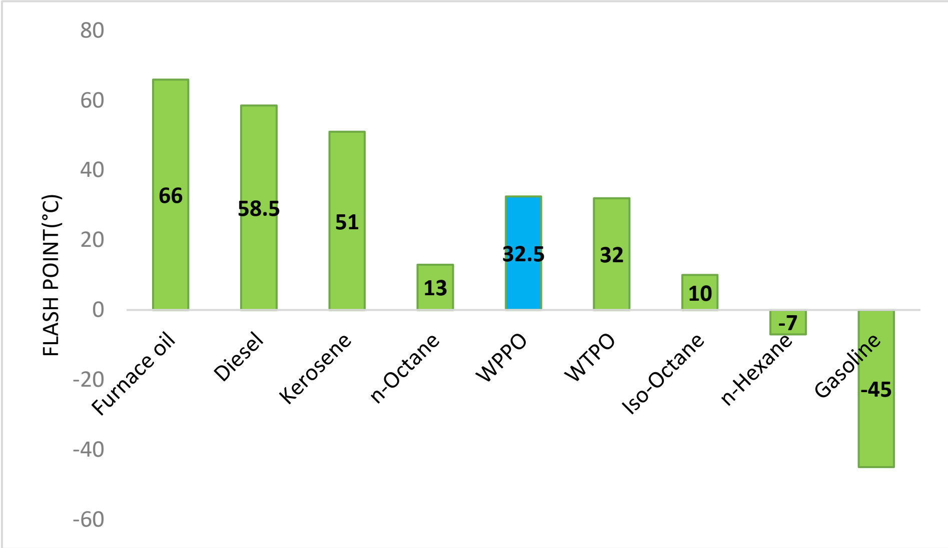


Figure 6: Graphical presentation of flash point of different oil.

Calorific Value: The efficiency of a fuel consuming device, refers to the proportion of the calorific content that is converted into usable energy. The more of the calorific value of the fuel can be utilized to perform whatever task the system is required to perform, the more efficient the system is. The calorific value of WPPO was estimated by bomb calorimetry method. The calorific value of WPPO was 42.96 MJ/kg. Figure 3.6 represents the comparison of calorific value of WPPO with other kinds of oil. This indicates that WPPO has higher calorific value than Furnace oil, Heavy fuel oil (HFO), Waste tire pyrolysis oil (WTPO) and Biodiesel.

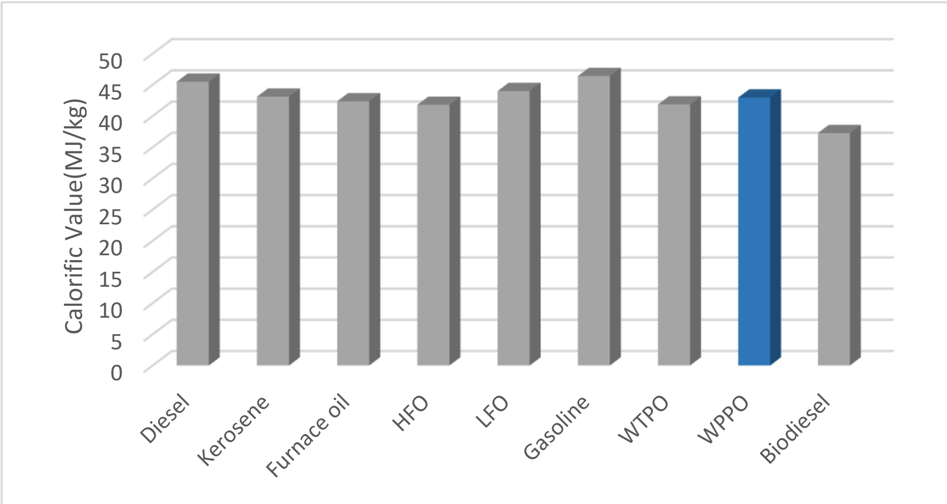


Figure 7:Comparison chart of calorific value of oil.

Price: With the increase of the fuel price in the world market, it also affects the local market of Bangladesh. The following curve reveals the most recent price of the fuel in Bangladeshi market. Comparing the price of the WPPO with the other fuels it reveals that it is possible to replace the costly fuel in future. It can be an alternative source of energy for a country like Bangladesh. Figure 3.7 represents the price of some fuels in Bangladesh.

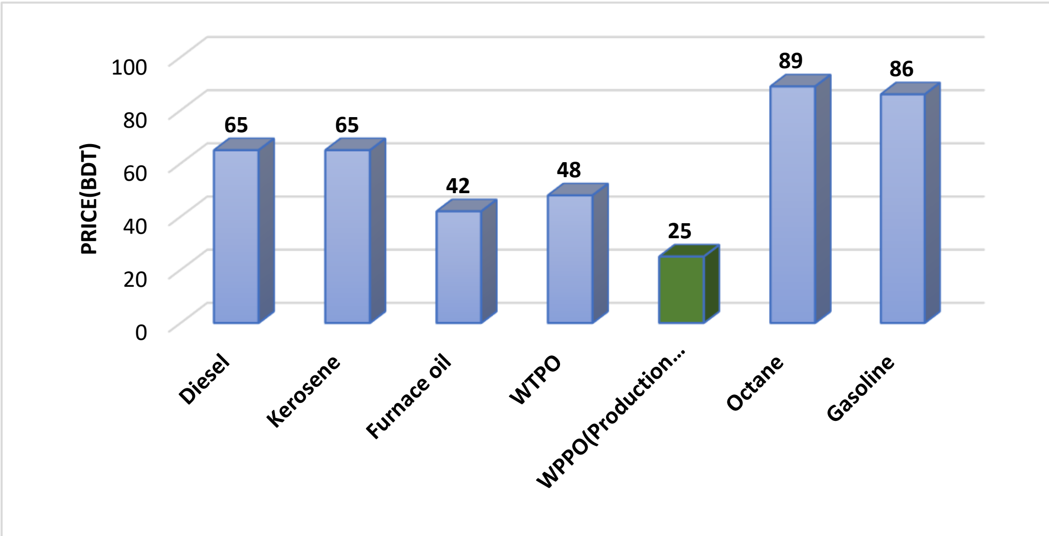


Figure 8: Comparison chart of price of oil.

CONCLUSION

The fuel oil obtained from the waste plastic by thermal pyrolysis is a valuable resource recovery. We used thermal pyrolysis because catalytic pyrolysis is a costly process as well as regeneration of catalyst is a cumbersome task. Mixed type of plastic yields a mixture of oil, gas and a very small amount of char. Higher temperature and longer reaction time increase the gas yield and decrease the char production. Volatile products are obtained at lower temperature and at higher temperature liquid mixture of fuels comes out. Liquid yield increases with temperature and time. Total process takes 55mins to 1hr and 10mins but holding time increases from 2hr to 3hr. The maximum yield 78% at 55min. Physiochemical properties of WPPO is very close comparable with the other fuel and can be used as a replacement of them. However further studies are necessary to utilize this oil as fuel or feedstock.

By converting plastic to fuel, we are solving two issues, one of the large plastics in earth and water and the other is energy crisis. The dual benefit, though will exist only as long as waste plastic lasts, but will surely provide a strong platform for us to build on a sustainable, clean and green future. By considering the financial benefit of such a project, it would be a great boon to our economy.

ACKNOWLEDGEMENT

We are very much grateful to the department of Mechanical Engineering and Materials and Metallurgical Engineering for their kind co-operation.

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PROPOSAL OF PUBLIC ENCOURAGEMENT TO MANAGE SOLID WASTE - A STUDY ON NIRALA RESIDENTIAL AREA, KHULNA

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ABSTRACT:

To ensure sustainable development, it is important to manage solid waste suitably. In the recent time, solid waste management (SWM) has become a serious obligation, globally and considered as a public policy agenda like Bangladesh. Khulna is the third largest city in Bangladesh having 1.5 M population and according to Khulna City Corporation (KCC), an average of 480 tons of waste is generated per day, masonry collection point is nearly about 1200 where waste is removed two times in a week, there are another 150 larger collection points around the whole metropolitan area. Nirala is the most important and old residential place in KCC area where Solid waste is extensively dumped on roads and into open drains lacking dumping site, thus leading to serious health risks and degradation of living environment for a huge number of urban people. The objective of this paper to evaluate the existing condition of solid waste management and propose some process to encourage people about SWM. By doing questionnaire survey analysis some vital problem was identified and on the basis of those problems suggested some operative policy such as door to door service, reward system, encouragement program like solid waste fair etc. to improve solid waste dumping and management system for the betterment of the residential environment.

INTRODUCTION:

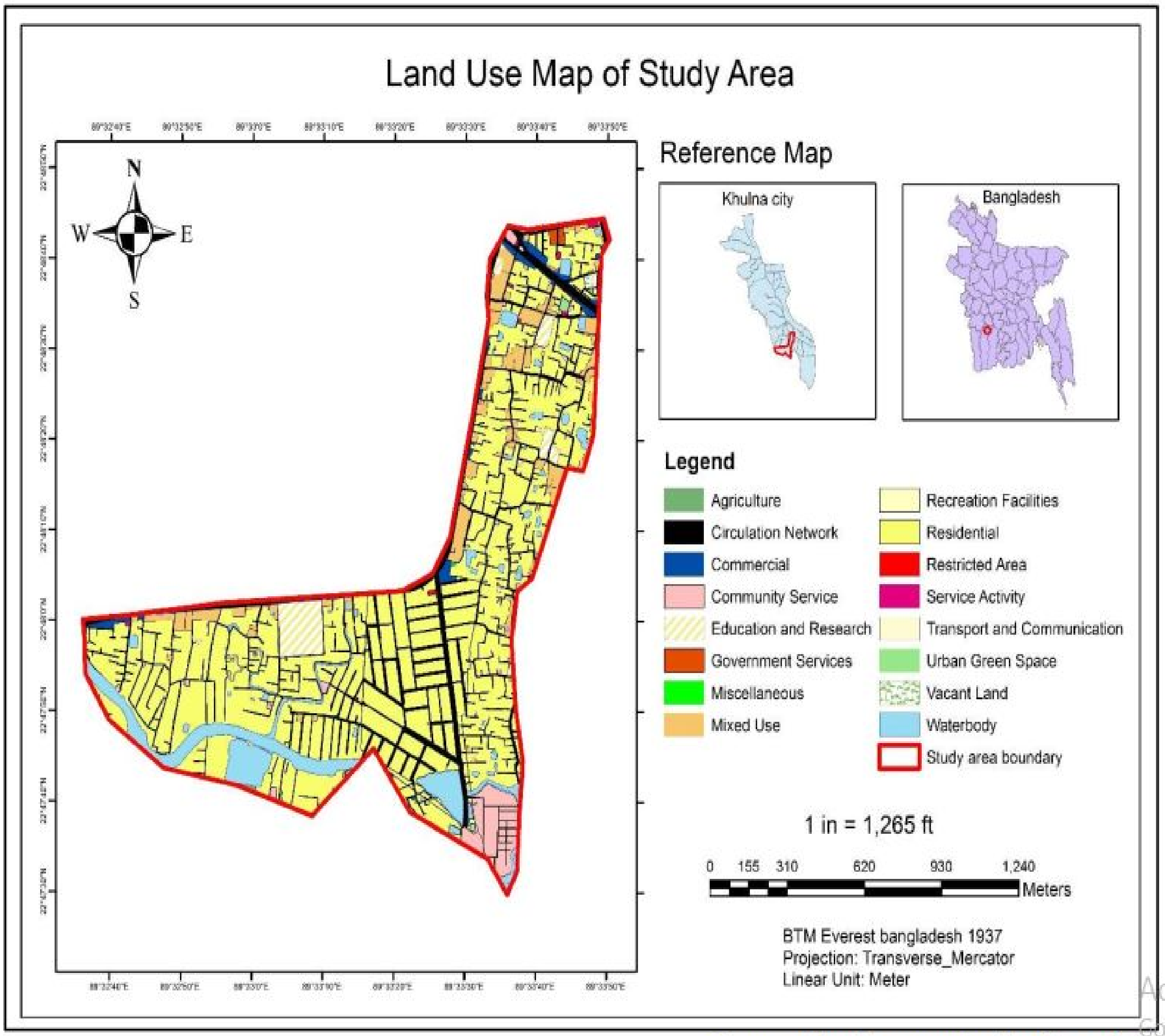
Waste is known as the amount of something which is remaining after the useable and beneficial components have been removed and that has no longer satisfactory or useful. Solid waste refers to the material of garbage arising from animal and human activities that are discarded as unwanted and useless. (Bhuiyan, Nasser, & al., 2003). It may harm in good physical shape of environment, spreading odor, make the site unpleasing to see. Safe and sustainable waste management system is the dreadful requirement in present time throughout theworld. During the last few decades MSW problem have assimilated analarming situation in most of the urban area of world. The importance of solid waste management is increasing day by day as it is an asset for producing energy, clearing environment, maintaining balance ecosystem which is already adopted in developed countries. (Ebistu, 2013) Globally, the estimated quantity of solid wastes expected to be generated annually by the year 2025 is about 19 billion tons (Yoshizawa et al., 2004). So it is a burning question to find socio, economic and eco-friendly solution for a better green environment.

Bangladesh is currentlyundergoing a period of rapid economic growth and urbanization. Due to rapid industrialization,urbanization and population explosion, mushrooming growth of markets restaurants and private clinics/hospitals the solid waste management in the municipal areas of Bangladeshbecome so hazardous that poses a great threat to the city dwellers. Waste disposal and management system is very poor in urban areas of the country. Bangladesh are in the primitive stage and needs modernization through innovative and appropriateapproach in association of local conditions for its proper management (Alamgir, 2009).

Khulna is one of the largest city and port area of Bangladesh. Nirala is mostly planned residential area where high class residential people want to make their community clean and clear as they are conscious about the bad effect of the wastes. Sometimes they cannot afford to minimize the amount of wastes so that they create pressure to the comparatively middle class people that whatever happens to the middle class people by dumping the wastes in their area so that the higher class peoples area may keep clear. If there established a collection system which is acceptable for all types of people of NIRALA residential area. On the basis of the need for effective and encouraging solution should be identified for the people that may help to keep the community clean and do not spread too much dirty wastes to the community.

STUDY AREA:

Khulna is the 3rd largest city of Bangladesh. Khulna City Corporation divided into 31 wards. The study area NIRILA is located in word no 24 occupies an area of 414.7 acres. It is located between22°47’29’’ and 22°48'44" north latitudes and between 89°32'40" and 89°33'50" east Longitudes. The ward 24, NIRALA is bounded on the north by Goborchaka, Seikhpara, and union east by Kakolibeg, Moulabipara union, south by Hatia river and west by Islambad and Baniakhamar union.



Source: Map is generated by the author

Figure 1: Land use map of Nirala

Table 1: General statistics of Nirala

Information	Nirala
Ward	24
Population	9681 (*Source* :BBS 2011)
Area	69 acres
Distance from Sonaganga	3.1 Kilometers
Maximum area coverage	Residential areas

METHODOLOGY:

At first a concept isestablished that unhygienic solid SWM creates an environmental descent in Nirala residential area. A huge amount of report and other source was reviewed for enhance knowledge about this topic. Base on study objectives some criteria was established for determining present condition of SWM. Two types of criteria was selected: (1) Services from city corporation such as collection time period, physical condition of collecting vehicles, number of people engaged with collection, (2) Public perception such as collection fees, distance of disposal site, type of waste, behave of collectors. Additionally, all factor is not be equally important. Primary was collected from field survey and questionnaire survey. Secondary data was collected from KCC, KDA. Then collecting data was analyzed to identify present scenario of SWM in Nirala by using frequency and descriptive analysis, correlation and comparative analysis in SPSS. Based on analysis some proposals was recommended for encouraging people.

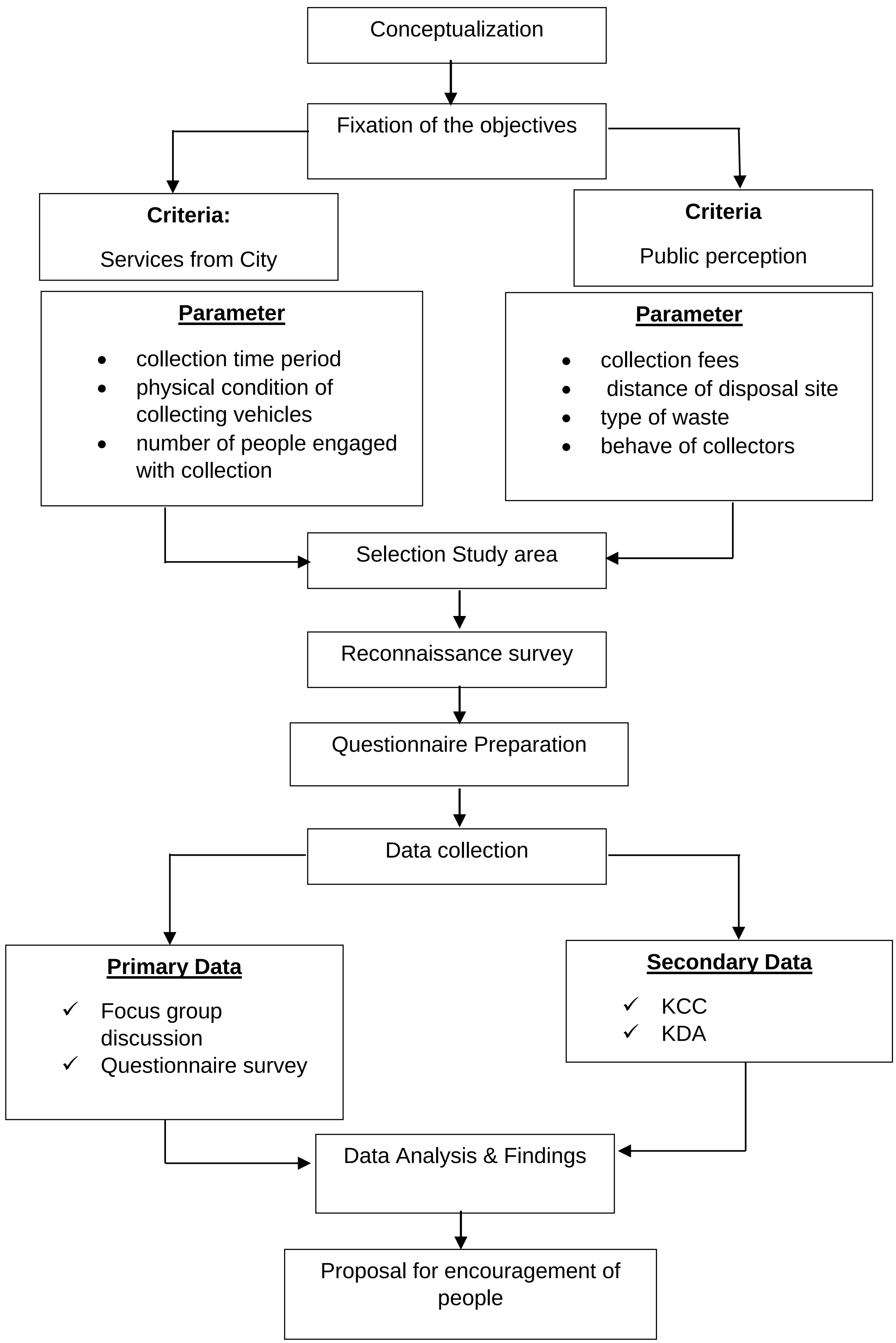

Conceptualization
Fixation of the objectives
Criteria:
Services from City
Criteria
Public perception
Parameter
collection time period
physical condition of collecting vehicles
number of people engaged with collection
Parameter
collection fees
distance of disposal site
type of waste
behave of collectors
Selection Study area
Reconnaissance survey
Questionnaire Preparation
Data collection
Primary Data
Focus group discussion
Questionnaire survey
Secondary Data
KCC
KDA
Data Analysis & Findings
Proposal for encouragement of people

Figure 2: Methodological Framework

ANALYSIS:

General Information:

The questionnaire survey was done among the Nirala residential people in which 81% are female. About 20% family's income range between 10000 and 20000. About 49% family's income range between 20000 and 40000 and 31% family's income range is above 41000 according to questionnaire survey.

Table 2: Income of Nirala residents

income	**Percentages**
10000-20000	20
20000-40000	49
>41000	31

Source: Field Survey

About 33% of household consist of family member Between 1 to 3 and about 51% of household consist of Between 4 to 5 in Nirala residential area.

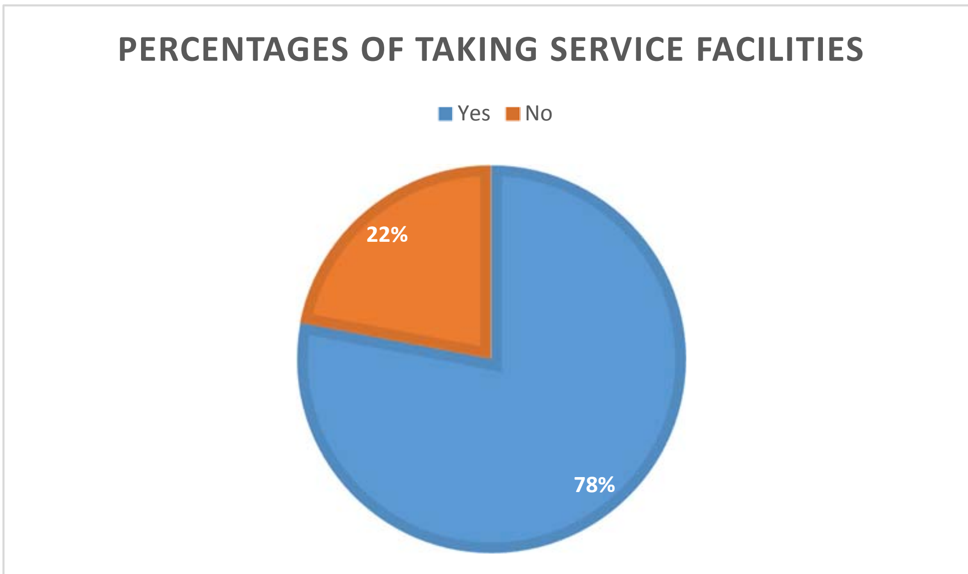
Table 3: Income of Nirala residents

Family member	%
1-3	33
4-5	51
>5	16

Source: Field Survey

Taking Service (waste collection) facility:

Most of the family of Nirala resident want to take waste collection service from municipality which percentages about 78%. About 22% household cannot want to take service. They consider illegal disposal is creating problem in daily life in urban life. The relevant problems of blockage of open drains. Encroachment of road ways offensive odors from waste, presence of mosquitoes and flies, degradation of environment.



Source: Field Survey

Figure 3: Percentages of Taking Service Facility

Service facility condition:

Most of people think that overall condition of waste collection service is bad which percentages is about54%. Collecting member's behavior and collecting time is the main reason to create bad condition of service. That's why most people consider illegal disposal is creating problem in daily life in urban life. The relevant problems of blockage of open drains. Encroachment of road ways offensive odors from waste, presence of mosquitoes and flies, degradation of environment.

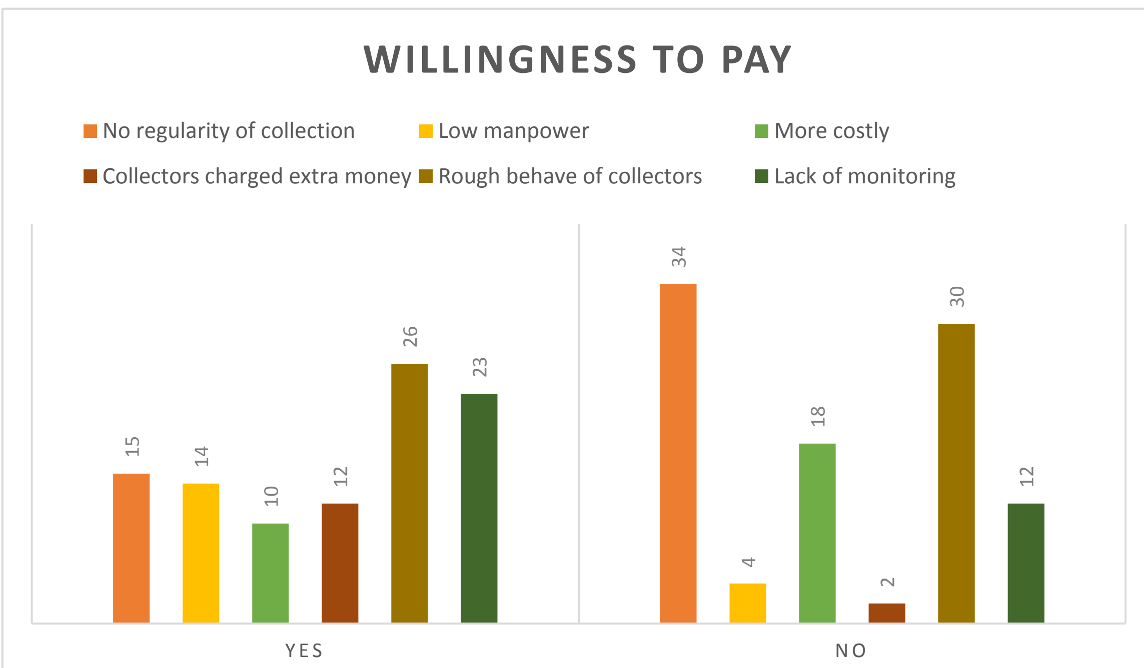
Table 4: Service facility condition

Overall service facility	% of response
Good	17
Moderate	29
Bad	54

Source: Field Survey

Willingness to Pay:

More than 66% householders are willingly pay to the collectors. Rest 34% householders are not interested to pay monthly 50 taka. People who want to pay willingly but they think collector behave and regularity of collection creates adverse impact for taking this services. In this area the per capita income level is high. It is not burden to them but they are not conscious about environmental degradation. Municipal authorities should be strong and impose legislation against this indiscriminately waste disposal.



Source: Field Survey

Figure 4: Willingness to Pay

Collection time schedule:

This table shows the waste collection time period from household. Most people said that waste was collect from household twice in a week which percentages is about 41%. Twice in a week is not enough for collecting period. That's why most household dump solid waste illegally into road, waterbody, open space and drain. The relevant problems of blockage of open drains. Encroachment of road ways offensive odors from waste, presence of mosquitoes and flies, degradation of environment

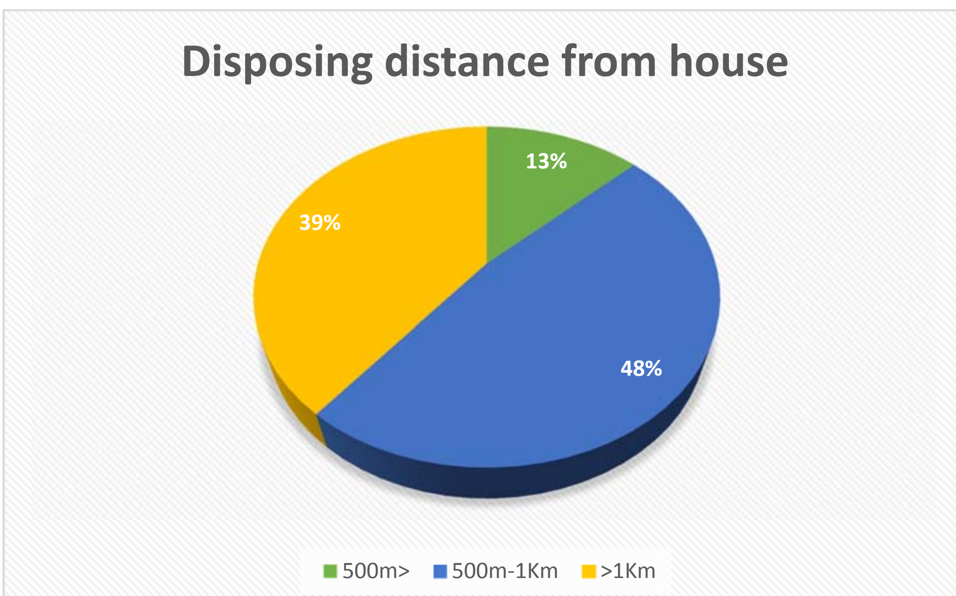
Collection time period	**Percentages**
Daily	17
Per two days	30
Twice in a week	41
Per week	12

Table 5: Collection time schedule

Source: Field Survey

Disposing distance from house:

Absence of available dustbin people dump their household waste into road, drain. It creates bad impact on surrounding environment. Most of people said that the dumping site from their house 500 m to 1 km which percentages is about 48% .

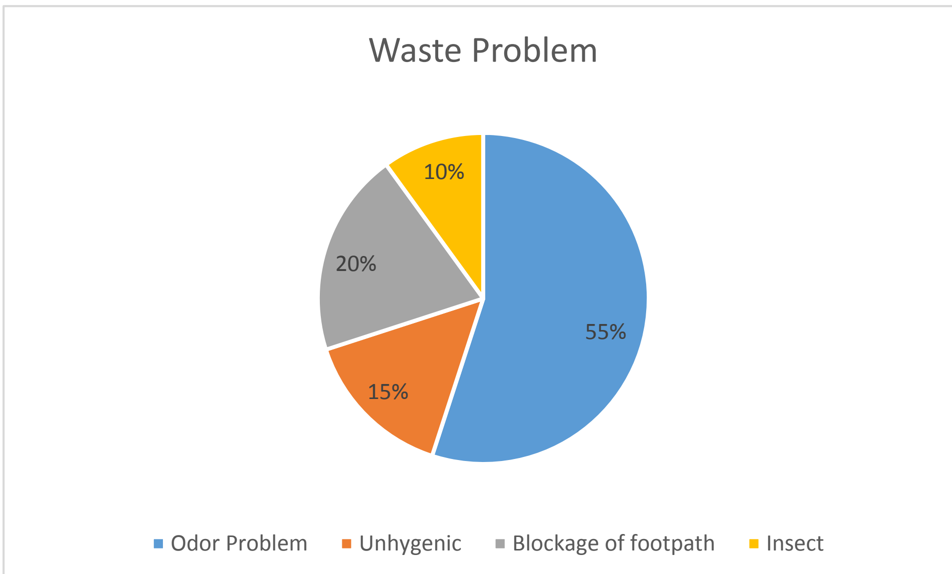


Source: Field Survey

Figure 5: Disposing distance from house

Problem of Indiscriminate of waste:

There are many problem which is created by indiscriminate disposal of waste near and there. Result of this offensive odor problem more than 55%, unhygienic 15%, blockage of road side or foot path 20% and insect problem 10%.



Source: Field Survey

Figure 6: Problem of Indiscriminate of waste

Present Scenario of Nirala:

Nirala is the most important residential area in Khulna city. For collecting waste from household total 24 people are involved and about 14 people are involved as a drainage labour. Total 7 rickshaw van are use as collecting vehicles from household. Disposal site in one and it is located besides the roads. That's why it is created so much environmental problem and odor problem.

Table 6: Present Scenario of Nirala

Manpower and Infrastructure

Total waste disposal labour	21
Drainage Labour	14
Rickshaw van	7
Tractor	1
Disposal site	1

Source: Field Survey

FINDINGS:

Khulna is the third largest city in Bangladesh and Nirala is one of the major residential area in Khulna city. According to analysis most number of people of Nirala want to take services from solid waste management authority but they are not satisfied to their services. Because most of people thought theirs behave, time schedule, collecting fees, lack of dustbin, lack of vehicles and manpower are mainly reason for this dissatisfactions. That's why huge number of people use illegal disposal way and they dispose their household waste into road, drain, waterbody, open space. For this activity it creates air pollution, odor problem, and many environment problem. Disposal site is so far from household, it also reason for illegal disposal and located besides main roads, it also creates environment problem.

PROPOSAL FOR PUBLIC ENCOURAGEMENT:

1. **Door to Door service**:
   Door to door collection of solid waste from every household and dump into selected site that's why people are not want to dump waste anywhere. Collection and transportation household solid waste up to secondary collection point. The successful collector will arrange for the collection of solid waste from door to door in such a way that it'll be taking from the rickshaw trolley/auto tipper to secondary storage point and then to compactor without touching the ground any time.
2. **Reward System:**
   Reward system is another process to encourage people for not dump their household waste everywhere. Some rules is creating this reward system process successfully. People who always give their household waste to the waste collector, they will rewarded by compromising 50% 0ff for their fees.
3. **Encouragement Program** :
   Different program like different seminar, meeting, and cultural program about giving knowledge of solid waste will efficient to encourage people for not dump their household waste everywhere. A big change should be brought into the people's attitude by this program. Separation of collection systems should be begin.

4. **Transportation System:** Using demountable container truck instead of open truck. Increasing their numbers
5. Providing adequate demountable containers and concrete bin in suitable open place.
6. Using modified rickshaw van. Increasing their capacities of loading.
7. Increasing the number of collectors and training for change their attitude and behave and their equipment's.

CONCLUSION:

Solid waste has been a part of human society for as long because the existence of humans. Historically unintended solutions are used choosing minimizing negative health impacts of waste in major cities. Throughout the last half of the twentieth century some components of the globe began to specialize in the disposal of waste. Therefore it's terribly required task for each town corporation to manage this large quantity of MSW that is created a day by town dwellers. Nirala is one of the major residential area in Khulna city. About 78% of people at Nirala want to take services from solid waste management authority but they are not satisfied to their services. Because most of people thought theirs behave, time schedule, collecting fees, lack of dustbin, lack of vehicles and manpower are mainly reason for this dissatisfactions. That's why huge number of people use illegal disposal way and they dispose their household waste into road, drain, waterbody, open space. For this activity it creates air pollution, odor problem, and many environment problem. Disposal site is so far from household, it also reason for illegal disposal and located besides main roads, it also creates environment problem. For solving this problem and encourage people take some proposal criteria or effort such as door to door service, reward system, Transport facility, training of collector.

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A GIS BASED SUITABILITY ANALYSIS FOR WASTE DUMPING ZONE – A CASE STUDY ON PABNA MUNICIPALITY, BANGLADESH

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ABSTRACT:

Waste is known as the amount of something which is remaining after the useable and beneficial components have been removed and that has no longer satisfactory or useful. Safe and sustainable waste management system is the dreadful requirement in present time throughout the world. The objective of the paper is to search out the acceptable location for dump the community waste of PABNA town. For full filling this, the study focuses on four core criteria of waste dump zone: (i) distance from the major road; (ii) distance from the structure (iii) distance from the water Body and (iv) drain facilities of the realm. This research data source based on secondary data collection from all stakeholders involved in the waste collection and disposal system, and on the Geographic Information System (GIS) based secondary analysis of waste collection points and their coverage. Data analysis is done with help of ArcGIS 10.4. Euclidean Distance Reclassify and weighted overlay is used for data analysis. The final site is selected which is not very close to the water body, road network is good and where there are absence of too much structure and not create bad impact on drainage facility.

INTRODUCTION:

Waste is known as the amount of something which is remaining after the useable and beneficial components have been removed and that has no longer satisfactory or useful. Solid waste refers to the material of garbage arising from animal and human activities that are discarded as unwanted and useless. (Bhuiyan, Nasser, & al., 2003). It may harm in good physical shape of environment, spreading odor, make the site unpleasing to see. Safe and sustainable waste management system is the dreadful requirement in present time throughout the world. During the last few decades MSW problem have assimilated an alarming situation in most of the urban area of world. According to Global Waste Management Market Assessment (2007), 2.02 billion tones MSW is generated globally and it increases at 8% rate per year.

Bangladesh is currently undergoing a period of rapid economic growth and urbanization. Due to rapid industrialization, urbanization and population explosion, mushrooming growth of markets restaurants and private clinics/hospitals the solid waste management in the municipal areas of Bangladesh become so hazardous that poses a great threat to the city dwellers. Waste disposal and management system is very poor in urban areas of the country. Bangladesh are in the primitive stage and needs modernization through innovative and appropriate approach in association of local conditions for its proper management (Alamgir, 2009)

Pabna is one of the old and rapidly growing cities of Bangladesh. The city area is expanding hurriedly with a massive growth of population at a rate of around 5 percent a year (BBS 2011). Solid wastes are being generated at a faster pace, posing a serious management threat. So it is important to fix up the location of disposal point to provide a better healthy environment for the future generation of Pabna municipality.

STUDY AREA:

The Pabna municipality is between 23°53'' N and 24°05'' N Latitude and 89°09'' E and 89° 25'' E Longitudes. It is bounded by Shalgaria and Laskorpur beyond the river Ichamoti on the North, Dakshin Ramchandrapur on the South, Arifpur- Mahendrapur-Madarbaria Hemayetpur and Pailanpur on the West part of the Paurashava. The Icham ootni Rtivheer iEs apsat ssainngd through the middle of the Paurashava. There are 23 Mauzas included in the Pabna Paurashava as per gazette (SRO No. 222) published in 1989.

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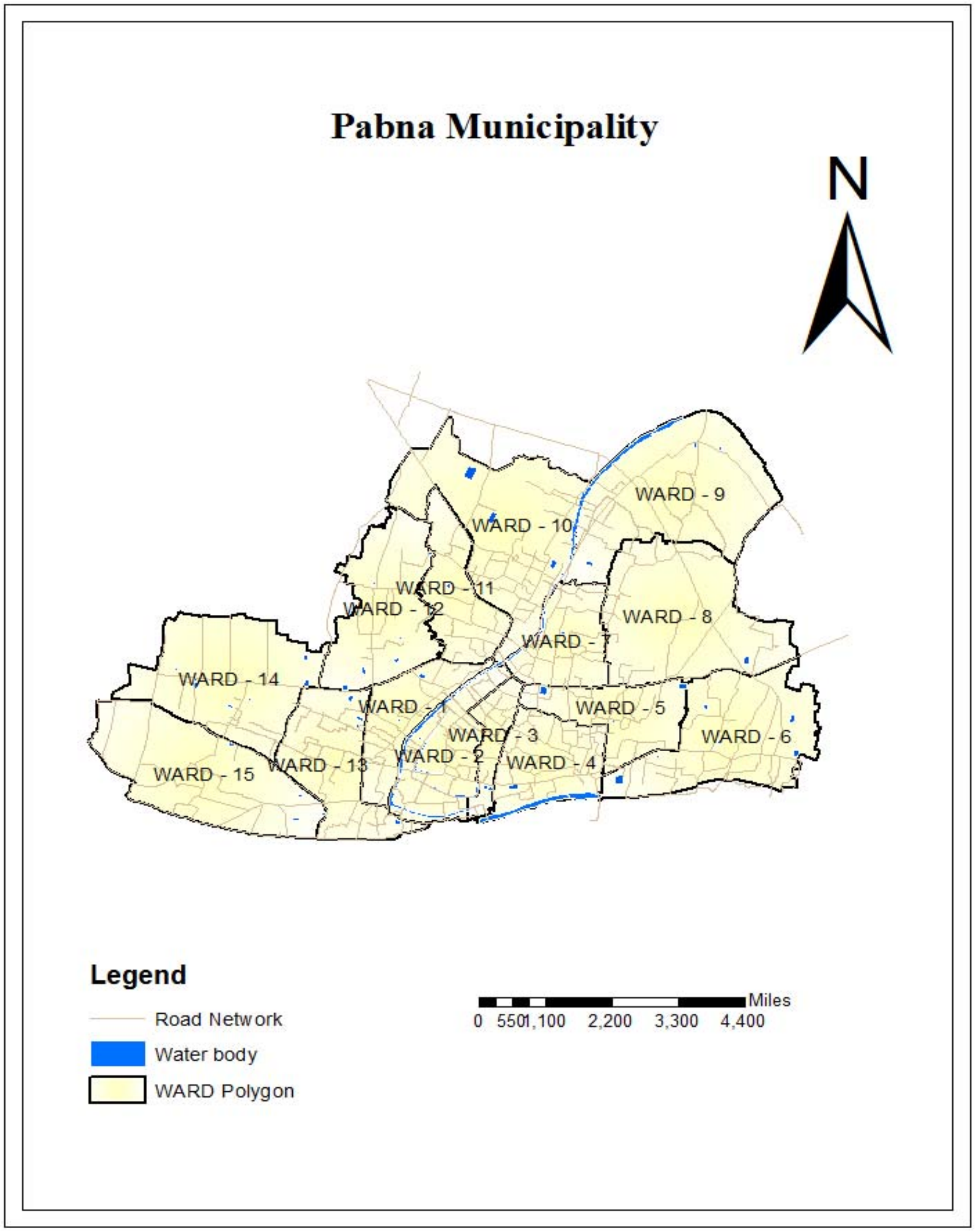


Source: Map is generated by the Author

Figure 01: Pabna Municipality

Table 1: Ward wish population and existing dustbin of Pabna Pourashava

Source: Conservancy department (Pabna Municipality), 2016

Name of ward	Total number of household	Total existing dustbin	Number of household per dustbin
Ward 1	2022	2	1011
Ward 2	3057	25	123
Ward 3	1763	12	147
Ward 4	1746	12	146
Ward 5	2088	9	232
Ward 6	2042	0	2024
Ward 7	2179	7	312
Ward 8	1560	4	390
Ward 9	2499	13	193
Ward 10	2481	3	827
Ward 11	3022	13	232
Ward 12	2354	4	588
Ward 13	2646	13	203
Ward 14	1584	4	396
Ward 15	2174	1	2174
Total	**32217**	**122**	

Table 2: Human resources of Pabna Pourashava in Conservancy Department

Types of personnel	Part time service	Full time service	Total number
Conservancy inspector	0	1	1
Engineer	0	1	1
Supervisor	0	1	1
Labor	220	0	220
Driver	0	3	3
Total	**220**	**6**	**226**

Source: Conservancy department (Pabna Municipality), 2016

METHODOLOGY:

The study area is chosen considering the necessity of solid waste retailing station and also the accessibility of the information for analysis. The study area Pabna has been taken because of the available data source of the area. Base on this data some criteria was established for determinant appropriate location. In addition, all issue isn't be equally necessary. Necessary of every issue confirm by review numerous report and seek advice from native folks. in order that the influence of the build-up space is just too a lot of than the others factors that if an appropriate location is chosen within the build-up space it's quite not possible to established the selling zone within the section in our country context. The data has been collected through the secondary materials. Secondary materials area unit out there from varied sources and this stuff area unit collected completely and some map was collected from varied sources like Pabna municipality. Then this map was digitized and excellent co-ordinate system has been outlined. Geo referencing was done with help of Ground

Control Point (GCP) which was taken by using Google earth and ArcGIS 10.4 is used for this purpose. When the data is prepared a small scale survey was held for ensure the accuracy level of secondary data. Data analysis is done with help of ArcGIS 10.4 Euclidean Distance Reclassify and weighted overlay is used for data analysis. When data is fully prepared, first tools that used in ArcGIS 10.4 is Euclidean distance. Euclidean distance tools describe every cell's relationship to a supply or a group of sources supported the straight-line distance. Second tool is classify .It reclassifies formation. Here the output of geometrician distance is classify base on established Criteria. Output of reclassify have 3 value one is Unsuitable, second is Moderate suitable and other is highly suitable. After reclassify the each factor, weighted overlay tools is used for determining the suitable place.

Table 3: Criteria for Site selection

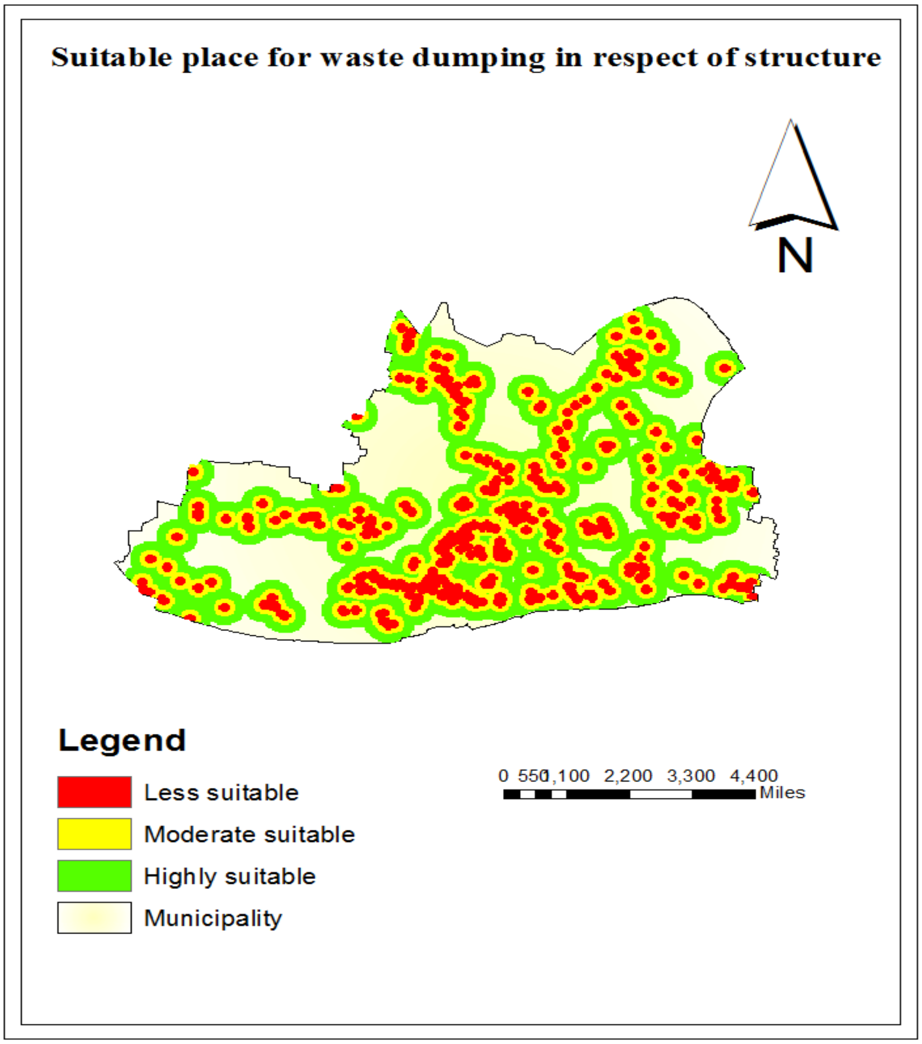
Serial No.	Factors	Suitable Level	Distance	Influence%
1.	Structure	Highly suitable	150-300	25
		Moderate suitable	50-150	
		Less suitable	0-50	
2.	Main Road	Highly suitable	150-250	20
		Moderate suitable	50-150	
		Less suitable	0-50	
3.	Drainage	Highly suitable	100-200	20
		Moderate suitable	50-100	
		Less suitable	0-50	
4.	Waterbody	Highly suitable	150-300	35
		Moderate suitable	50-150	
		Less suitable	0-50	

Source: Expert Opinion Survey

ANALYSIS:

There are different types of maps are generated by using ArcGIS 10.4 on the basis of four established criteria. It will help to find the suitable location for four different perspective and finally the overlay map is shown to mention the suitable places that satisfied all the criteria.

Structure Map:

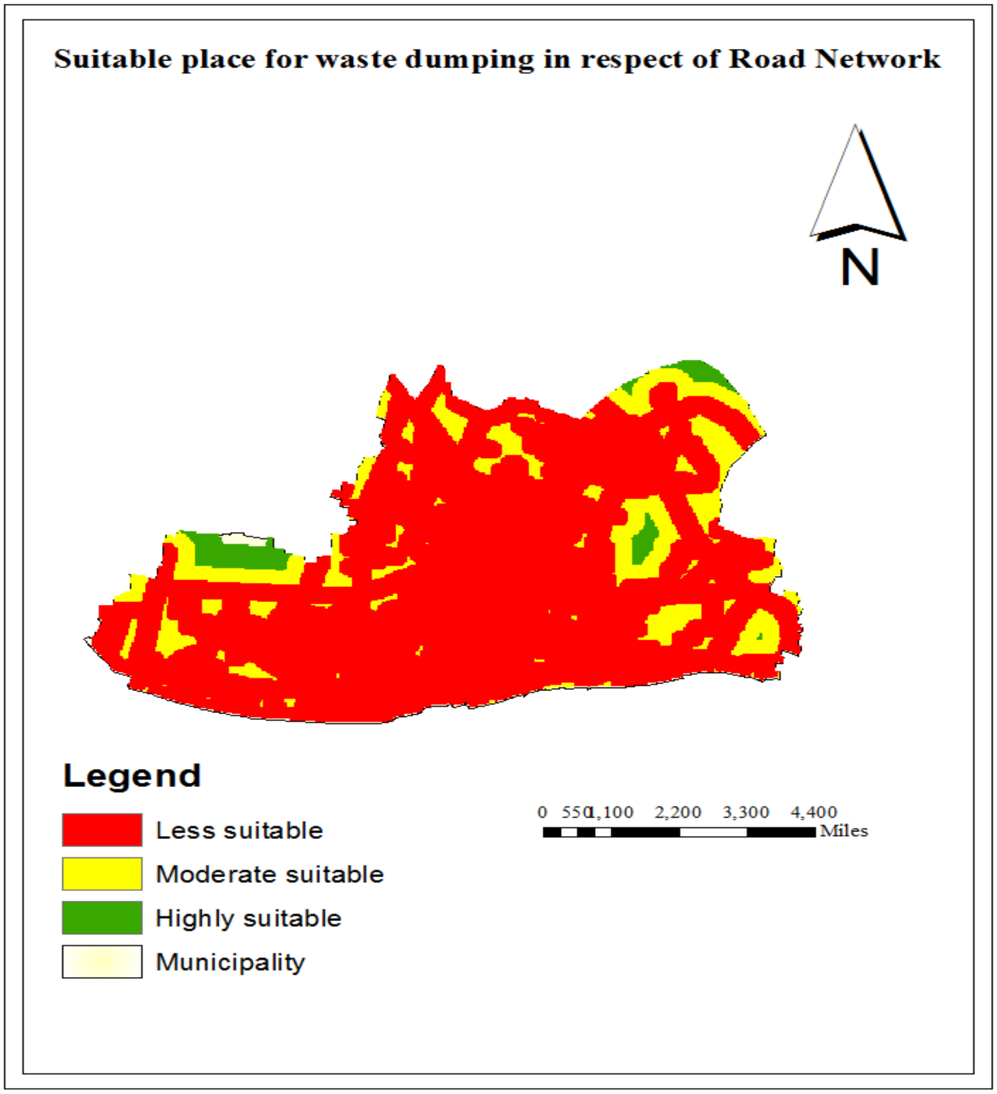


Source: Map is generated by the Author

Figure 2: Suitable place for waste dumping in respect of structure

Here seen that red zone is less suitable for waste dump because this site is very close to the different structures. Here also seen that less suitable area for waste dump is more than moderate suitable and highly suitable. Yellow zone is moderately suitable and Green zone is highly suitable area for waste dump.

Main Road:

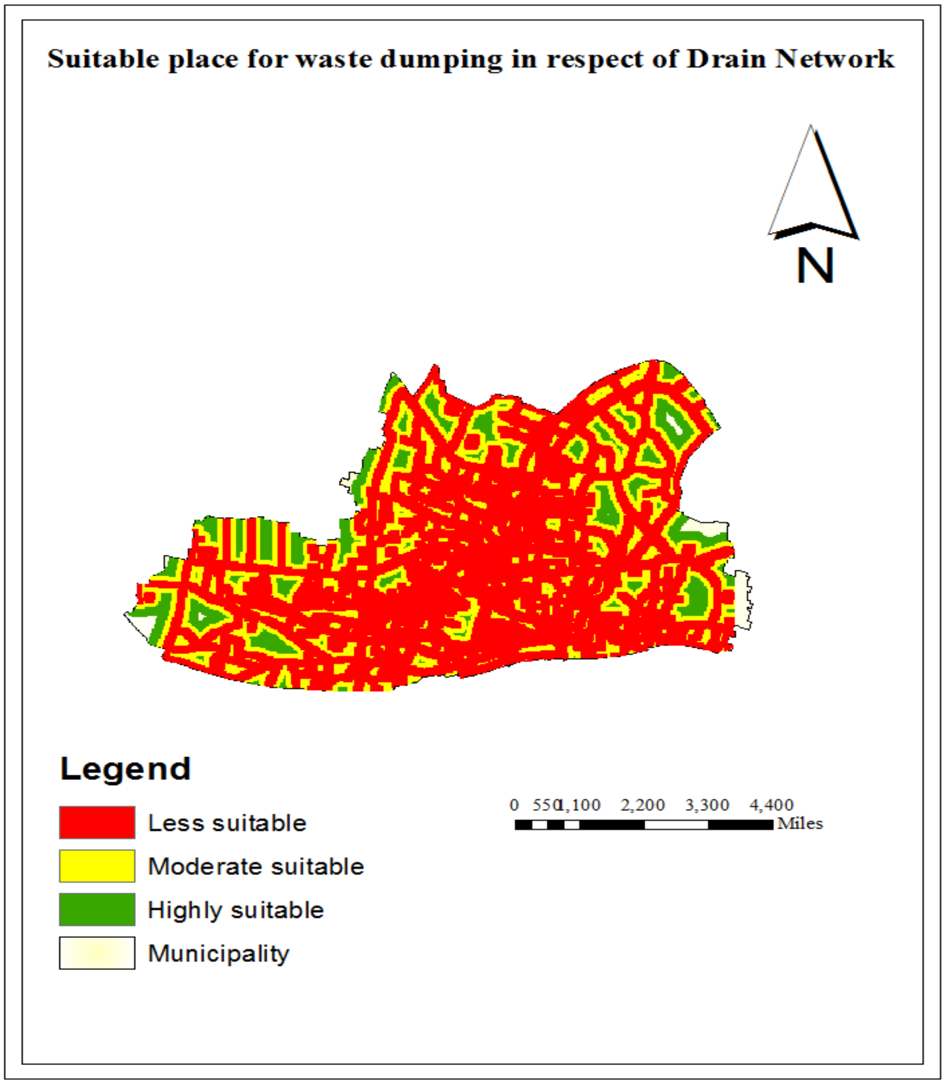


Source: Map is generated by the Author

Figure 3: Suitable place for waste dumping in respect of Road Network

Here seen that red zone is less suitable for waste dump because this site is very close to the different main road. Here also seen that less suitable area for waste dump is more than moderate suitable and highly suitable. Total areas about78% is less suitable area. Yellow zone is moderately suitable and Green zone is highly suitable area for waste dump. West part of Pabna is a suitable zone for waste dump.

Drainage Facility:

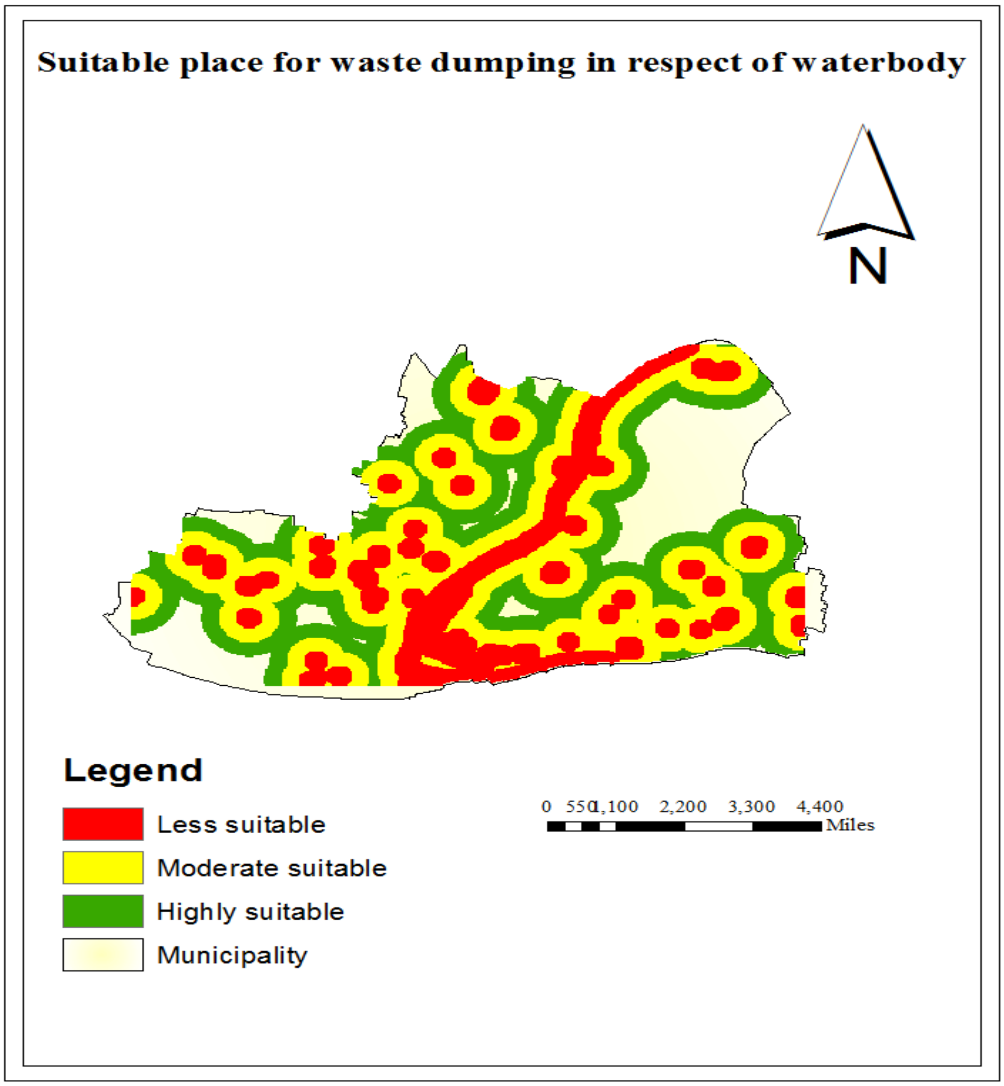


Source: Map is generated by the Author

Figure 4: Suitable place for waste dumping in respect of Drainage facility

Here seen that red zone is less suitable for waste dump because this site create bad impact on drainage flow. Here also seen that less suitable area for waste dump is more than moderate suitable and highly suitable. Total areas about 67% is less suitable area. Yellow zone is moderately suitable and Green zone is highly suitable area for waste dump. West part and east part of Pabna is a suitable zone for waste dump according to this factor.

Waterbody:

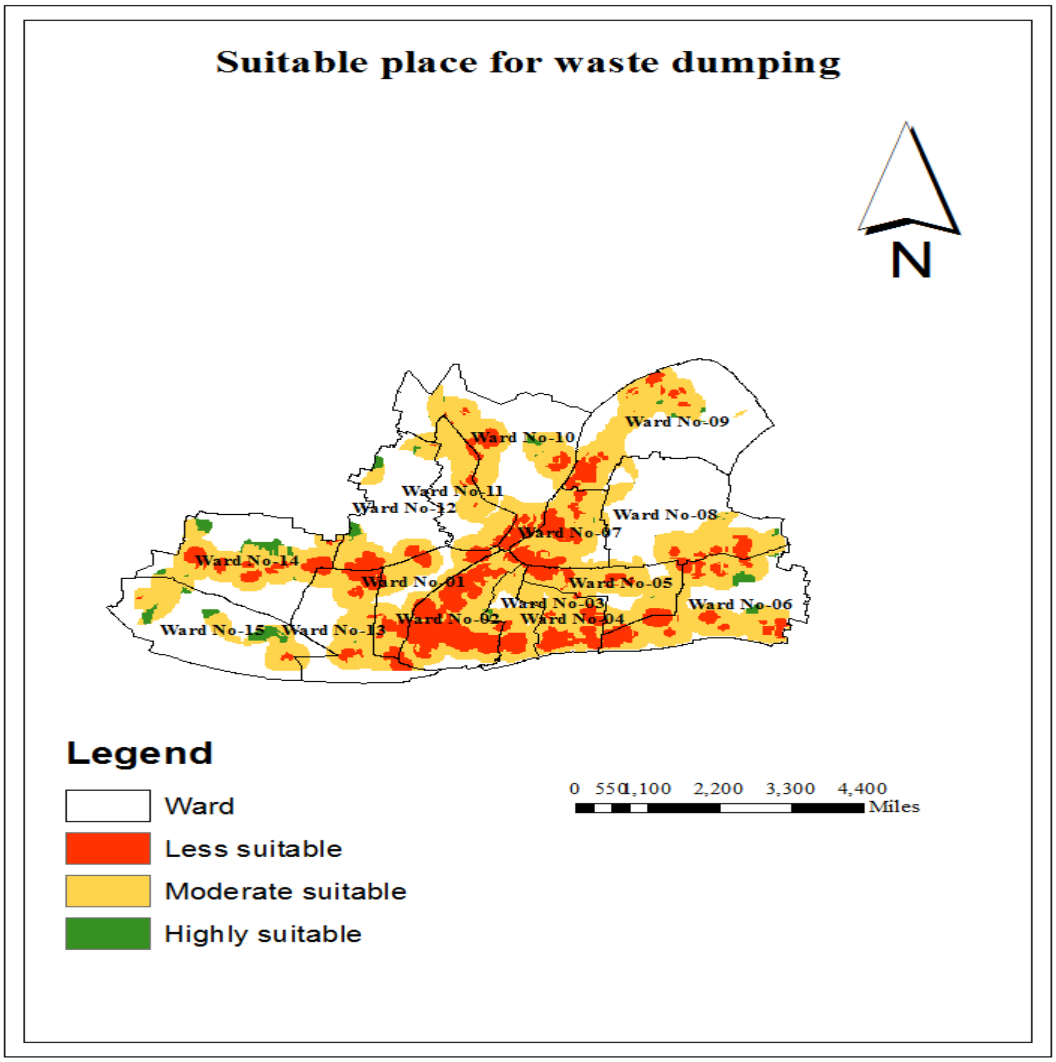


Source: Map is generated by the Author

Figure 5: Suitable place for waste dumping in respect of Drainage

Here seen that red zone is less suitable for waste dump because this site is bad impact of waterbody. Here also seen that less suitable area for waste dump is more than moderate suitable and highly suitable. Yellow zone is moderately suitable and Green zone is highly suitable area for waste dump. About 27 % area is suitable area between whole areas of Pabna for waste dump.

WEIGHTED OVERLAY AND FINDINGS:



Source: Map is generated by the Author

Figure 6: Suitable place for waste dumping

Here seen that suitable area is about 1.07% between whole areas of Pabna. Most area is moderately suitable for waste dump but it cannot to be a suitable area according to our four criteria. Ward no 14, Ward no 15 and ward no 06 is the efficient and highly suitable for waste dump site in Pabna.

CONCLUSION:

The analysis states the matter associating the waste promoting system within the Pabna and by minimizing the problem it identifies an appropriate location for waste promoting in its own boundary. The place can solve the matter that arises beside the most road by marketing the wastes here and there. It'll keep the community clean and clear further as relieve the pressure from the center category peoples round the space. Totally different tools and techniques were utilized in ArcGIS ten.4 to seek out the acceptable location a lot of accurately.

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DESIGN AND PERFORMANCE ANALYSIS OF A BENCH SCALE BIOLOGICAL WASTEWATER TREATMENT PLANT FOR SHRIMP PROCESSING INDUSTRIES

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ABSTRACT

The shrimp culture and processing is the central important in Bangladesh particularly in the context of export earnings. About 80% of the shrimp farming areas are situated in the country is southwestern region while the rest are in the southeastern part. One ground survey has estimated that effluents 47500L/day/plant generated are directly released in the environment. This study has been performed to find cost effective biological effluent treatment plant for shrimp processing industries wastewater treatment. Based on raw wastewater parameters a bench scale biological treatment plant has been designed, operated, parameters tested and analyzed. A circular type primary and secondary clarifier with rectangular aeration basin has been designed, installed and operated. Diffused air has provided. Maintained flow 20 ml/min in inlet and outlet. Treated value of wastewater is used to analysis of design. It has shown the bench scale biological treatment plant has removed remarkable organic load from wastewater.

Keywords: *Shrimp process wastewater, Activated sludge process, BOD, COD*

Introduction

It is common practice in Bangladesh to discharge of effluent in environment without treatment. Many industries do not follow the ‘Bangladesh Environment Conservation Rules – 1997’ and the ‘Bangladesh Environment Conservation (Amendment) Act – 2010.’ The Khulna is known as industrial area. There are many types of industry is here. Shrimp processing industry is one of them. There are 162 fish processing plants in the country among 96 are GoB licensed (Kabir, 2014). A ground survey has measured 47,500 L/day/plant wastewater generated and directly released in the environment (Billah, 2016). Maximum of these industries are situated nearby road side and river bank. That’s why Khulna and nearby is polluting by shrimp processing industries wastewater. Shrimp processing industries are not only located in Khulna but also in Bagerhat, Satkhira and other coastal districts. In 1960s shrimp culture has started from the coastal Satkhira districts. Gradually it has expanded to the other coastal belts of Khulna, Bagerhat, Cox’s Bazar and Chattagram (Naureen et al., 2006). Export earnings has been estimated from 1973, the export earnings were only US$ 3.17 million, which stands at US$ 420 million in 2004-05 and US$ 526.45 million in 2016-17 fiscal year (BFFEA, 2006). Though it has great contribution in national economy of Bangladesh, contrary inverse impact in environment. It contain objectionable level of pollutants. Mainly, organic loading is high of shrimp processing industries wastewater. Different experiments have found different inorganic and organic parameters value of wastewater. A study on seafood (shrimp processing) industries wastewater of Khulna has shown effluents contains of pH 8.06±1.12, Dissolved Oxygen 7±0.12 mg/L, TDS 1777±553 mg/L, TSS 543±187 mg/L, BOD 377±15 mg/L, COD 593±10 mg/L (Billah, 2016). Nevertheless, there is no such initiative in the treatment of wastewater of shrimp processing industries. One reason may be operating cost due to regular chemical feeding. In this study, no chemicals were used in designed bench scale biological wastewater treatment plant and found good result.

Methodology

A shrimp processing industry was selected first. Then wastewater was collected from the industry according to standard sampling method and selected parameters were measured in laboratory. Based on the parameters of laboratory test a treatment process and design was done. According to design, a bench scale laboratory treatment plant was installed. Wastewater from selected industry was collected regularly and fed in to the designed bench scale treatment plant. Then sample was examined in environmental engineering laboratory. Result from the laboratory examined was recorded and analyzed by a spreadsheet software. Performance of the bench scale treatment plant was analyzed with respect to obtained result. Based on this result, design calculation was also analyzed. This study has been performed during October 2017 to July 2018. The research methodology can be seen at a glance from the following figure.

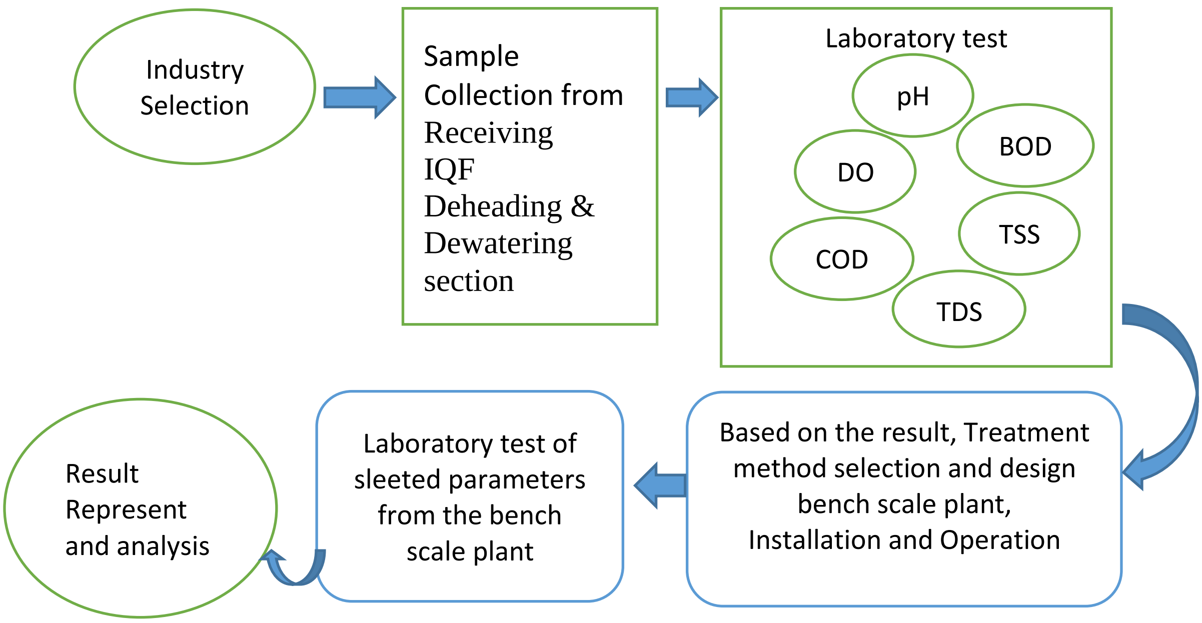

Figure 1 Research Methodology

From the chosen shrimp processing industry, wastewater was collected and selected parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) were tested. Laboratory test data is given in the following table.

Table 1: Raw wastewater parameters of selected shrimp process wastewater

Parameters/points	Receiving shrimps and initial washing	Initial icing (or IQF)	Deheading	Dewatering or production room
pH	7.5	7.51	7.61	7.66
Dissolved Oxygen (DO), mg/L	1.39	1.26	1.83	1.46
Biochemical Oxygen Demand (BOD), mg/L	270	234	489	362
Chemical Oxygen Demand (COD), mg/L	756	655	1370	1013
Total Suspended Solids (TSS), mg/L	640	80	50	480
Total Dissolved Solids (TDS), mg/L	2380	3380	2380	2900

Based on this result, treatment method was selected and bench scale plant were designed. Though the above value were obtain from the laboratory test but a range of value was considered as design criteria and it is given in the following table 2.

Table 2: Range of design criteria that considered as design value

pH	DO (mg/L)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	TDS (mg/L)
7 – 9.5	1 – 2	360	450 – 650	300	1500 – 3500

Extended aeration activated sludge process was selected as treatment method. Thus, a bench scale treatment plant was designed based on the above data (table 2) of different parameters. Following figure is about process flow and then design calculation has shown.

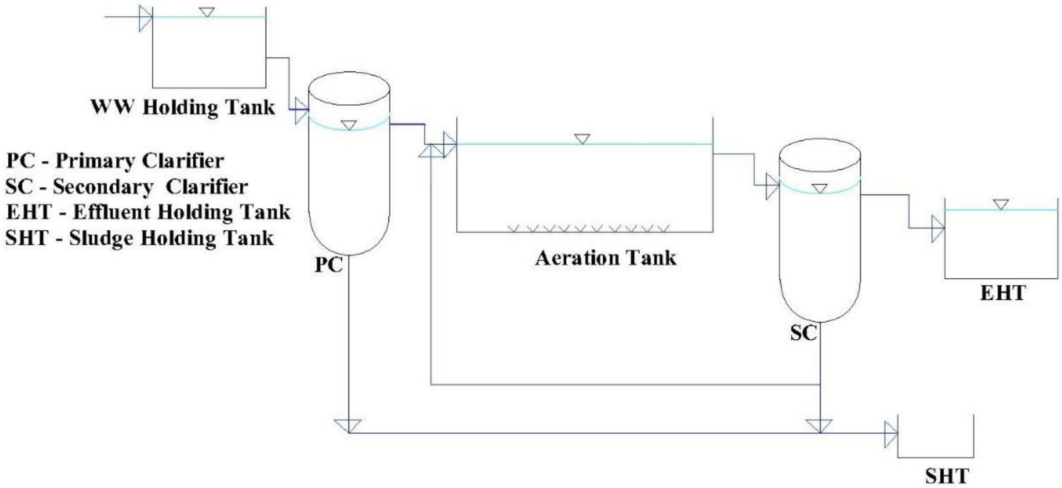

Figure 2: Process Flow Diagram of the Bench Sale Plant

Continuously 20 milliliter per minute flow was maintained and thus flow Q was 20 ml/min. Design calculation was performed based on the data of table 2. The calculated result of design with design consideration is precisely given below (table 3). Primary and secondary clarifier volume and size was kept same. One aeration unit was used. Design calculation and consideration was performed as per Metcalf, 1995 and Karia, 2010.

Table 3: Design consideration and design data of bench scale WW treatment plant

Primary Clarifier	Aeration Basin
Flow (Q), m^3/s – 20 ml/min	
Influent SS – 300 mg/l	Influent SS – 150 mg/l
Influent BOD_5 – 360 mg/l	Influent BOD_5 – 250 mg/l
SS Removal Capacity – 50%	Effluent BOD_5 – 30 mg/L
BOD_5 Removal Capacity – 30%	Growth Rate Constant, K_s $100\ mg/L\ BOD_5$
Hydraulic Retention Time (HRT) – 1.0 hr	Maximum Growth Rate Constant (μ_m) – $2.5/d$ Decay rate (K_d) – 0.05 / d
Volume of clarifier (Process Zone) – 1.3 Liter = 79.33 Cubic Inch	Yield Coefficient for Conversion of BOD_5 into Bacterial Cells (Y) – 0.50 mg MLVSS/mg BOD_5 remv.
Diameter – 0.1 m = 4 inch	Length & Width 0.32 m (12 inch) & 0.18 m (7 inch)
Surface Area – 12.5 $inch^2$	Surface Area – 0.0576 m
Liquid Depth – 0.17 m = 6.5 inch	Liquid Depth – 0.13 m
Tank Type – Circular	Aeration Volume - 3 L/min Continues and Completely mixed Diffused Aeration (by Aquarium stone diffuser)
Composition of Tank –High Density Polyethylene (HDPE)	

As per above data, a bench scale biological wastewater treatment plant was installed and operated regular basis. Samples were collected from this bench scale plant and tested regular. The layout and cross section of the plant and an original photograph of the plant is given in next two figures.

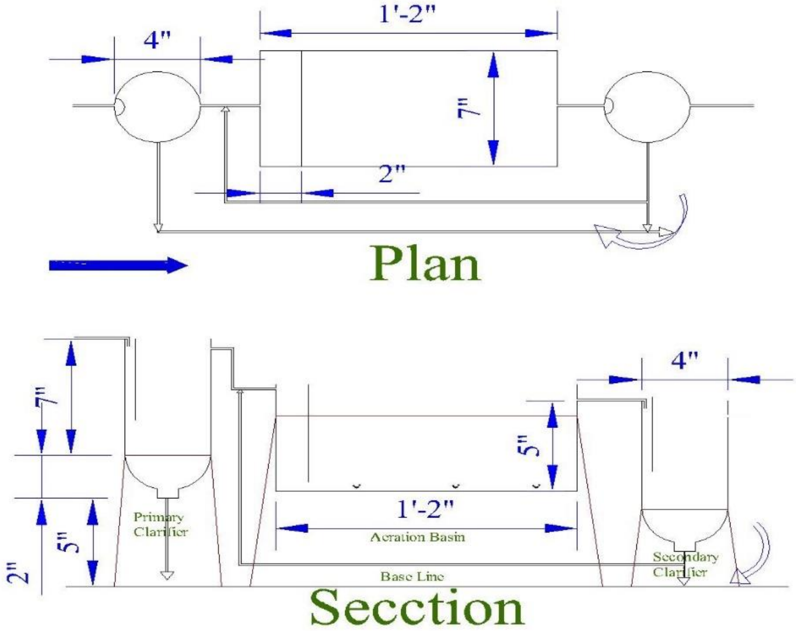

Figure 3: Layout and cross section of designed bench scale WWTP

Figure 4: The bench scale biological wastewater treatment plant

Results and Performance Analysis

The bench scale treatment plant was run continuously. Therefore, regular it was checked different parameters regular basis. Samples were collected from equalization basin, primary clarifier, aeration basin and secondary clarifier. Selected parameters were tested and recorded. Based on the treatment results the performance analysis of the bench scale plant was represent. Following precise discussion about performance analysis of the bench scale plant.

pH & Dissolved Oxygen

There was no much variation found of pH in raw wastewater and treated wastewater in this study. In raw wastewater, pH measured typically 7.0 – 8.0. This pH condition was good for process design and bacterial growth. Therefore, no chemical needed to use. As no mentionable chemicals are used in

shrimp processing that may influence the pH level of wastewater, as a result it was found typically good range of pH. The lowest value of pH was found 7.31 whereas highest one was 8.53. There was thirteen raw samples were measured for pH and average arithmetic mean value was found 8.03 and standard deviation was found 0.37. Finally treated wastewater leaves through the secondary clarifier. Due to settling and aeration, pH was reduced in little amount. The variation of pH was state of being more or less 7 to 8. Effluent contained average pH 7.73. The Bangladesh standard of pH value is 6 – 9 for effluent discharging in to the environment.
Dissolved oxygen in raw wastewater of shrimp process wastewater was found low to critically low. The least value of raw wastewater was measured 0.75 mg/L and highest one was 3.56 mg/L. The arithmetic mean value was determined 2.07 mg/L. In Bangladesh guideline by Department of Environment (DoE) is 4.5 to 8.0 mg/L. DO value was gradually increased after each unit operation. In aeration basin air was injected consequently DO increased. After final clarifier sample was measured and found DO level is above 4.5 mg/L. The higher one was found 6.3 mg/L and the arithmetic average value was noted 4.68 mg/L.

Biochemical Oxygen Demand

Five day Biochemical Oxygen Demand of raw wastewater was measured and found average 177 mg/L. The higher value of BOD_5 was found 354 mg/L and the lower one was 75 mg/L. Bangladesh standard for effluent discharging is 50 mg/L. BOD_5 was decreased in primary clarifier, aeration basin and finally secondary clarifier. Primary clarifier was removed 5.64% of BOD_5. The aeration basin was removed almost 50% of BOD_5. The final effluent was contained 41.3 mg/L. The average reduction rate was calculated 77% of BOD_5. State of BOD_5 of the bench scale wwtp is given in the following figure.

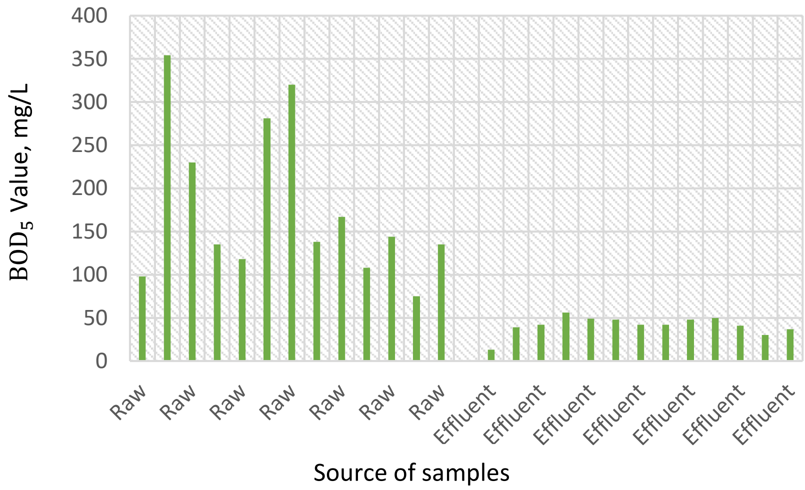

Figure 5: Biochemical Oxygen Demand before and after treatment

Chemical Oxygen Demand

The typical value of COD of this study was found 160 mg/L to 948 mg/L. The arithmetic mean value was calculated 355 mg/L for wastewater. Between this ranges most values were recorded above of 200 mg/L. In aeration basin significantly removed COD from wastewater. Almost half of the value reduced in the aeration basin. In the final stage, secondary clarifier has taken the final action and reduced COD significantly. The higher value was found 170mg/L and the lower one was 34 mg/L of effluent. Arithmetic mean value was found 117 mg/L whereas national standard is 200mg/L. There were 15 samples tested from effluent. The average rate of COD removal was found 67% by the bench scale plant.

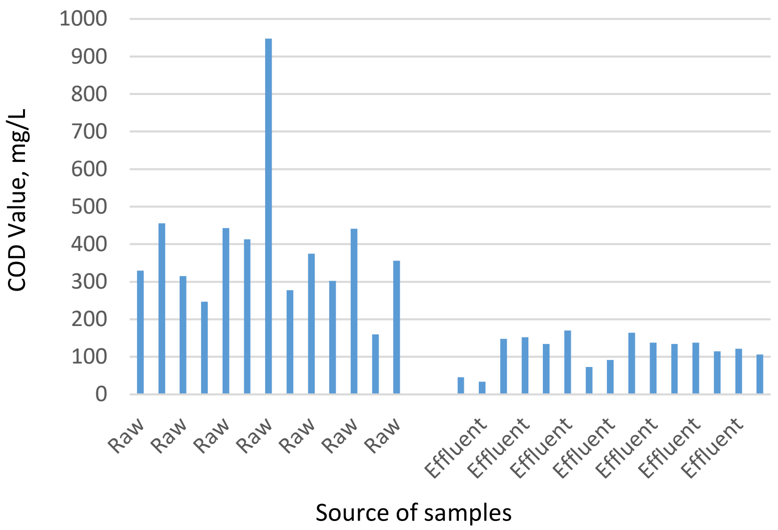

Figure 6 Chemical Oxygen Demand in raw sample and effluent

Total Suspended Solids

This study was measured Total Suspended Solids (TSS) 383 mg/L as average value from 13 samples. The highest value of TSS was found 960 mg/L and lowest one was 127 mg/L. Where the standard level is 150 mg/L and raw wastewater contained more than 150 mg/L of TSS. Shrimp process wastewater contains huge amount of organic solids. Raw wastewater was given fluctuate values that easily is seeing in the figure 7. The value was fluctuated because of all samples were not collected at same time and date. Samples were collected and measured in environmental engineering laboratory. Effluent was contained less than the standard level (50mg/L) when the wastewater leaving from the bench scale plant. The designed bench scale plant reduce mentionable level of TSS. There were 13 samples taken under tested. Higher one of COD value of effluent was found 380 mg/L and lower one was 43 mg/L. The arithmetic mean value was noted 137 mg/L. All samples from bench scale plant were found under 150 mg/L. The following figure is giving clear concept about TSS of raw and effluent wastewater.

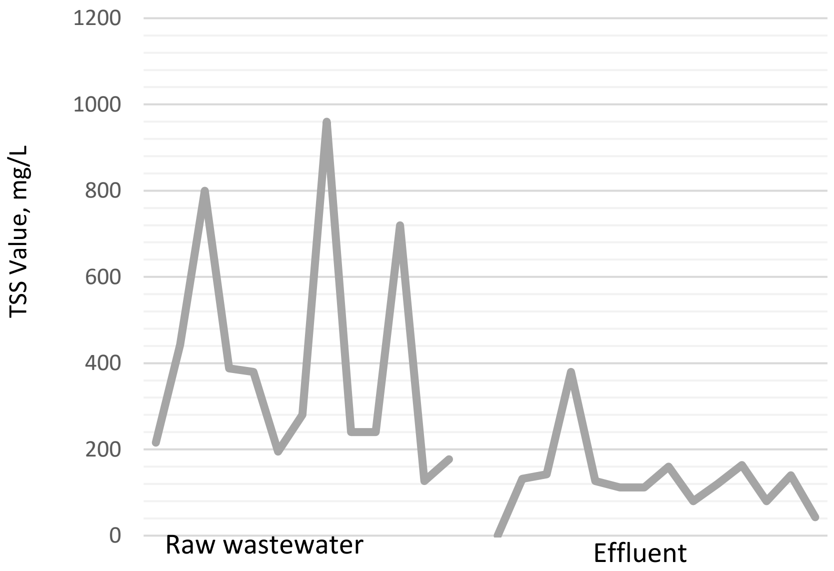

Figure 7: Total suspended solids removal in bench scale plant

Total Dissolved Solids

Dissolved solids or total dissolved solids (DS or TDS) represent all organic and inorganic constituents present in water or wastewater in dissolved form. TDS also represents the total salt of water. This study was found large amount of TDS in wastewater of selected shrimp processing industry. It was recorded up to 4720 mg/L dissolved solids in raw wastewater. On the other hand, the least value was recorded 1325 mg/L. The Bangladesh standard for TDS is 2100 mg/L to discharging wastewater in environment. The designed bench scale plant significantly separated total dissolved solids from the wastewater in both primary and secondary clarifiers. Thus, the final effluents contain mentionable less amount of TDS rather than the raw wastewater. Final effluents was measured and found mean value of TDS 1805 mg/L. There were thirteen samples measured and noted all samples found under the standard level of TDS. Only two or three results were found higher than the standard level. But mean value was met the Bangladesh standard level of TDS. The following chart is representing raw wastewater and effluent TDS together.

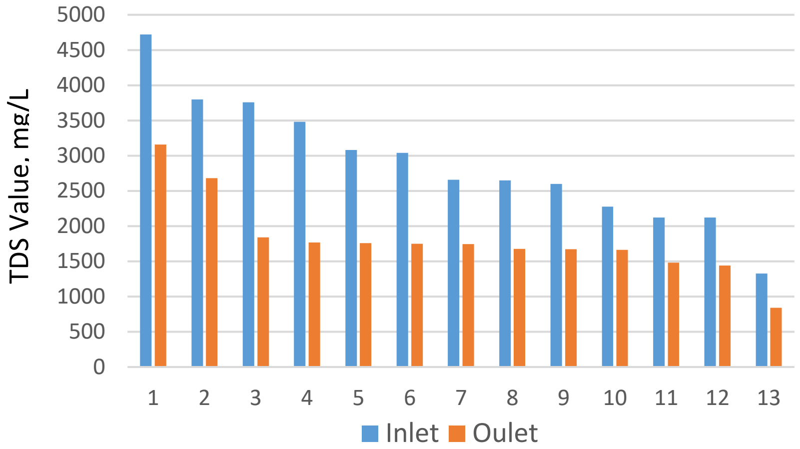

Figure 8: Total Dissolved Solids removal in bench scale plant

The overall performance of the designed bench scale plant for BOD_5 removal was calculated 77% and COD removal efficiency was calculated 67%. Dissolved oxygen was increased double of raw sample contain. Calculated effluent DO was increased 126% of influent DO. For dissolved solids removal, the bench scale plant was performed 37% reduced of its raw value. Suspended solids removal rate was measured 64% thus the plant was treated shrimp processed wastewater excellently. The following table is expressing increasing or decreasing level of different parameters of the bench scale plant.

Table 4: The increasing and decreasing rate of different parameters of the bench scale plant.

Parameter(s)	Raw	Effluent	Decrease %	Increase %	Unit
pH	8.03	7.73	3.73		
DO	2.07	4.68		126.08	Mg/L
BOD_5	177	41	76.83		Mg/L
COD	355	117	67.04		Mg/L
TDS	2,894	1,805	37.62		Mg/L
SS	383	137	64.22		Mg/L

When designed the plant, it was considered influent BOD_5 contain 360 mg/L but in raw wastewater contained average 177 mg/L BOD_5 which kept 30 to 50 mg/L after treatment. To get below 50 mg/L BOD_5 in treatment effluent, the plant had to remove 70% of BOD_5. In design consideration it was assumed 30% of BOD_5 removal rate for primary clarifier. But, designed bench scale plant removed only 6% of BOD. Rest 60 to 65% of BOD_5 was removed in aeration basin and final clarifier. Aeration basin removed 50% BOD_5 of raw wastewater and final clarifier removed 77% of BOD_5 of raw wastewater.

Conclusion and Findings

It was the first study about wastewater treatment of shrimp process industries in Khulna using local treatment setup so far. It is clear from the study, no chemical coagulation is required. From the study of the bench scale plant, it has shown that treatment level was moderate in practical, when continuous treatment will be run with large amount of wastewater the efficiency of treatment will be increased.

ACKNOWLEDGEMENT

The author is indeed acknowledged to Mr. Sayed Ahsan Ali, Technical officer; Mr. Sarder Shahidul Alam, Technical officer, Environmental Engineering Laboratory and Mr. Monirul Islam, Assistant Technical Officer, Geotechnical Engineering Laboratory, Khulna University of Engineering & Technology (KUET), Khulna, for their assistance in conducting different testes of the study.

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A Study on E-Waste Generation and Its Impacts on Pabna Municipality Area of Bangladesh

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ABSTRACT

In recent years, technological revolution with rapid economic growth increases the consumer demand on electric and electronic gadget which results in increasing electronics waste all over the world. Electronics waste also recognized as "E-waste" which is combination of unwanted or used electronic products. The aim of this study is to find out the amount of E-waste generation and its impacts on Pabna municipality area of Bangladesh. According to primary survey result from various parts of Pabna municipality area such as Poilanpur, Shibrampur, Dilalpur, Shalgaria, Radhanagar the daily generation of E-waste were found to be 60kg, 85kg, 140kg, 115kg, 70kg respectively. Most of the waste is directly dumped into landfills, open spaces, drains and Ichamoti river which may cause environmental pollution and health hazards. In this regard this study tries to address the hazardous impacts of E-waste in Pabna municipality area and proposed some recommendation to save the environment.

Key words: *e-waste, environmental impacts, health impacts, environmentally sound management.*

INTRODUCTION

Electrical and electronic waste as well as E-waste are everywhere in our society and it is considered to be the reckless growing waste stream; about 4 percent growth a year (Karin, 2012). Electronic waste (E-waste) can be termed as the waste generated from all secondary electronics stuffs like mobile phones, television, computer, stereo equipment and so on, whether castoff, traded or contributed by their original holders (ESDO, 2010). In each year, the amount of generated e-waste is about 40 million tones (Schluep, et al., 2009). In present time E-waste has become one of the most potential curses in our society because e-waste contains harmful toxic substances that are hazardous, and can pollute the soil, air and that can be a threat to the environment and human health. In this regard insufficient management of Electrical and electronic waste can be a threat human being and environment. E-waste possess more than 1,000 harmless components like plastic (19%), ferrous material (38%), non-ferrous material (28%), glass (4%) and others (including wood, rubber, ceramic) (11%) (Wath, et al., 2011). But the harmful components in E-waste like chromium (VI), lead, cadmium, mercury, halogenated constituents (e.g., CFCs) have adverse environmental consequence. In this regard indiscriminate disposal of e-waste may reduce the crop production furthermore natural food chain can be contaminated by heavy metals like mercury, lead, cadmium, chromium etc. (Rana et al., 2015). Environmental impact such as air pollution, water pollution, land pollution in accordance with some health impact such as cancer, nerves breakdown, visual problem, asthma may also generate from e-waste mismanagement.

According to environmental protection agency electronics waste is growing at three time's higher rate than municipal waste (EPA, 2001). China is facing serious situation from their rapid e waste product. Major home appliances such as computers, televisions, air conditioners, refrigerators production was near 500 million units in 2009 in china and from that production china export 240 million units (Alam et al., 2015). In this regard annual e-waste generation in china rise very fast and approximately 50 million units of e-waste generation happen in 2010 (A country report of China on E-waste, 2013). The huge amount of e-waste generation creates serious problem for the surrounding environment.

Bangladesh is a south Asian developing country with rapid economic growth, therefore demand of electrical and electronics product is increasing is day by day. In Bangladesh, the increasing number of consumers of home appliances buy huge amount of electronic gadget such as television, refrigerator, air conditioner, computer and so on, therefore e-waste is becoming a concerning issue in Bangladesh. According to Bangladesh Electric Manufacturer and Merchandiser Association; Bangladesh ingests around 3.2 million tons of electronic products each year (Ahmed, 2011), but very less amount of them is recycled and most of them dump into landfills, drains, open spaces, river and canals. Lack of awareness about proper handlings of e-waste is creating risk for human health. Adequate information gap on e-waste hazards dumping also creates risk for surrounding environment. According to ESDO, 2010 (Environment and Social Development Organization) Bangladesh generated approximately 2.8 million metric tons of E-waste. This result is based on six major e-waste producing component such as mobile, television, and CFL bulb, computer, medical and dental equipment. “Bangladesh has generated 10,504 metric tons of toxics E-waste by cell phone sets within last 21 years. Every year around 296302 TV sets become scrape and generated 0.17 million metric tons of E-waste” (Alam et al., 2015). According to ESDO, 2010 (Environment and Social Development Organization) near fifty thousand children’s are involved in e-waste collection, handling and recycling process from them every year near 83% of workers are exposed to toxic component of e-waste and every year 15% child worker died because of e waste recycling and handling process amongst them about 40% are involved in ship breaking.

Pabna is one of the oldest City under Rajshahi division where the consumer of electrical and electronics waste is increasing day by day. In pabna city most of the e-waste are mobile phone, television, computer gadget, refrigerator, bulbs and light, air conditioner etc. some of them is reuse as secondary products and there is very less opportunity for recycling the huge amount of e-waste in the city, therefore most of the e-waste is dumped into the land field, river, canal, drain and open space. The huge amount of e-waste has become a concerning issue for the city because harmful component of these waste rising new threat for human health and environment of the city. This study tries to determine the amount of e-waste generation in various location of pabna city. This study also tries to find out the harmful impact from improper dumping e-waste that could threat for the environment and human health of pabna city.

METHODOLOGY

The study was performed according to present e-waste generation scenario and harmful environmental consequence from improper e-waste management across the Pabna municipality area, therefore a primary survey was conducted to understand the amount of e-waste generation in various parts of the city. In this regard firstly the location of various e-waste reuse shops was identified then information about e-waste was collected by primary questionnaire survey from the owner and workers of different e-waste collection shop. The survey question includes the types of e waste generation from different part of pabna municipality area, amount of e-waste collection per day, the present price of each type of e waste. The survey also includes collecting Information about non-recyclable e-waste dumping scenario in different land field, river, canal, drain, pen space and their harmful impacts on environment as well as human health.

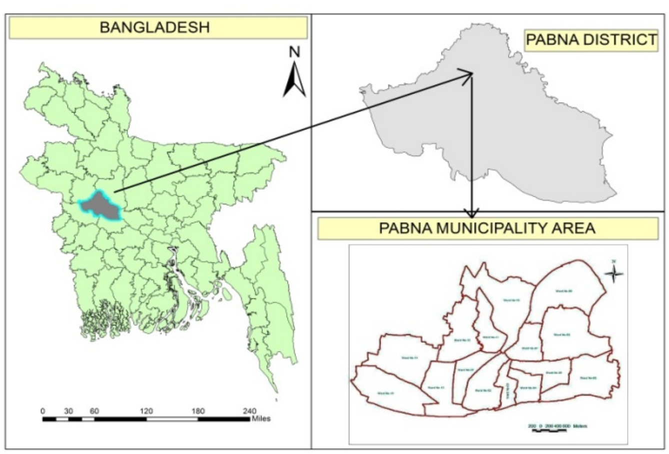

Figure 1 Location of the study area

DATA ANALYSIS AND FINDINGS

In recent years, Bangladesh has a rapid exponential growth in emerging market of electronic appliances and gadgets which results in high amount of E-waste generation. Pabna is not exceptional from that situation. The amount of E-waste is increasing day by day along with the consumers demand for latest electronic appliances. A large proportion of waste generation in the study area comprises E-waste including television, computer monitor, cell phone, telephone, machineries, air conditioners, electronic toys, etc.

E-waste production

Electronic waste can be defined as the secondary electronic items which whether discarded or sold by their owners. Electronic item's participation in annual E-waste production usually depends on its mass, quantity in the market and average life cycle.

$$E = MN/L \tag{1}$$

Here, E (kg/year) = electronic item's participation in the annual E-waste production, M (kg) = electronic item's mass, N= quantity in the market and consumption and L (year) = average life cycle. Basically average life cycle differs for same product from different companies. Consumption quantity depends upon population growth as well as socio-economic condition of people in a country. (Terazono et al., 2006).

Quantity of E-waste generated in Pabna

In recent years, the amount of E-waste has increased at a very remarkable rate in Pabna municipality. This study shows that the majority portion of the waste usually generated from television waste, computer monitor, computer board, electric bulb, and electric fan and so on. This growing amount of equipment which is discarded annually is a matter of great concern in E-waste management. There is no specific E-waste management system in this study area. Very few of them is being recycled or reused. Most of the waste is directly dumped into landfills, open spaces, drains and Ichamoti River which may cause environmental pollution and health hazards.

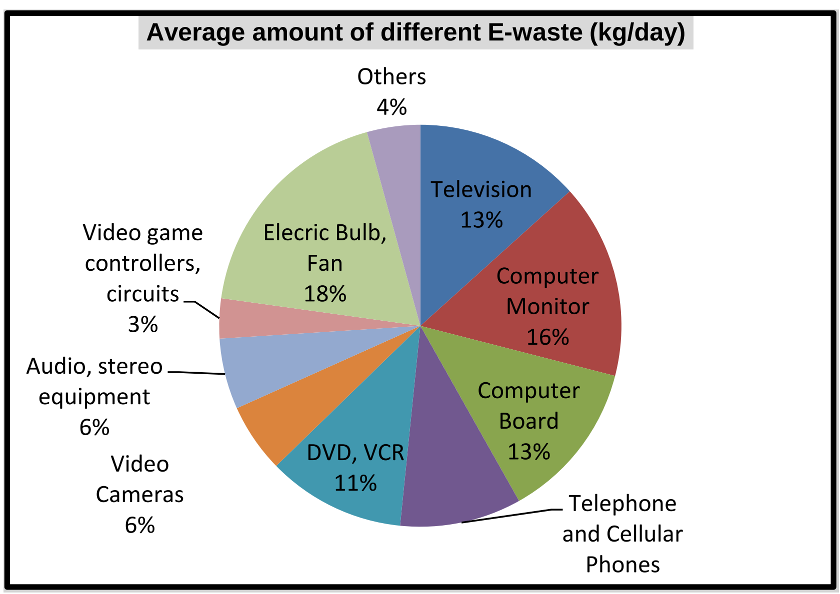

Figure 2 Average amounts of different types of E-waste

These wastes have significant economic values. Different types of equipment have different market values. According to the primary survey, most of the disposed or recycled waste materials are collected by the street hawkers and some local shops. According to ESDOs (2010), approximately fifty thousand children's are involved in the E-waste collection and recycling process in Bangladesh. They primarily collect these wastes and usually sell these items to the wholesales. Sometimes these wastes are re-used by the lower income people because of these products availability at a cheap rate.

Table 1 Estimation of E-waste in Pabna Municipality

Type of e-waste generating equipment's	Average Amount (kg/day)	Average BDT value per kg	BDT value per day
Television	187	25	4675.00
Computer Monitor	220	25	5500.00
Computer Board	180	55	9900.00
Telephone and Cellular Phones	137	18	2466.00
DVD, VCR	156	42	6552.00
Video Cameras	78	54	4212.00
Audio, stereo equipment	80	22	1760.00
Video game controllers, circuits	45	12	540.00
Elecric Bulb, Fan	260	18	4680.00
Others	60	7	420.00
	Total		40705.00 BDT

E-waste Concentrated Area in Pabna Municipality

Following figure 3 represent the percentage of daily e-waste generation in differents locations of Pabna municipality area. According to primary survey result from various parts of Pabna municipality area such as Poilanpur, Shibrampur, Dilalpur, Shalgaria, Radhanagar the daily generation of E-waste were found to be 60kg, 85kg, 140kg, 115kg, 70kg respectively. E-waste generation is high in the Dilalpur area and Shalgaria area that is about 29.79% and 24.27% respectively which is a large percentage to be recycled, where the rest of the areas represent a quite small percentage of E-waste with respect to Dilalpur and Shalgaria area. So, extra management and monitoring is needed to focus on Dilalpur and Shalgaria to recycle this huge portion of E-waste with sustainable management system.

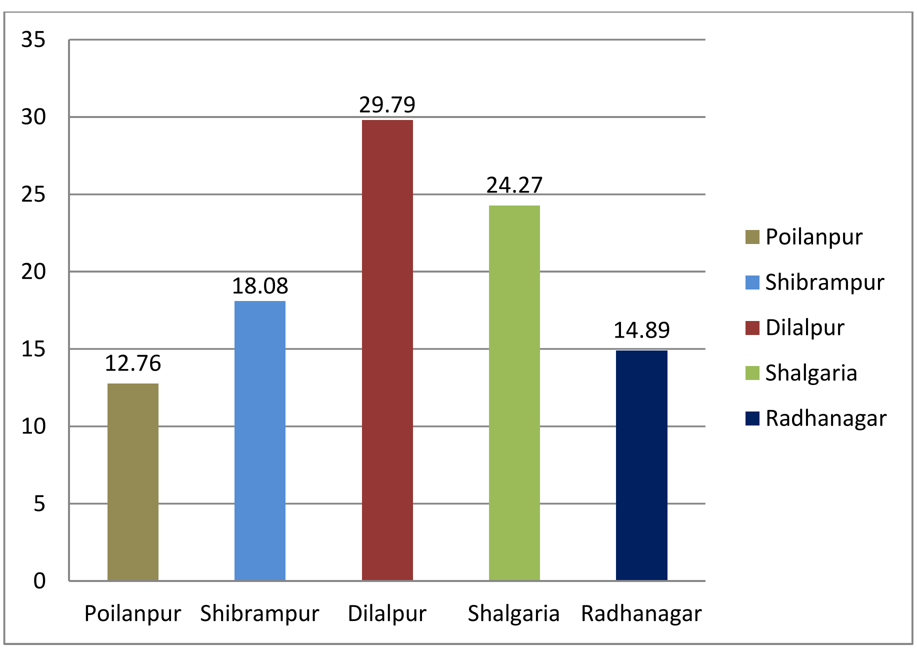

Figure 3 Percentage of daily E-waste generation in different areas.

Total Estimation of Collection & Annual Worth of Collected E-Waste

According to the field survey, it has been found that there are a number of recycling shops at Pabna municipality which are situated at Poilanpur, Shibrampur, Dilalpur, Shalgaria, Radhanagar and few shops at other places. For this study purpose, data has been collected from almost every recycling shop at Poilanpur, Shibrampur, Dilalpur, Shalgaria, Radhanagar. Reuse of electronic equipment is a common practice in this country. In Pabna, recycling and dismantling of electronic equipment is a growing business. Survey has been conveyed at 58 shops of Pabna municipality.

Table 2 Total estimation of collection & annual worth of collected E-waste

Location	Date of Survey	Number of shops	Total average amount (kg/day)	Total daily value	Total yearly value
Poilanpur	02/05/2018-03/05/2018	5	60	5500	1980000
Shibrampur	04/05/2018-07/05/2018	6	85	9700	3492000
Dilalpur	09/05/2018-12/05/2018	18	140	12700	4572000
Shalgaria	13/05/2018-15/05/2018	19	115	10500	3780000
Radhanagar	16/05/2018-17/05/2018	10	70	4200	1512000
	Total	58	470		15336000

Potential Environmental Pollutants Produced from E-waste

There are a number of potential pollutants reside in electronic waste materials. The chemical composition of discarded E-waste depends on their type and age. These potential substances can cause several health issues if they are not properly managed or monitored. There are a number of substances like CFC, PVC, Zinc, Lithium, Copper, Chromium, Arsenic, Beryllium, Cadmium, Lead, Nickel, Barium and so on which are huge threat for human health as well as the environment.

Table 3 Potential Environmental Pollutants Produced from E-waste

Substance	Occurrence in E-waste
CFC	Cooling unit, Insulation foam
PVC	Cable insulation
Zinc	Supplied Interior of CRT screens, mixed with rare earth metals
Lithium (Li)	Li-batteries
Copper (Cu)	Cabling
Chromium (Cr)	Data tapes, floppy-disks
Arsenic	Small quantities in the form of gallium arsenide within light emitting diodes
Beryllium (Be)	Power supply boxes which contain silicon controlled rectifiers and x-ray lenses
Cadmium (Cd)	Rechargeable NiCd-batteries, fluorescent layer (CRT screens), printer inks and toners,) photocopying-machines (printer drums)
Barium (Ba)	Getters in CRT
Lead (Pb)	CRT screens, batteries, printed wiring boards
Nickel (Ni)	Rechargeable NiCd-batteries or NiMH-batteries, electron gun in CRT
Mercury (Hg)	Fluorescent lamps that provide backlighting in LCDs, in some alkaline batteries and mercury wetted switches

(Gaidajis G. et al. ,2010)

Impacts of E- Waste on Environment of Pabna Municipality Area

E-waste mismanagement during collection, processing, recycling and land filling has adverse environmental impact. Pabna municipality does not have advance technology for proper e-waste management, therefore toxic component of e-waste spread into land, air, water, river, canal, drainage and open space that leads to serious environmental pollutions.

Impacts on Ichamoti River

Pabna municipality area is surrounded by ichamoti River. Several e-waste elements from computer accessories, mobile phone accessories, refrigerator accessories are randomly duped into the ichamoti river, that obstacles the free flow and reduce the oxygen level of ichamoti river.

Figure 4 Ichamoti river pollution.

Impacts on Surface Water Body

Several harmful e-waste components such as lithium (Li) from li-ion batteries, zinc and cadmium (Cd) from CRT screen, chromium (Cr) from flopy disk, and mercury (Hg) from LCD contaminate the ichamoti river and that creates vulnerable situation for the biodiversity of ichamoti river. Several electronic circuit parts also pollutes the surface water body of pabna municipality area.

Impacts on Land and Open Space

Improper e-waste management pollutes the land and open space of pabna municipality area. Plastic materials from keyboards, computer monitor, lithium ion battery cell, computer mouse, headphone, mobile phone, charger does not decompose and reduce the fertility of the soil. Indiscriminate dumping of Copper (Cu) and Nickel (Ni) from various solid e-waste also affect productivity of the microorganisms of soil.

Blocking of Drainage System

Proper drainage system ensures the sustainability of a city. Some e-waste is dumped into both natural and artificial drain of pabna municipality area that block the drainage system. Indiscriminate dumping of computer accessories, mobile phone accessories, and home appliance product into the drain is considered as potential cause of frequent urban flood in pabna municipality area.

Figure 5 Blocking of drainage

Impacts on Air

Some e-waste such as cables, cell phone, keyboard, television boxes are burned before dumping into the land field. These e-wastes contains polyvinyl chloride (PVC) product that pollutes the surrounding environment. Burning of e-waste also releases toxic substance into the air such as lead, cadmium and mercury that are the potential cause for air pollution in pabna municipality area.

Impacts of E- Waste on Human Health of Pabna Municipality Area

E-waste collection, handling and processing sometimes leads human life into danger situation. Some chemical, heavy metals such as leads, cadmium, chromium, mercury affect the nervous system and lung, develop cancer and hormonal problems. Some impact of e-waste on human health of pabna municipality area is given below-

Skin Disease

E-waste has adverse impact on the human screen. Chemical materials from LCD monitor, lithium ion and rechargeable NiCd-batteries are harmful for human screen, therefore burning, processing, shorting of different e-waste without safety gloves and mask develop various skin disease of the worker of pabna municipality area.

Figure 6 Skin disease of e-waste collector

Chronic Disease

A common e-waste product in pabna municipality area is CPU which possess potentially harmful substance such as lead, cadmium, beryllium that are responsible for development of cancer to the handling, processing and recycling worker.

Infections

Infection is another common disease from e-waste. Various solid e-waste products such as computer, mobile and another electronics circuit are responsible for the infection of e-waste collection and processing workers of pabna municipality area.

RECOMMENDATION

As e-waste has adverse environmental consequences, therefore much precaution needs to be established for effective e waste management. In this regard, some recommendation for effective e-waste management is given below-

- Public awareness needs to be established among the local people of Pabna municipality area.
- E-waste law needs to be established in accordance with the goals of sustainable development
- Municipal authority should monitor the land field dumping of e-waste.
- Workers of e-waste collector should wear safety gloves, mask and glass.
- Land, river and open space needs to be protected from harmful component of e-waste.
- Harmless e-waste should be reuse as much as possible.
- E-waste recycling industry should establish within pabna municipality area.

CONCLUSION

E-waste possesses various toxic substances that have adverse environmental consequence. Air pollution, water pollution, land pollutions are some major environmental pollution from e-waste product. Harmful components of e-waste such as chromium, lead, mercury, cadmium, and zinc may lead the human health into wide range of diseases. In this regard adequate precaution should be taken for collection, handling, reuse and recycling of e-waste.

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MONITORING OF SOLID WASTE DISPOSAL BY URBAN SLUM DWELLER IN RAJSHAHI CITY AND ITS IMPACT ON THE RIVER WATER QUALITY

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ABSTRACT

Large cities situated at big river are frequently observed that most of the slums are built near the river because of low land price as the land is low and often being inundated by river water at rainy season which washes away all solids deposited recklessly. Because of financial and physical characteristics of the urban slums, they are hardly facilitated by the municipal waste management system. Waste collection system often fails because of the densely built houses and narrow paths and illiteracy causes not to dump the wastes at the dustbin or selected place given by the municipality. This research finds the amount of solid wastes that are disposed at the exact point which is selected by the municipality as well as the wastes that are dumped in the river or in the bank of the river which is restricted by the Environmentalist and how is these wastes are doing to pollute water. The amount of solid wastes which are not properly dumped calculated from the total solid wastes produced by the households and the amount of wastes collected by the municipality. Assessment of water quality parameter includes pH, Turbidity, BOD, COD, Electric conductivity, TDS and TS. The result of the study indicates why and what to be done to improve the river water quality and the municipality environment.

INTRODUCTION

Waste management is a great challenge to the municipality all the time. This municipal solid waste is not useful but increasing day by day (Olanrewaju & Ilemobade, 2009) . Solid waste management (SWM) becomes more challenging when the municipality contains varieties of classes of people. Different class of people has a different choice of waste disposal practice and it becomes severe when all classes of people do not get the same waste management facilities. The word slum is a general image of poverty (Manikandan 2015). Slum people hardly get SWM facility because of the poverty (Fayaz and Bhat, 2017). Not only the poverty but also the geographical condition of slums increases the problem for SWM. Majority of the poor countries do not dispose of their waste considering environmental betterment (Gabriel, and Olusegun, 2012). In our country, most of the slums are built by the bank of the river as the land price is low. Generally, slums are too densely populated so that municipal waste management often fails to reach there. As the slum people are likely to live by the riverside they use the river for the maximum purpose. Though some people burn their waste for disposal but the rate is not satisfactory (Akni, et al., 2016). Most of them are likely to dispose of in the river. When water gets contaminated with various metals and substances it brings change in the river water quality parameter such as pH, EC, DO etc (Islam, et al., 2013). The aim of this study is to investigate the present studies of SWM in slum area and its effects on quality of river water.

BACKGROUND OF THE STUDY AREA

Rajshahi is one of the oldest city corporations. This city lies between 24°07′ to 24°43′ north latitudes and between 88°17′ to 88°58′ east longitudes (Rahman, 2013) in the bank of river Padma. It has an area of 97.17 sq. km with a population of 0.5million (Division-of-Rajshahi n.d.) People in Rajshahi City Corporation(RCC) generates 400 ton/day (Halder et al. 2014) This municipality has an efficiency of 56.67% efficiency for waste collection (Enayetullah and Hashmi 2006). This city corporation contains 30 wards, many of them are just in the bank of the Padma river. This research was done in the slums of ward no 23 and 24, because of the geographical location of these wards since slums are present on the bank of the river in these wards.

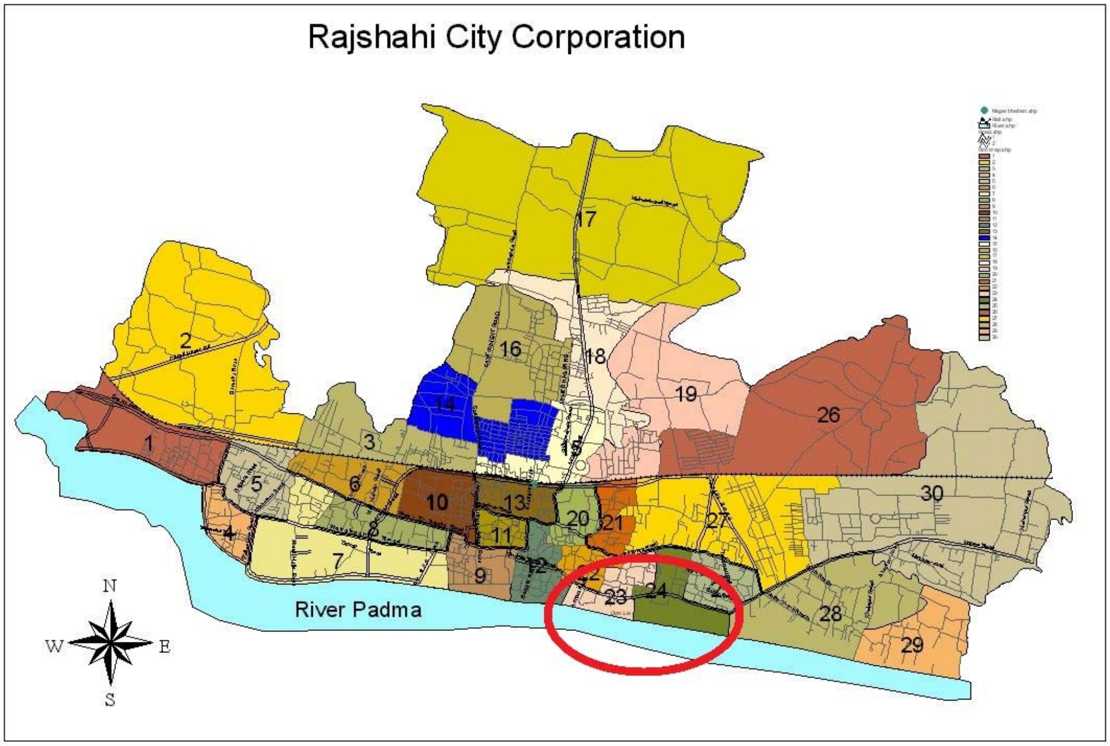

Figure 1: Map of RCC and the study area(Red circled marked in the figure) ***Source****: (Rahman, 2013)*

These slums are so congested that the municipal waste collection van (Figure *2*) cannot reach these households. Since the slums are very close to the river the households have a natural tendency to through their waste in the river.

Figure 2: Municipal waste collection van used for door to door waste collection system.

METHODOLOGY

Ten households were selected to measure the daily waste generation rate. They were given a 20L bucket each and asked to put their waste into it. The weight of the bucket was taken at every 24hrs and the weight was divided by the number of the family members and waste generation rate was calculated. The field study was conducted for 10 days to determine the average rate of waste generation.

To measure the river water quality 6 points were selected in the river and the water quality was measured from some water parameter. For testing the river water quality pH, Turbidity, Electric Conductivity (EC), Dissolve oxygen, Oxygen Reduction Potential (ORP), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS) and Total Solid (TS) was measured. The test was done with *Multi 3430 IDS: Multi-parameter digital portable meter* for field test and for laboratory test Local DPHE (Department of Public Health Engineering) was used.

DATA ANALYSIS AND RESULTS

Error! Reference source not found. shows the daily waste generation rate of different households which are beyond the waste management facilities because of the narrow roads connecting their houses (Manikandan 2015). They used to through their waste directly to the river or sometimes they gather the waste together and at a certain time, small family member of their house left them to the river. Some households made some drains connecting to their house to the river which they use to pass their waste to the river without going near the river.

Figure 3: Weighing of waste generated from one household

Table 1: Daily waste generation and rate of waste generation

Name of the House hold	No of Family memb ers	**Weight of Daily waste (kg)**											**Rate of waste Generati on (kg/day)**
		Day										**Average (kg)**	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
A	6	3.6	3.5	4	6.2	4.1	3.9	4.3	2.2	2.6	2.8	3.72	0.62
B	7	5.6	2.6	6.4	1.3	2.9	5.6	6.5	4.2	4.8	4.6	4.45	0.64
C	6	1.2	2.9	1.5	2.6	1.4	3.2	1.5	1.6	2.3	1.4	1.96	0.33
D	8	2.2	2.6	2.5	1.8	0.9	2.6	2.1	6.5	1.3	4.5	2.70	0.34
E	8	1.3	4.5	1.8	2.5	2.6	2.4	2.3	2.6	2.5	1.2	2.37	0.30
F	12	3.6	6.2	1.5	3.8	4.8	7.2	5.2	4.3	6.2	7.1	4.99	0.42
G	15	4.5	5.6	2.3	8.2	5.6	4.5	5.4	7.2	5.5	5.6	5.44	0.36
H	6	2.6	2.5	2.3	2.4	2.5	2.1	2.2	2.2	2.3	2.6	2.37	0.40
I	8	3.6	1.3	2.3	5.4	1.3	6.3	5.6	2.6	2.6	2.8	3.38	0.42
J	9	5	2.6	1.8	2.6	2.6	1.3	1.2	5.2	5.4	1.9	2.96	0.33
											Average	3.43	0.41

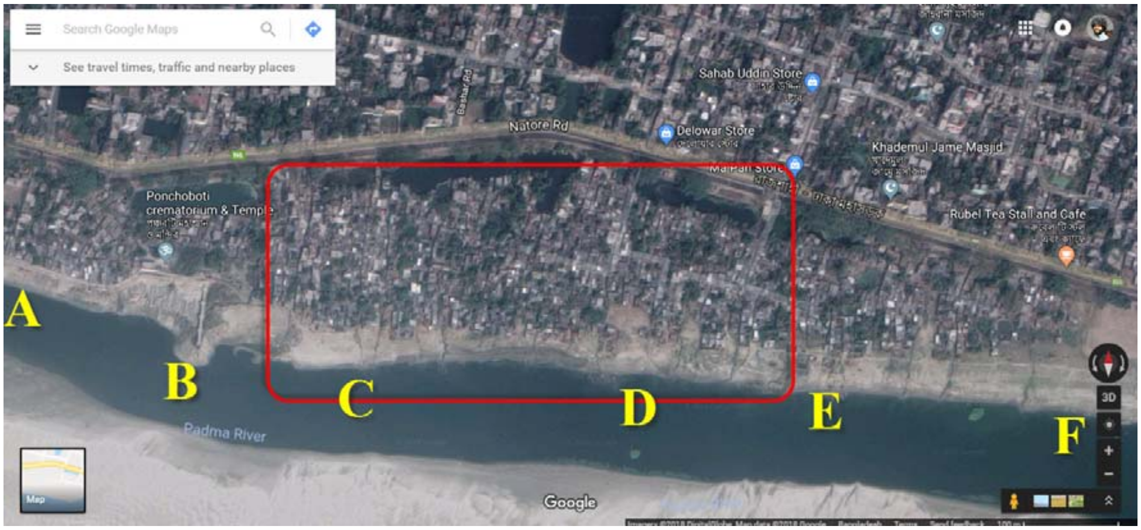

Figure 4: Location of the water sampling points in the river. The Red box is the slum area

To measure the river water quality, 6 points in the river was selected (Figure *4*). Between the points two of the points (**Point A & B**) were **before the slums started to contaminate river water**, two of them **(point C & D) were beside the slums** and two of the points **(Points E & F) were in the river where there was no slum or source of contamination.**

Table 2: Water quality parameters at different points

Point	Position in the River w.r. to Slums	Water Sample Depth(ft)	Temperature (°C)	pH	EC (µS/cm)	DO (mg/L)	ORP (mV)	Turbidiy (NTU)	TDS (ppm)	BOD (ppm)	COD (ppm)
A	u/s	1	26.2	7.26	703	5.91	-56.75	112	1060	41	75
		2	26	7.26	703	5.9	-58.92	118			
		3	26	7.25	705	5.9	-59.2	116			
B	u/s	1	27.6	7.63	693	4.26	-78.25	130	1152	45	89
		2	27	7.58	705	4.21	-72.63	132			
		3	26.2	7.66	706	4.2	-71.16	136			
C	Beside	1	27.5	7.88	709	3.86	-95.62	190	1268	52	112
		2	27.2	7.86	709	3.85	-96.51	190			
		3	27	7.85	709	3.86	-96.55	191			
D	Beside	1	26.9	7.69	713	2.91	-102.6	225	1380	88	180
		2	26.6	7.89	715	2.95	-102.8	226			
		3	26.2	7.66	715	2.95	-102.4	225			
E	d/s	1	27.3	7.97	713	4.62	-98.5	256	1150	56	108
		2	26.8	7.92	713	4.6	-98.4	256			
		3	26.3	7.66	713	4.61	-98.3	256			
F	d/s	1	26.9	7.99	714	4.77	86.25	160	980	44	82
		2	26.8	7.85	714	4.75	86.3	165			
		3	26.8	7.63	715	4.77	86.5	165			

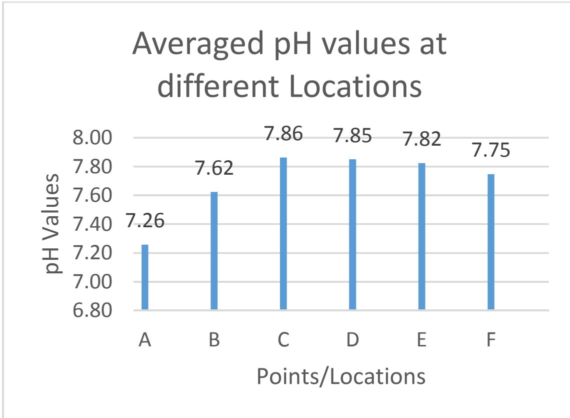

Figure 5: Averaged pH values at different Locations

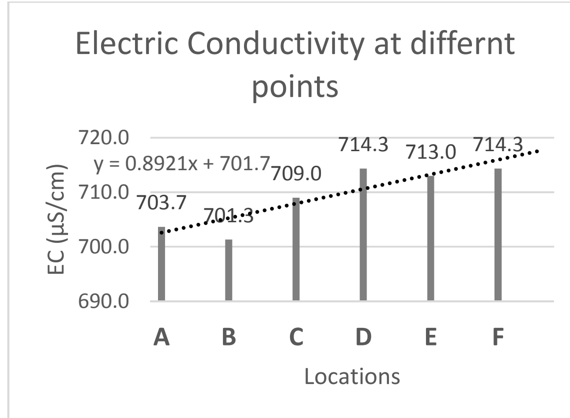

Figure 6: Electric Conductivity at different points

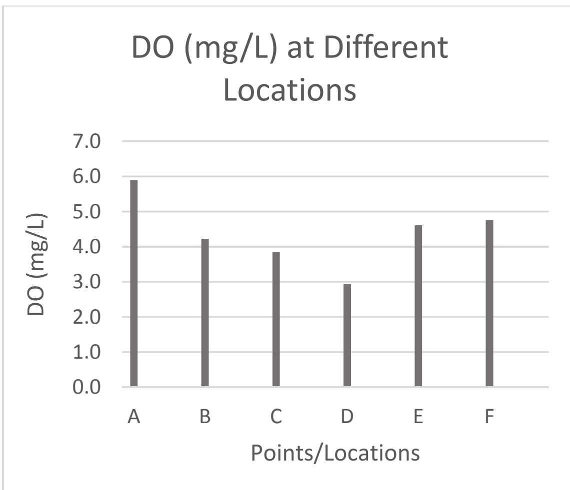

Figure 7: DO (mg/L) at Different Locations

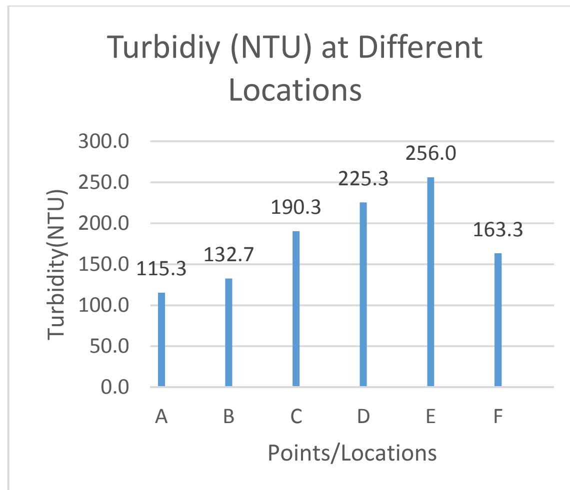

Figure 8: Turbidity (NTU) at Different Locations

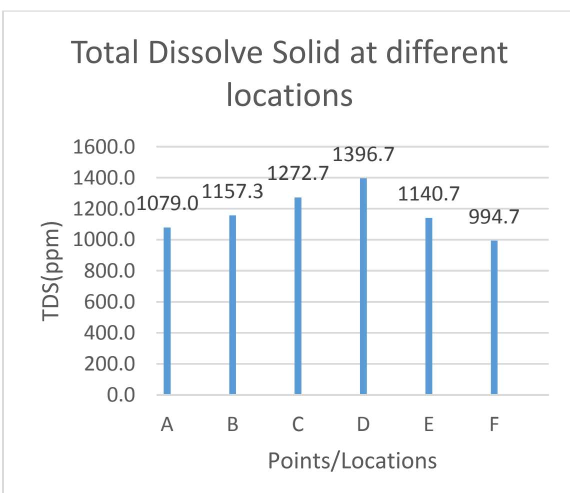

Figure 9: Total Dissolve Solid at different locations

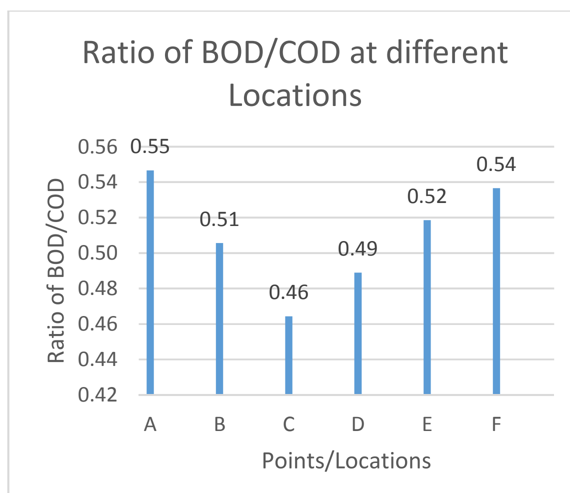

Figure 10: Ratio of BOD/COD at different Locations

Figure *5* shows pH values which are slightly above 7 which means the water is carrying more alkalinity which is an indication of pollution. Though pH level is not that much high it may rise with the increase in the waste disposing rate. Figure *6* shows a trend line to increase in salinity or electric conductivity in river water and increases more rapidly after passing through the slum's waste discharging points. Figure

7 shows a decrease of the oxygen level in the river water at the slum points. Which may cause to death of the fish and other aquatic flora and fauna. Figure *8* shows an increase in the turbidity in the river water this increase stays until the waste from the slums discharges and settle down after a long distance from the slum points. This turbid water decreasing the natural aesthetic of the Padma river. TDS values show a great contamination in river water, with a minimum value of 994.7mg/L or parts per million and the highest value of 1396.7mg/L which is at location D which is actually at the side of the slums. Most important findings of this Figure *9* are that no water from the above points is drinkable. The last figure (Figure *10*) refers to the result of the ratio of BOD and COD. Which was found around 0.5 which indicates that the water is contaminated but not that much harmful or polluted but treatable (Samudro and Mangkoedihardjo 2010). High BOD and low DO level indicates more oxygen is being used by the bacteria (Md. Rafiu Zaman1, Md. Mahmud Hossain2 2018)

Table 3: Comparison of ratios of various parameters used to characterize wastewater

Type of wastewater	**BOD / COD**
Untreated	0.3 – 0.8
After primary settling	0.4 – 0.6
Final effluent	0.1 – 0.3

Source : (Samudro and Mangkoedihardjo 2010)

Main Findings

From the above data and figures, it is proved that the slums are contaminating water by disposing of their household waste. But the people living in the slums are not completely responsible for this pollution. They are not getting waste management facilities provided by the municipality. They have almost no safe place to dump their waste except the river. Though this contamination level is still not high enough like the industrial pollution or other severe pollution if the concerning authorities do not take necessary steps to improve the waste management facilities in the slums this pollution would become a threat for the lives that depend on the river.

Suggestions

1. Currently, the city corporation uses such waste management system where workers for the conservancy department of the city corporation move house to house for waste collection on a daily basis. As the connecting road to the slum household are so narrow that the collection vehicle fails to reach the household. The municipality should change the type of vehicle they are currently using. One wheeler Trolly (Figure 11) may be a good way for the collection of the waste.

Figure 11: One wheeler Trolly

2. Recycling can be a very good option, according to the formation of waste composting can show a sustainable path for resource recovery (Yasmin 2017).
3. Raising awareness among the slum people about the adverse effect of dumping waste into the river.
4. Improving the Infrastructure of the slum area such as sanitation, road cluster, security lighting etc (Fayaz and Bhat 2017).
5. According to (Lohri, Camenzind, and Zurbrügg 2014) there is evidence that private company was able to show an excellent service with fewer cost.

CONCLUSIONS

The Padma is one of the most important rivers which plays a great role in the economy of Bangladesh. River pollution is no less than a river destruction. This greatest blessing enters into Bangladesh through Rajshahi. So if the upstream of this river gets polluted there is always a great chance for the pollution of the downstream. Industrial waste, Medical waste, Lather wastes are polluting river very much and household waste is doing a very little compared to the previous wastes, but if the authorities do not put a concern for the pollution by the slums (Household wastes) it may become a great threat in some recent years.

Due to illiteracy slum, people have little concern about having a healthy environment. Though they have to pay municipal taxes duly but poverty bereaves them to get the municipal facilities. So authorities have to put a good concentration on them not only for the improvement of the slum condition but also for the whole country as it largely depends on the Padma.

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ASSESSING THE IMPACT OF FAECAL SLUDGE OF TRAIN TOILET AT CHITTAGONG, BANGLADESH.

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ABSTRACT

Chittagong is the second largest city of Bangladesh. In the perspective of Bangladesh railway is one of the most important and cost effective transport system. Everyday around 20 trains depart from the station in different directions to different cities or within the city of the country. Thousands of people use this transport system to move from one place to another. As the traditional system of the train of our country is totally open defection. This paper analyze the effect of the existing toilet system of trains in Chittagong. Relevant data was collected from the Chittagong railway authority and from the literature review. It is seen that the traditional toilet system (hopper toilet) is used in all of the train. This type of toilet is not environment friendly as it discharge sludge and urine directly on the rail tracks and pollute the surrounding environment components. It has a serious impact on the human health to the people. To reduce the environmental pollution different countries are already implement different alternative toilet system which have reduced the pollution in a good amount. In respect of Bangladesh considering the feasibility and applicability a different type of toilet system is proposed that can easily be complied with the existing traditional toilet system which will be ecofriendly and provide healthy sanitation.

***Key words**: faecal slug, train toilet, Chittagong.*

INTRODUCTION

Railway is the major and proficient mode of transport in Bangladesh as it carries more and use less energy for transportation of passengers and goods (Ahsan et al., 2016), (Hassan & Iqbal, 2017). The railway carries 20% passengers among road, water and air transport of Bangladesh (Ahsan et al., 2016) and it provide transport service in the time emergency situation like flood, cyclone etc. (Uddin, 2017). Toilet facilities have been provided in almost all the passengers train in Bangladesh (Rahaman & Rahaman, 2009). As travel time of train journey is longer, this facility is an essential during the travel (Hassan & Iqbal, 2017). But quality of this toilet facility is not up to the mark in Bangladesh (Rahaman & Rahaman, 2009). In Bangladesh passenger trains usually used for disposal of waste of toilets are known as Drop Chute Toilets or HopperToilets(Vegad & Paruthi, 2017), (Hassan & Iqbal, 2017) and this toilet system directly drop dump toilet waste onto the railway track(RMT, 2015). The main problem related to this system is completely unhygienic and injurious for environment stability(Toilet-guru, 2016)as it discharge sludge and urine directly on the rail tracks and pollute the surrounding environment components(Gensch et al., 2018).

Restriction in contamination toilet waste or excreta in the ground or surface water is the major eligible criteria of sanitary latrine and it should not spread different environmental pollution of the soil, water and air whichare reason for different health risk (Abed et al., n.d.). But hopper toilet does not maintain any of this criteria.To reduce the environmental pollution occurred due to use of hopper latrine system in passenger trains different alternative toilet system, which will reduce the pollution in a good amount, should be implemented. Also different measures for reduction of pollution of environment should be undertaken.

Chittagong is the second largest city of Bangladesh (Mia et al., 2015). Everyday around 20 trains depart from the station in different directions to different cities or within the city of the country(Railway, 2017). Thousands of people use this transport system to move from one place to another. As the traditional system of the train of our country is totally open defection which is the reason of environmental pollution. This paper aim to analyze the effect of the existing toilet system of trains in Chittagong and in respect of Bangladesh proposing a different type of toilet system considering the feasibility and applicability that can easily be complied with the existing traditional toilet system, which will be ecofriendly and provide healthy sanitation.

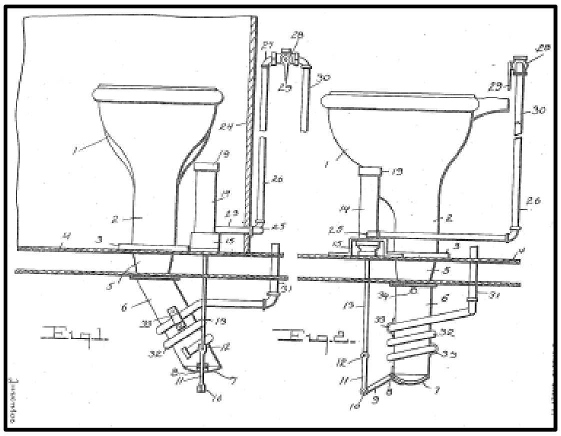

Figure 1Hooper Toilet System

[Source: toilet-guru.com, 2016)]

OBJECTIVES & METHODOLOGY OF THE STUDY

Objectives of the study are given below

- ✓ To investigate the present condition of the existing toilet of train in Bangladesh.
- ✓ To find out the generated waste from the trains depart from Chittagong railway station.
- ✓ To propose alternative toilet facility for trains.

Secondary data was collected to perform analysis for this study which all collected from the authority of Chittagong Railway Station. All the twenty trains in Chittagong Railway Station, that are reach or start, were selected to perform investigation on train toilet. Among the twenty trains, nine trains are intercity train daily that are reach or start in Chittagong and other eleven trains are local trains.

To conduct this analysis, passenger capacity was determined with the total number of compartment and capacity of the compartments for each train. The Journey time of each train was also considered as an important factor. After collection of the data, the data was interpreted and analyzed using Microsoft Excel Software. Alternative toilet was proposed based on literature review.

IMPACT OF HOPPER TOILET

Health Concerns

Germs of many water-borne diseases like diarrhea, cholera, typhoid, hepatitis and many others, are manly contaminated with the human waste. Not only are that parasites like hookworm, tapeworm, roundworm and pinworm manly spread through human waste. For a developing country like Bangladesh, deposing of human waste through hopper toilet in trains is very harmful for the human health, specialy near the railway station where the poor people live in high-densly slums areas.

Environmental Concerns

Disposing the human waste in railway track by the train through its toilets, the environment is polluted very larly. Because it may contaminate various harmful and deadly micro-organisms which causes many diseases. The micro-organisms mix with the water of rivers, canals and str eams and causes water pollution in many urban areas.

Reduction of life-time of the Railway Tracks

Because of open disposing of the human waste in railway tracks, the railway tracks are getting dirty and the life time of the tracks are decreasing. Specially in the urban areas near the railway station, deterioration of the railway tracks is seen mostly (Devwrat Vegad and Sunny Paruthi, 2017).

DATA COLLECTION AND INTERPRETATION

Survey Data Analysis of train:

Around 20 trains starts from Chittagong railway station goes to the different point of the country. From the appendix we can also find out the passenger capacity and the estimated time to their destination of trains. The data has been collected from the Chittagong railway station.

According to literature typically a person daily produce 1500 gm of excreta which has 300 gm of faeces and 1200 gm of urine (Dahi, 1996). Everyday around 12,309 person travel with train from Chittagong railway station in 20 trains. According to railway authority the trains which journey length is less than or within 50 km do not have the toilet facility. Within this criteria 5 trains do not have any kind of toilet facility. So the number of passengers of this 5 trains are excluded from this analysis.

Total Amount of Discharge of faeces = Per hour discharge of faeces* Total Journey Hour* Total Passenger

Total Amount of Discharge of urine = Per hour discharge of urine* Total Journey Hour* Total Passenger

Total Amount of discharge = Total Amount of Discharge of faeces + Total Amount of Discharge of urine

For example of the calculation of the discharge of the Sonar Bangla train is shown below:
According to the schedule of the Bangladesh Railway Sonar Bangla train reach Dhaka from Chittagong within 5 hours and it has a capacity of containing 586 passengers in 14 compartment.

Total Amount of Discharge of faeces = (300/24)*5*586=36625
Total Amount of Discharge of urine = (1200/24)*5*586= 146500
Total Amount of discharge = 36625+146500= 183125

All 15 trains with around 10,000 passengers generate approximately 1104850 gm of feaces and around 4419400 gm of urine, total amount of discharge is 5524250 gm which is around 5534.35 kg.

PROPOSED ALTERNATIVE TOILET FACILITY FOR TRAINS

Bio toilet:

Bio toilet is a solution of waste management problem which is eco-friendly through a bacterial composting process. It changes over human waste and all natural waste into clean reusable scent free water and bio Gas. Here the anaerobic procedure inactivates the pathogens in charge of water-borne maladies and treats the fecal issue without the utilization of an outer vitality source. The side-effects of the waste treatment process are without pathogen water, or, in other words cultivating, and bio-gas, which can be utilized for cooking. In bio tank, there are three or four chambers, right off the bat in chamber one the gigantic human squanders are broken by charged microbes states and after that the broken squanders and waste water goes two second and by same process it goes to last chamber where everything that remaining parts are water. Which can be release by outlet into rail tracks with not hurting the earth. Most extreme Indian railroads are currently utilizing it (Banka, 2017).

Figure 2 Bio Toilet System in Train

[Source: (Engineer, 2018)]

Vacuum toilet:

Vacuum toilets are flush toilets that utilize suction for the expulsion of dung and pee bringing about an insignificant prerequisite of water (0.5 to 1.5 liters). Vacuum toilets give indistinguishable level of solace from customary flush toilets and they help sparing expenses because of the limited measure of flush water. Vacuum toilets are particularly adjusted for the utilization in mix with discrete greywater and black water treatment; or high-impact assimilation treatment for biogas generation. Vacuum toilet systems are applicable both in large and small buildings, trains, ships and airplanes. (Stauffer, 2018)

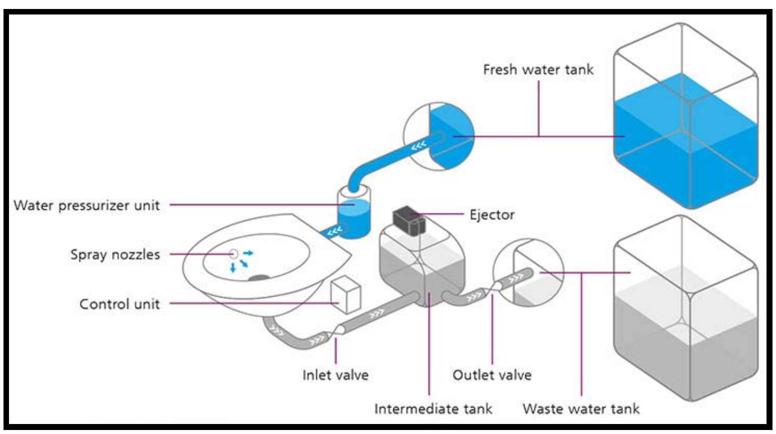

Figure 3 Vacuum Toilet System

[Source: (Aerospace, 2016)]

Composting Toilet:

Fertilizing the soil toilets utilize the common procedures of deterioration and vanishing to reuse human waste. Squander entering the toilets is more than 90% water, or, in other words brought back to the climate through the vent framework. The little measure of staying strong material is changed over to helpful treating soil by normal decay. The right harmony between oxygen, dampness, warmth and natural material is expected to guarantee a rich situation for the high-impact microscopic organisms that change the loss into preparing soil. This guarantees smell free task and finish decay of waste.

CONCLUSION

Solid waste management is very important due to various reason like environmental pollution, disease spreading & like so on. To reduce this loss we must have to take a major step by establishing environment friendly toilet system.

From the data interpretation we can easily find that a huge amount of waste is generated every day from the train as lot of passengers from all over the country journey on train for several hours. The existing hopper toilet system is not good for the environment and no solid waste management system is maintained. Considering the environmental degradation due to open defection bio toilet can be a good solution for waste management generated from train toilet. Bio toilet is much better than other alternative like vacuum or composting. In composting toilet system the liquid part of the waste is without treatment which is harmful for environment. Though vacuum toilet is good for management but it is very much costly.

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Municipal Waste Management of Kushtia Municipality: Challenges and Opportunities

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ABSTRACT

Municipal waste management is amongst of those most crucial issues of the world. Nowadays different international organizations i.e. WHO, ISWA etc. are working on introducing waste management system to ensure a better living atmosphere. The waste management system of Bangladesh is not up to the level. Recently, few municipalities have developed their municipal waste management system and Kushtia Municipality is one of them. The municipality owns composting plant where they compost municipal waste and sell into market as organic fertilizers. Though it is a revolutionary work and lot of opportunities are available in comparison with the current scenario of other municipalities in Bangladesh, there are some challenges faced by Kushtia municipal authority. This study aims also to identify the existing weakness and threats on the basis of SWOT analysis. And recommendations based on analysis of the existing scenario will go a long way to solve the problems faced by the authority. More importantly, to satisfy the increasing demand, a new landfill site and two transfer station are proposed. Also the shortest path is found by using GIS.

Keywords: Municipal waste management; composting plant; SWOT analysis; shortest path; GIS;

INTRODUCTION

In a developed country, the average citizen produces about half a ton of waste every year (Jouhara et al., 2017). As a result waste management is a crucial process that needs to be maintained properly. Old waste management systems consist the collection of mixed waste and transporting it a long way to disposal sites. It has a significant negative impact on the environment and humans. An integrated waste management system is one of the major challenges for sustainable development. Integrated Solid Waste Management (ISWM) represents a contemporary and systematic approach to solid waste management. The U.S. Environmental Protection Agency (EPA) defines ISWM as a complete waste reduction, collection, composting, recycling, and disposal system. An efficient ISWM system considers how to reduce, reuse, recycle, and manage waste to protect human health and the natural environment (Rick Leblanc, 2018). In large cities sustainable waste management system is in a complicated situation due to waste materials type and quantity, rapid population growth, less financial resource. In most developing countries solid waste is disposed of in low-lying areas without taking precaution or operation control. As a result, local and regional environment and public health are significantly affected by this unscientific disposal of industrial, bio-medical and municipal solid waste (Essays, 2013). In Kenya, a low income developing country like Bangladesh, the involvement of stakeholders as well as community-based organizations (CBOs), non-governmental organizations (NGOs) and the private sector in offering solutions towards the improvement of MSWM (Henry, Yongsheng , & Jun, 2006). In Nepal, sustainability strategies are developed by the waste collection firm of the municipality of Naples (WCFMN). It is a public utility firm owned by the municipality of Naples. This organization helps executives and managers of public service organizations to identify and exploit the most effective means of managing the adoption of corporate social responsibility.

This study is done to analyze the opportunities the challenges of solid waste management system in Kushtia Municipality. For fulfilling the goal, certain objectives are fixed to investigate the existing waste disposal system, to do a SWOT analysis of the existing waste disposal system, to find out the suitable location of a new land fill site and transfer stations, to provide some recommendations for the further development of existing situation and finally to find out the shortest route for collecting waste and saving time, money.

This study has multi-dimensional scopes. In this work, a SWOT analysis is made by investigating the existing situation. After that some proposals are made for the further betterment of the existing facilities. A suitability analysis is made by Arc GIS to find out the suitable location of the new landfill site. Finally a route analysis is done by Arc GIS to find out the shortest route for the fastest collection of waste. It will save money as well as time. There are some limitations such as lack of information especially all types of secondary data is not available, geographic database that is provided is not accurate so for better result new geographic database is prepared. It is also time consuming.

Kushtia Municipality Solid Waste Management Process

Kushtia Municipality is the 1st municipality in Bangladesh in which recycling of solid waste and fecal sludge is introduced. Every day around 50 tons solid waste is generated and on an average 20 tons are collected. 12000 liters fecal sludge are collated every day. At present 2 secondary transfer stations are available and only one landfill site is available. The fecal sludge and organic solid waste are processed and turned in fertilizer in the composting plant. The inorganic solid wastes are dumped into the nearby landfill site.

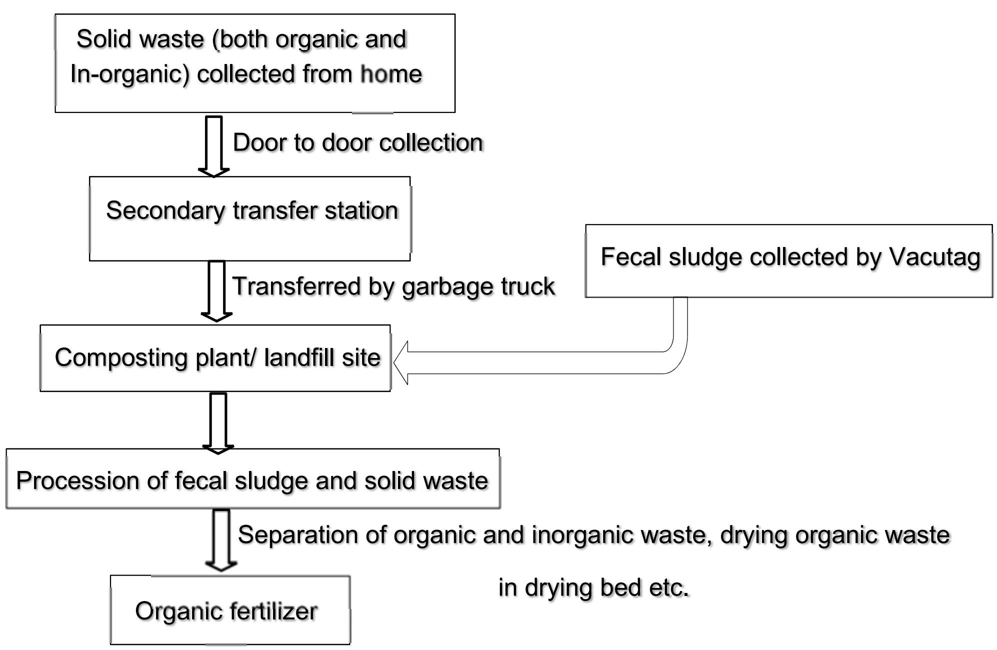

Figure 1 Kushtia Municipality Solid Waste Management Process

METHODOLOGY

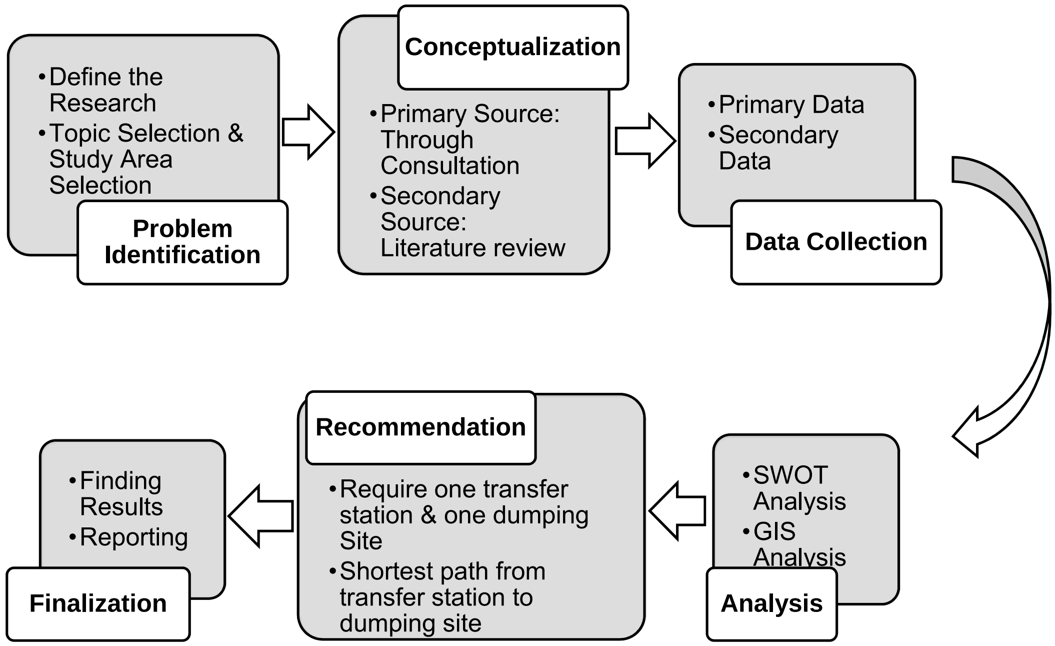

Figure 2 Methodology with a flowchart.

This study is carried out in six stages. *First stage* involves in identifying problems. Urban waste problem is a crucial issue all over the world. So, urban waste management is essential to solve this problem. Ineffective management causes various population e.g. air pollution, water pollution etc. Kusthia Municipality is trying to manage their municipal waste. For this they have developed Kushtia Municipality waste management. There are some strengths in their management system but there are some weaknesses also. This study aims to evaluate the municipality's management system. *Second stage* includes conceptualization. This is done in two ways i.e. through consulting with experts and reviewing previous research related to urban waste management. *Third stage* involves data collection. Both primary and secondary data sources are used to evaluate the waste management system in Kushtia Municipality. Primary data is obtained through field investigation, site visit. Secondary data is collected from BBS, Kushtia Development Plan, website of Kushtia Municipality (www.kushtiamunicipality.org) etc. *Fourth stage* involves analysis. SWOT analysis is done to meet the goal of the study i.e. to find challenges and opportunities as it is a recognized tool. In these study, challenges refer to weakness and threats whereas opportunities include strengths and opportunities. SWOT is a tool for determining external and internal factors which refer to strengths, weaknesses, opportunities and threats of an activity. A detailed SWOT analysis is performed based on the research questions developed. Answers to those questions are extracted through analyzing information obtained from field observations, governmental reports and related literature. Geographic Information System (GIS) is used through suitability analysis to find suitable location for a new transfer station and a new dumping site based on some specific and realistic criteria. GIS is also used to find shortest route from transfer station to dumping site. *Fifth stage* refers to recommendation. After analyzing, some policies are recommended. The municipality requires one transfer station and one dumping site. *Sixth stage* involves finalization. This refers to finding results and formal presentation.

STUDY AREA PROFILE

Kusthia, the cultural capital of Bangladesh, is situated in the south-west part of the country. It's a district in the Khulna administrative division. It is bounded by Rajshahi, Natore and Pabna districts on the north, Chuadanga and Jhenaidah districts on the south, Rajbari district on the east, west Bengal of India and Meherpur district on the west. Kushtia Municipality is the administrative head-quarters and main city of the district(Banglapedia, 2012). It lies between 23°42´ and 24°12´ north latitude and between 88°42´

and 89°22´ east longitudes. Kushtia Municipality was established in April 1, 1869. After about 100 years in 1981, the municipal area once again was extended with the inclusion of north Lahini, Horekrisnapur, Kalisankarpur, Housing Estate and part of Chourhas(“History Kushtia Municipalty,” 2018). Recently, the municipality area is extended. Now, its total area is 42.79 square kilometers and number of word is 21.

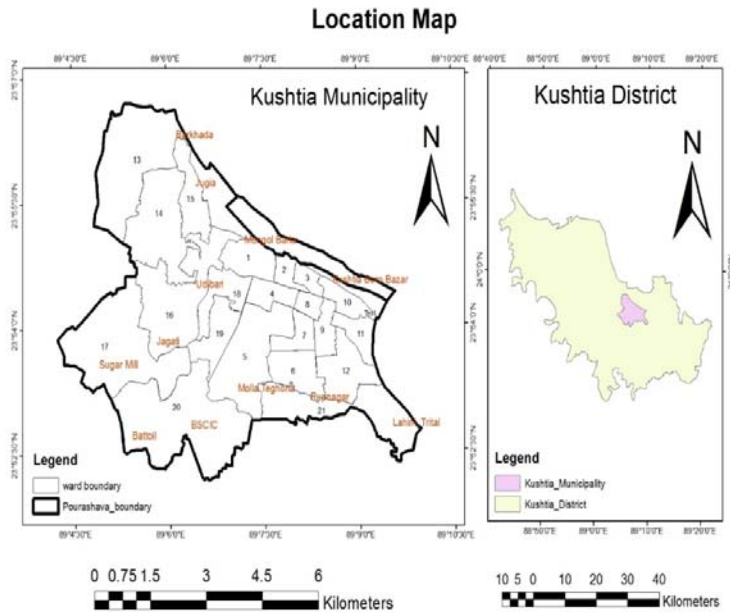

Figure 3 Location map

Table 1. Study area at a glance

Class of the Municipality	:	A
Name of Mayor	:	Anwar Ali
Establishment	:	1 April,1869
Municipal Area	:	42.79 sq.km
No. of Ward	:	21
No. of Mouza	:	19
Municipal Staff	:	165
Population	:	3,75,149
Total Roads	:	433 km
Total Drains	:	318 km
Number of Street Light	:	5900
Water Supply Pipe Line Coverage	:	33%

RESULTS AND DISCUSSIONS

SWOT Analysis of Municipal Solid Waste Management of Kushtia Municipality

In this study a SWOT analysis is done to investigate the existing situation and find out the gaps between existing waste management condition and ways to improve them.

Table 2 SWOT analysis findings at a glance

Strengths:	**Weakness:**
1. The Municipal Authority is concerned about the necessity of waste management system. 2. The 1st Municipality of Bangladesh who start making compost fertilizer through proper treatment of solid waste and fecal sludge. 3. Providing door to door household waste collection system in old wards. 4. Waste is accumulated at transfer stations rather than dustbins. 5. Providing septic tank and pit latrines empting services through a fixed service charge. 6. Revenues made by composting the waste and selling them as fertilizer. 7. Extracted water from Faecal Sludge Management (FSM) is being used in farming. 8. Dumping site at Baradi is located at environmentally safe area.	1. Inadequate number of transfer station and dumping site. 2. No shortest route for garbage truck from transfer station to dumping site. 3. Lack of equipment in Municipality to manage the wastes. 4. Shortage of fund to introduce advanced technical system. 5. Lack of technical maintenance farms. 6. Unawareness of general people to dispose and segregation of wastes. 7. Lack of segregation of waste at household. 8. Door to door waste collection system is unavailable in new wards. 9. Inefficient waste sorting system. 10. Less capacity of composting plant & drying bed.

Opportunities:	Threats:
1. Lands are available for further land filling/dumping site. 2. Door to door waste collection system can be increased. 3. Obtaining external supports from government (such as SHREDA, Ministry of Environment, Forest and Climate Change etc.) and non-government organization (such as IGES, Waste Concern etc.) 4. Getting help regarding FSM services through government and non-government organization.	1. Health problems are faced by waste pickers and employees of treatment plant due to chronic exposure to waste. 2. Dumping of waste in open space is more than dumping in sites. 3. Environment surrounding transfer stations is vulnerable

Strengths

The Municipal Authority is concerned about the necessity of waste management system. Kushtia Municipality introduced IRRC in 2012 with the help from UN-ESCAP and Waste Concern. At present, the IRRC has the capacity of 2 Ton of solid waste and 2-3 m^3 of faecal sludge per day (Ahmed, 2018). For proper waste management, the authority started door to door van service for collecting household waste collection. At present, there are 36 vans in the municipality area. It charges only BDT 50/per household per month. This service is still active in twelve old wards and new one word. The Municipality has 6 Garbage Truck to collect solid waste from different transfer station situated within the city. About 35 Tonne of Solid waste is generated every day in Kushtia municipality, whereas municipality can collect about 18-20 ton of waste every day(Ahmed, 2018). The authority maintains an environment friendly system. After collecting wastes from household, van driver accumulates wastes at transfer stations. So, there is very few number of dustbins in the city. Dustbins are provided only some special area e.g. Borobazar. For this, a pedestrian hardly gets bad odor during walking within the municipality area. The Municipality also provides septic tank and pit latrines empting services through a fixed service charge. The Municipality has 3 Vacutug. There is composting plant in which collected solid waste and fecal sludge are treated and turned into fertilizer. Revenues are made by composting the waste and selling them as fertilizer. The Municipality has outsourced it's IRRC to Aprokashi Ltd, a private firm has the experience and License of producing and marketing of the produced compost(Ahmed, 2018). The extracted water from Faecal Sludge Management (FSM) is being used in farming. The drying bed has a filtering mechanism, after getting filtered the drying bed the liquid waste water is treated again treated at the Coco-pit filter(Ali, 2017). Dumping site at Baradi is located at environmentally safe area. It is an important aspect of Kushtia Municipality waste management. The site is 4 km far away from the heart of the city.

Co-compost plant at Baradi.

Door to door Van service for household organic inorganic waste collection

Waste is accumulated at transfer stations rather than dustbins.

Garbage Truck.

Vacutag provides septic tank and pit latrines empting.

Organic Fertilizer: Production of Co-Compost Plant.

Extracted water from Faecal Sludge Management (FSM)

Dumping site at Baradi is located at environmentally safe area

Figure 4 Strengths of the Municipal waste management

Weaknesses

Existing two transfer cover those areas of the municipality where door to door household waste collection system is available. If the authority start their services at newer words where door to door household waste collection system is not available, these two stations are insufficient. Besides, dumping site and co-compost plant is located at Baradi (Ali & Ahmed, 2015) has not capability for increased wastes. Shortest path is used for reducing cost, saving time and efficiency. But there is no shortest route for garbage truck from transfer station to dumping site. So, shortest route can be proposed. It will save cost and time. Number of garbage trucks and vacutags is not sufficient. Moreover, if one transfer station and one dumping site are established, the municipality will need more equipment. But, the municipality alone has not the ability to establish more composting plant, more drying bed due to shortage of fund. The municipality is facing lack of technical maintenance farms. For example, if the pump of vacutag is crippled during operation, the authority has to go Dhaka for repairing. It is quite impossible to go Dhaka in every cases as distance is about 300 km. For solving this problem, the authority is using Shallow machine instead of pump (Ali, 2017). The maximum inhabitants of the municipality have less awareness about disposal and segregation of wastes. Many people dispose their solid wastes into drain, waterbodies, road etc. in lieu of giving waste collecting van. Even they connect pit latrines with drains. Further, the Municipality has no policy for increasing consciousness about segregation of wastes during waste collection at household. Waste sorting system of the authority is inefficient. It is done manually. It is also time consuming and is not cost effective. Advanced technology is not used. The municipality is emptying about 14-15 m^3 faecal sludge per day through Vacutug operation, whereas the IRRC can treat only about 3-4m^3 faecal sludge per day. So, the municipality is also facing challenges of managing that faecal sludge.

No segregation of wastes

Inefficient sorting system at compost plant.

This compost plant has not capacity to manage whole wastes of the city.

Figure 5 Weaknesses of the Municipal waste managemen

Opportunities

Recently, area of Kushtia Municipality is extended and enough lands are available for further land filling/dumping site. There are much agricultural land, open spaces, barren land at northern-western, western, western-southern part of the municipality. Door to door waste collection system is available in the old wards. There is opportunity to introduce it in the new wards. It will develop the whole waste management system of Kushtia Municipality. There is also opportunity to get external supports from government (such as SHREDA, Ministry of Environment, Forest and Climate Change etc.) and non-government organization (such as IGES, Waste Concern etc.). Recently, SHREDA (a govt. organization) has proposed that they will establish a power plant based on solid wastes. Moreover, the municipality is getting help FSM services through SNV Netherlands Development Organization with fund from Bill and Melinda Gates Foundation. This system would be more efficient and the quality of the service can be improved if any help can be taken by govt. organization. At present, Kushtia Development Plan (under PDP project) draft final is ready and waiting for final approval. These will solve various present and future problems regarding waste management system of Kushtia Municipality.

Threats

Health problems are faced by waste pickers and employees of treatment plant due to chronic exposure to waste. As labors are not aware about health issues. Dumping of waste in open space is more than dumping in sites. People are not careful about this. So, drainage condition is becoming worse day by day. As people dispose wastes in drains, waterbodies, open spaces etc. Environment surrounding transfer stations is vulnerable. Fig. 5.13 shows this situation more clearly. Though there is better condition in the transfer station located at housing estate, condition of transfer station located beside Kushtia Govt. Women College is vulnerable.

Environment surrounding transfer stations is vulnerable

Labors are not aware of health issues.

Figure 6 Threats part of the Municipal waste management

RECOMMENDATIONS

Proposed Land Fill Site and Transfer Stations

For a new landfill site, Rupnagar is selected which is situated in ward number 21. Udibari, Jugia, Mongol Baria, Boro Bazar, Molla teghoria and Barkhada are rejected as these sites are populated and landfill site will harm the people around it. Though Sugar Mill, Battoil, and Lahini areas are less populated they are far from the transfer stations. So transportation cost will be increased. As for being industrial area BSCIC area are rejected to be taken as a landfill site. Also, Udipara and jagati are showing growth trend. So for developing a sustainable town, these sites shouldn't be used as landfill sites. Here, Rupnagar situates not too far from the central area and most of its land is open land. This site is also not too far from the road so transportation of garbage will be easy. So Rupnagar will be the suitable site for landfilling.

Also, the new transfer station will be required as the municipality territory has increased, a lot of garbage are produced and transportation of garbage from ward number 13-20 is becoming tough. If we select a landfill site in Rupnagar then transfer station is not required for ward number 20 and 21. 13-19 number wards are situated a bit far from the landfill sites so two new transfer station will be required as the need assessment and as the distance from the new landfill site. Also, new 2 transfer stations will be so close to the existing landfill site.

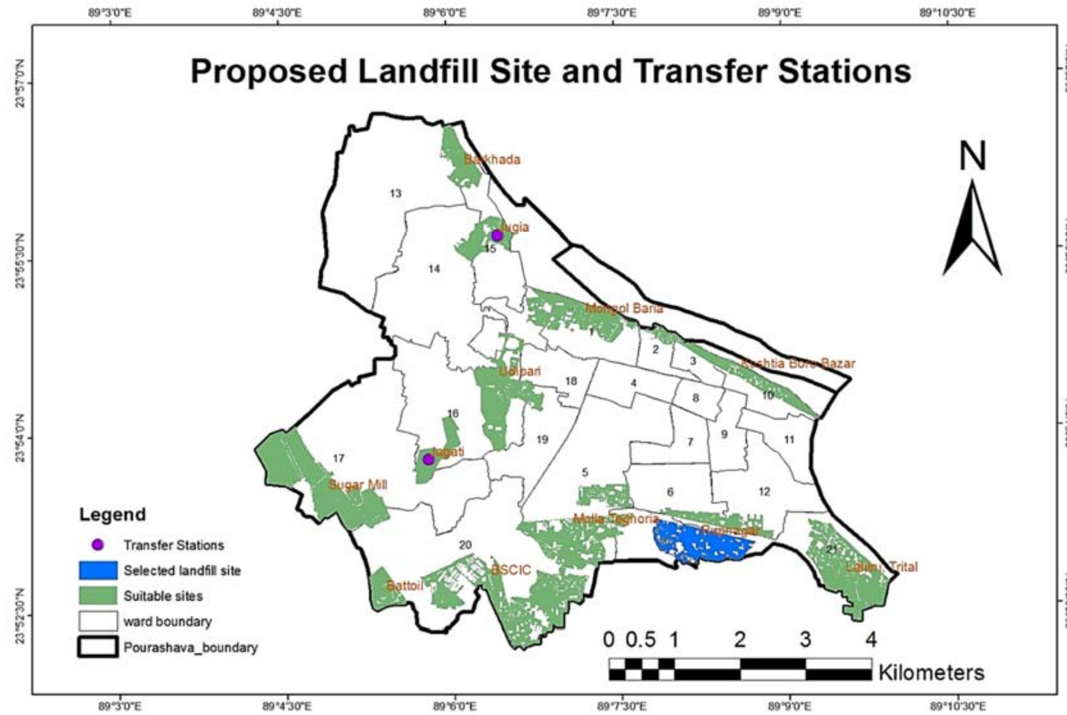

Figure 7 Proposed land fill site and transfer stations

Proposed Shortest Path from Existing Transfer Station to Dumping Site

There are 6 trucks which are used for transfer the collected waste to the dumping site. But there is no selected route for the trucks. For find out the shortest route first of all the routes including primary, secondary and access road are digitized and created network dataset from geographic information system (GIS). Finally, the two transfer stations (housing d block and beside mahila government college) and dumping site are marked and analyzed the shortest route which will save time and transportation cost. There is only one dumping site situated at Baradi in Kushtia. About 12-ton solid waste and fecal sludge is produced in kushtia municipality but only 2-ton waste is used for creating organic fertilizer. One dumping site is not enough for 4 lacs people. In this case another dumping site and two new transfer stations are proposed. The new dumping site is situated in rupnagar, behind the kushtia medical college. The existing two transfer stations if use the proposed dumping site the route will be short and cost efficient. And the two proposed transfer station if use the existing transfer station it also would be the same. So the eastern part of the municipality is proposed to use the new dumping site and the western part is used the existing dumping site it would be very cost effective and time saving transportation system because shortest route is available in this condition.

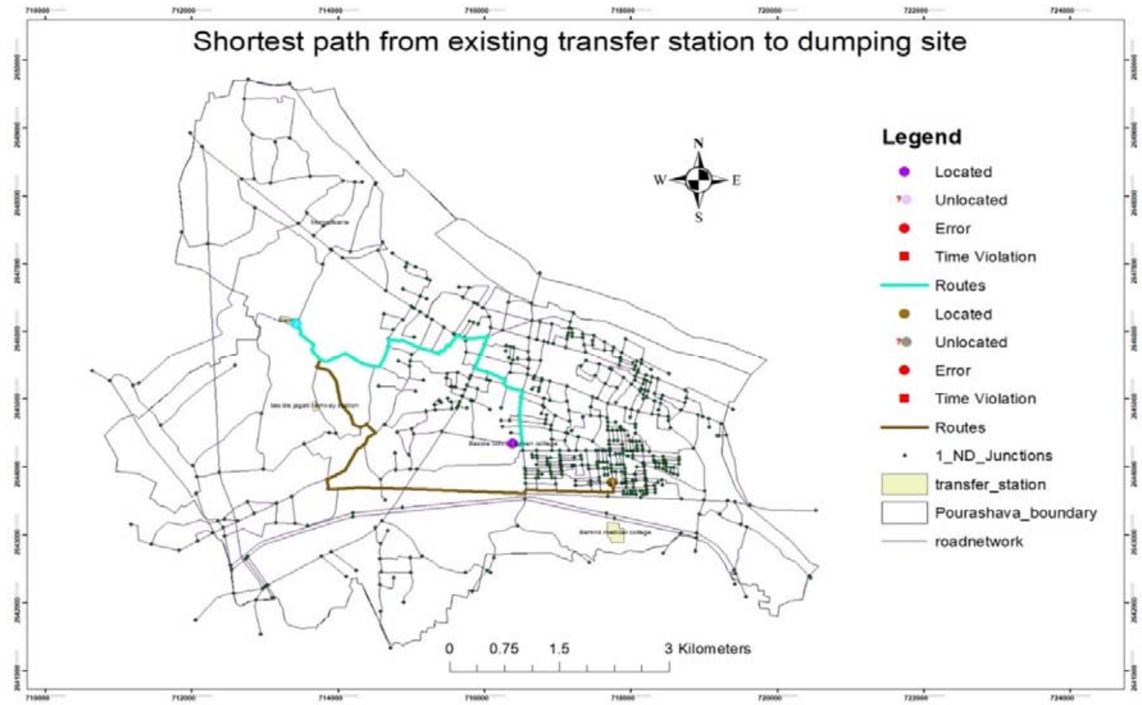

Figure 8 Proposed shortest path from proposed and existing transfer stations to existing dumping sites.

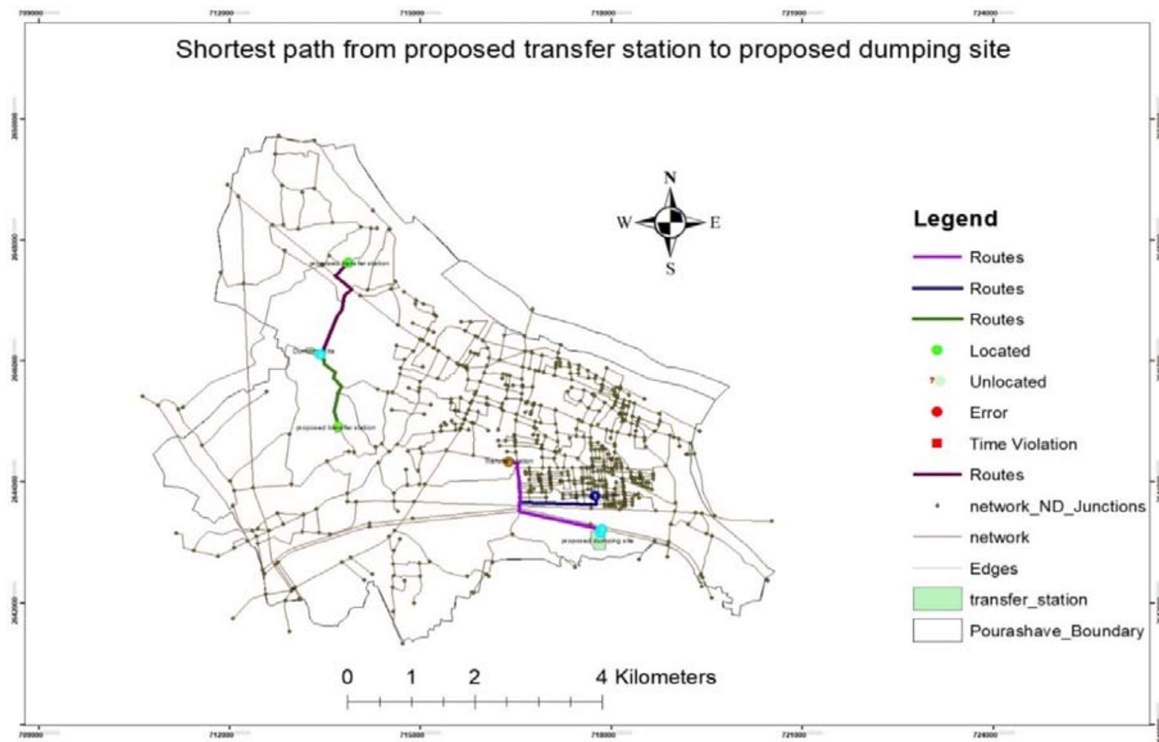

Figure 9 Proposed shortest path from proposed transfer station to existing dumping site and proposed dumping site

Important Recommendations Based on SWOT analysis

- Number of equipment related to waste management should be increased
- The Government should allocate more fund towards the municipal waste management.
- Technical farms should be more developed and advanced with the help of government and non-government organizations.
- Policy should be developed and campaigns, workshops can be organized at route level for increasing awareness about the necessity of segregation of wastes.
- Door to door van services can be started in newer wards.
- Waste sorting system should be developed.
- Capacity of compost plant and drying bed should be increased

CONCLUSIONS

Above study reveals clearly that Kushtia Municipality has a successful history of waste management system and doing better day by day. At present, the municipality is working in this sector in full swing. But there are some challenges and opportunities. If the government, non-government organizations provide assistance and the municipal authority is careful about this, the inhabitants of the Kushtia city will get a better, environmentally safe and pollution free Kushtia.

ACKNOWLEDGEMENTS

First of all, we would like to express gratitude to Almighty, Allah for his kindness and to give us strength for completing this research work. There is no word to express profound gratitude to Anwar Ali, Honorable Mayor, Kushtia Municipality. Last but not the least, we are thankful and indebted to all who helped us directly or indirectly in completion of this study.

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ALUMINUM WASTE RECYCLING PRACTICE IN KHULNA CITY

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ABSTRACT

Municipal Solid West Management (MSWM) has emerged as one of the biggest challenges faced by the least developed Asian countries like Bangladesh in environmental protection. In this paper the recycling practice of Aluminum waste in Khulna City are described. Aluminum recycling is the process by which scrap Aluminum can be reused as products after its initial production. Aluminum waste generation was found approximately 2545 kg per day in Khulna City. The Aluminum waste of Khulna City mainly consists of Thai Aluminum (26.33%), Casting Aluminum (32.61%), Broken Utensils (35.40%), and Soft Drink Can (5.66%). In most of the countries of the world, recycling has become one of the primary strategies for sustainable management of MSW. Aluminum has become an essential part of our daily life because of its captivating, durable, sustainable and lightweight properties. In this study, a traditional recycling practice of Aluminum waste in Khulna City has been investigated. Through interviews with waste collectors, primary dealers and secondary dealers, a complete sequence of waste collection process is identified and the profit has been set at each level. Recycling scrap Aluminum requires only 5% of the energy that is used to make Aluminum from the raw material. In Khulna City there are no industry for recycling Aluminum waste material. The study reveals that of the total Aluminum waste of 2545 kg/day that is collected, 2400 kg/day is sorted and processed in Khulna City for recycling of Aluminum waste.

Keywords: *Municipal solid waste, Aluminum waste, Aluminum waste recycling, Influence factors*

INTRODUCTION

Recycling results in reductions of greenhouse gas emission by saving energy needed to extract natural resources, using less energy in manufacturing and reducing the amount of waste burned or melted. Aluminum recycling is one of them. It has a number of key environmental and economic benefits (Rydh, 1999). Now a day's Aluminum is the most widely used material in the world. We cannot think of a single day without it. As we are using it in our everyday life enormous amount of Aluminum waste are being produced every day. Khulna is situated at the south-western part of Bangladesh near the world's largest mangrove forest Sundarbans as well as on the bank of river Rupsha and Bhairab shown in Figure 1.

The area of Khulna district is 4394 km^2 and the Khulna city area is 20.6 km^2 with population of 1.6 million. But the waste management process is inadequate. Due to the rapid population growth and improvement of the living standards of the residents, the amount of waste in Khulna City has been increasing in recent years. Therefore, the necessity of a reliable recycling system has become a major priority for Khulna city. The waste collection process is not proper in Khulna City. If these wastes can be collected by proper grading and separating, then the recycling process may be easier than the present recycling management process. Although the process of recycling Aluminum is not as simple as recycling paper, glass and metals, because the greater number of steps involved for extracting dyes, fillers and other additives (Moniruzzaman, 2018). By Aluminum recycling, keeping energy and cost savings in mind, many producers now have targets of increasing their use as a secondary material. There are different types of Aluminum products made from Aluminum sheets. There is a very little percent of Aluminum (3-4%) that is lost during the remanufacturing of Aluminum sheets. This produced Aluminum are used widely in a buildings, construction works, furniture, interior or exterior decorations, power supply, electric supplies, transportation etc. However, a very little work on Aluminum recycling is done in our country so far. In this research, the amount of Aluminum waste collection for recycling and the recycling process prevailed in Khulna City is determined.

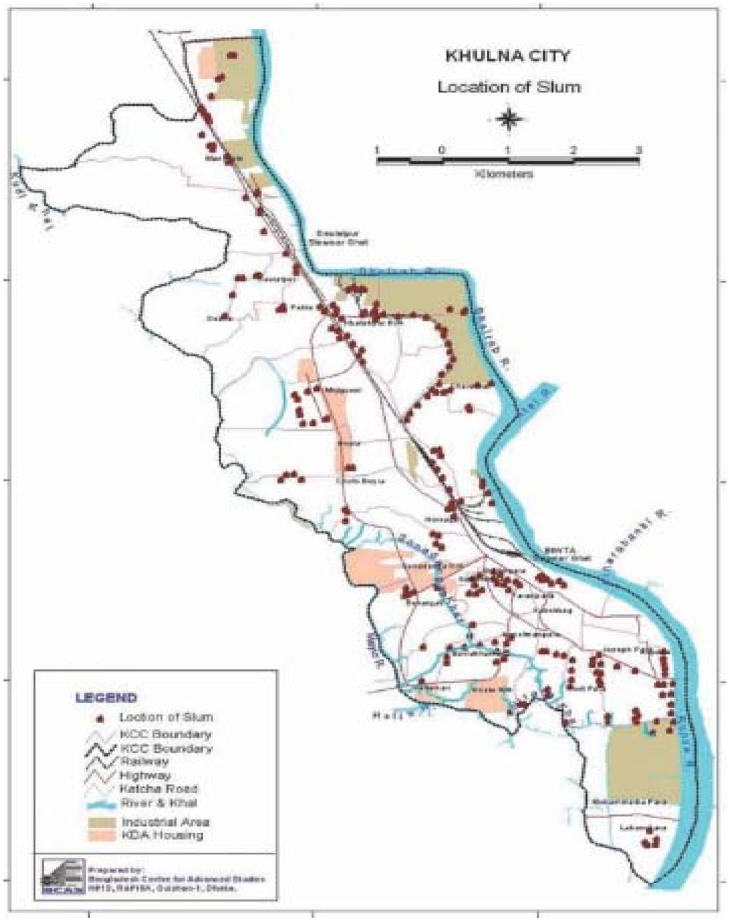

Figure 1: Map of Khulna District

RESEARCH METHOD:

Now a days the population of Khulna city has been increasing day by day. The life leading standards of people is also changed with the increase of population. For this reason, the people use more materials than before and the result is excess generation of Aluminum waste is making serious problem for the Solid Waste Management System (SWMS) (Moniruzzaman, 2018). According to the recent report of Khulna City the current actual collected Aluminum waste is 2.55 tons per day. On the other hand, the rapid population growth rate and urbanization cause a significant fluctuation of Aluminum waste generation in this city which consequently results in many problems.

Area selection and Data collection:

In order to become aware of the existing aluminum waste collection, storage and recycling pattern in Khulna City, a detailed questionnaire survey and field monitoring was done by the Waste collector (Fariwala / Tokai), primary dealer (Vangari shop), secondary dealer and industrial owner. Eight area are selected for survey work such as Fulbarigate, Maniktala, Daulatpur, Natunrasta, Khalishpur, Sheikhpara, Goalkhali, Zeropoint. The person who purchases the Recyclable Aluminum Waste from family and sells them to the primary dealer as well as secondary dealer is generally known waste collector. The person who buys RAW Aluminum only from the feriwala and sells them to the secondary dealer and recycling industry is known primary dealer and the secondary dealer buys RAW Aluminum from both feriwala and primary dealer and sells only to the recycling industry. The total no of Freiwala, Primary dealer and Secondary dealer are 60, 25 and 15. There is no any Aluminum recycling Industry in Khulna City. Generally secondary dealer shops are relatively large compared with the primary dealers

(Moniruzzaman, 2018). The recycling industries generally collect their recyclable Aluminum as raw materials from the primary dealers as well as the secondary dealers. All the data are collected for the recycling from the secondary dealers only who send the Aluminum waste to the industry in Khulna City. The number of feriwala, primary dealers, secondary dealers & recycling industries are given with respect to the different places of Khulna City in Table 1. Four photographs of Thai Aluminum, Soft drink can, Casting Aluminum and Broken Utensils are shown in Figure 2, Figure 3, Figure 4 and Figure 5 respectively.
The Quantity, price, source and destination of collected Aluminum waste according to Feriwala, Primary dealers, Secondary dealers & Recycling industry are determined.

Table 1: The number of Feriwala, Primary dealers, Secondary dealers & Recycling industries in different places of Khulna city.

Places	**Freiwala (No's)**	**Primary dealer (No's)**	**Secondary dealer (No's)**	**Industries (No's)**
Fulbarigate	08	02	01	00
Maniktala	06	02	02	00
Daulatpur	11	06	02	00
Natunrasta	07	02	02	00
Khalishpur	12	06	03	00
Sheikhpara	13	05	04	00
Goalkhali	03	02	01	00
Zeropoint	00	00	00	00
Total	**60**	**25**	**15**	**00**

Figure 2: Thai Aluminum

Figure 3: Soft drink can

Figure 2: Casting

Figure 3: Broken Utensils

RESULTS AND DISCUSSION

The main objectives of this study was to find out the total amount of recyclable Aluminum wastes produced daily in Khulna City and the recycling procedure of Aluminum waste to the Aluminum ingots. The Aluminum recycling process adopted by the industries of Khulna City was also observed. The buying and selling price of the recyclable Aluminum waste and the implication of Aluminum recycling and their uses in future also a part of this study. The collected amount of different types of Aluminum waste in Khulna City are shown in table 2.

Table 2: Different types of Aluminum waste in Khulna City.

Waste Aluminum	**Thai Aluminum**	**Soft Drink Can**	**Casting Aluminum**	**Broken Utensils**
Quantity (kg/day)	670	144	830	901
Total=	2545kg/day			

It has been found that the total Aluminum waste collection in Khulna City is 2545kg/day i.e. 2.55 tons per day. After collection of the recyclable Aluminum waste by the secondary dealer shops send them to the worker for sorting. Manual methods are taken to sort out the Aluminum waste in Khulna City. They are generally done by eye inspection. Generally, clear Thai Aluminum, Casting Aluminum, Broken utensils and Soft drink cans are positively identified and separated from the stream. Sorting is also done according to their types, size and shape. The financial efficiencies of recycling process is mainly governed by this step. The improvement of this process will increase the workability of recycling process as well as the financial profit. After the completion of sorting process, they are sent for cutting. This is the process in which the sorted Aluminums are reduced to a desired size by a cutting machine. This machine consists of a motor and a cutter inside. There is a half conical shape basket from which it is supplied with Aluminum. After the cutting process, the small pieces of Aluminums are put into the melting machine. The melting process is done by the machine. In this process 99.99% $N_2(g)$ are pumped to refine the Aluminum alloy. In order to maintain accurate proportion of initial metal components of the alloy samples, they are taken in the laboratory for the tests. The making of the blade only begins if the quality of the product is ensured. Before starting, the material is cleaned up by the firing gas or special kind of powder. Instantly the liquid material is passed through the pipe, then the blades are molded by using various molds, and stored after cooled in cold water. The blades are taken into the cutting machine for breaking them into fragments. These fragments are taken into the extrusion section. Using the cutting unit of this section, the fragments are cut out as needed. To straighten up the sheets, two end of the sheet are fixed with the straight machine and placed in the specific area. Then these sheets are put into the heater machine for a period of eight hours. It is done to develop the strength of the Aluminum sheets. Then they are taken into analyzing unit, and cleaned up with the refine water, and colored as needed afterwards. Then these colorful profile of Aluminum sheets are taken into the packaging unit and brand name or company name are written on them with the laser machine. Then the completed sheets are sent to the destination as needed. This full process is shown in the figure 6.

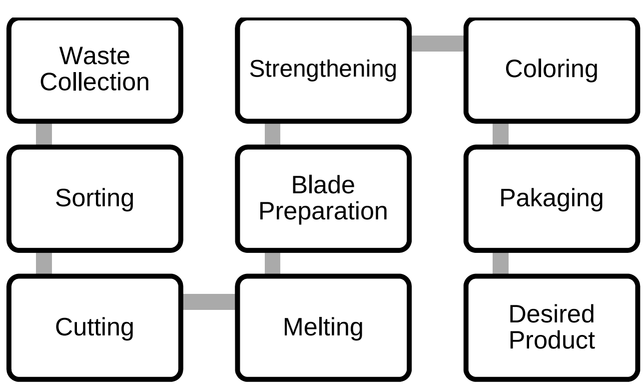

Figure 6: Flow diagram of Aluminum recycling in Khulna City.

The whole process from Aluminum Waste collection to the desired product are observed in Chunhua Aluminum Industry. Figure 6 represents the flow diagram of recycling of Aluminum in Khulna city. The typical photographs of sorting, cutting, melting and molding of Aluminum recycling process are shown

in Figure 7, Figure 8, Figure 9 and Figure 10 respectively.

Figure 7: Sorting of Aluminum

Figure 8: Cutting of Aluminum

Figure 9: Melting of Aluminum

Figure 10: Molding of Aluminum

Aluminum waste collection rate per day in Khulna City are shown in figure 11.

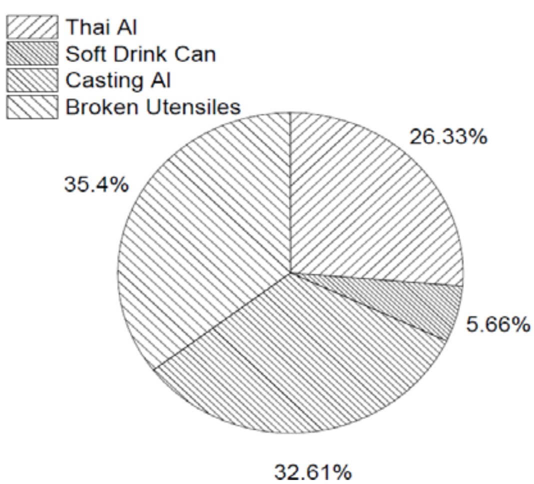

Figure 11: Aluminum waste collection rate per day in Khulna City.

Total quantity of recyclable Aluminum wastes collected by Feriwala and different shops are presented in a tabular form. The table shows the quantity of different type recyclable Aluminum waste collection per day, their buying and selling price. The source and the destination of Aluminum waste are also shown in the table.
Table 3 represents the daily collection of recyclable Aluminum waste from house to house by a Feriwala. Table 4, Table 5 also represent the daily collection, buying and selling price, source and destination of recyclable Aluminum waste of primary dealer shop, secondary dealer shop respectively.

Table 3: Quantity, price, source and destination of collected Aluminum waste according to Feriwala.

Types of Recyclable Aluminum waste	**Amount collection (Kg/day)**	**Price (Tk./day)**		**Source and Destination of Aluminum waste**
		Buying	**Selling**	
Thai Aluminum	10-15	85	90	Collected : From houses Destination: primary and secondary dealers
Soft Drink Can	8-10	80	85	
Casting Aluminum	8-10	144	150	
Broken Utensils	12-15	126	130	

Total amount of collected Aluminum waste by a Feriwala is 42 kg/day in which 40 kg is recyclable. Total number of feriwala is 60. So Total amount of recyclable Aluminum waste collected by all Feriwala = 60 x 40= 2400 kg = 2.4ton/day.

Table 4: Quantity, price, source and destination of collected Aluminum waste according to Primary dealer shop.

Types of Recyclable Aluminum waste	**Amount collection (Kg/day)**	**Price (Tk./day)**		**Source and Destination of Aluminum waste**
		Buying	**Selling**	
Thai Aluminum	25-30	90	96	Collected : From Feriwata Destination: Secondary dealers and Higher Industry
Soft Drink Can	18-20	85	92	
Casting Aluminum	15-20	150	158	
Broken Utensils	20-25	130	137	

Total amount of collected Aluminum waste by a Primary dealer is 84 kg/day in which 80 kg is recyclable. Total number of primary dealer shop is 35. So the total amount of recyclable Aluminum waste collected by all primary dealer shop = 25x80 = 2000 kg/day = 2.0 ton/day.

Table 5: Quantity, price, source and destination of collected Aluminum waste according to Secondary dealer shop.

Types of Recyclable Aluminum waste	**Amount collection (Kg/day)**	**Price (Tk./day)**		**Source and Destination of Aluminum waste**
		Buying	**Selling**	
Thai Aluminum	48-55	96	104	Collected : From Feriwala and Primary dealer shop Destination: Higher Industry
Soft Drink Can	25-30	92	98	
Casting Aluminum	25-30	156	165	
Broken Utensils	40-50	136	142	

Total amount of collected Aluminum waste by a Secondary dealer is 165 kg/day in which 160 kg is recyclable. Total number of secondary dealer shop is 15. So the total amount of recyclable Aluminum waste collected by all secondary dealer shop = 15 x 160 = 2400kg/day = 2.4 ton/day. There is no Aluminum Recycling Industry in Khulna City. So all the collected waste material go to the recycling Industries outside Khulna for the recycling. After recycling new Aluminum product are prepared. Figure 12 represents the mass balance diagram of recycling of Aluminum waste in Khulna city. The approximate net profit per day for a feriwala, primary dealer, secondary dealer and recycling industry are given in Table 6.

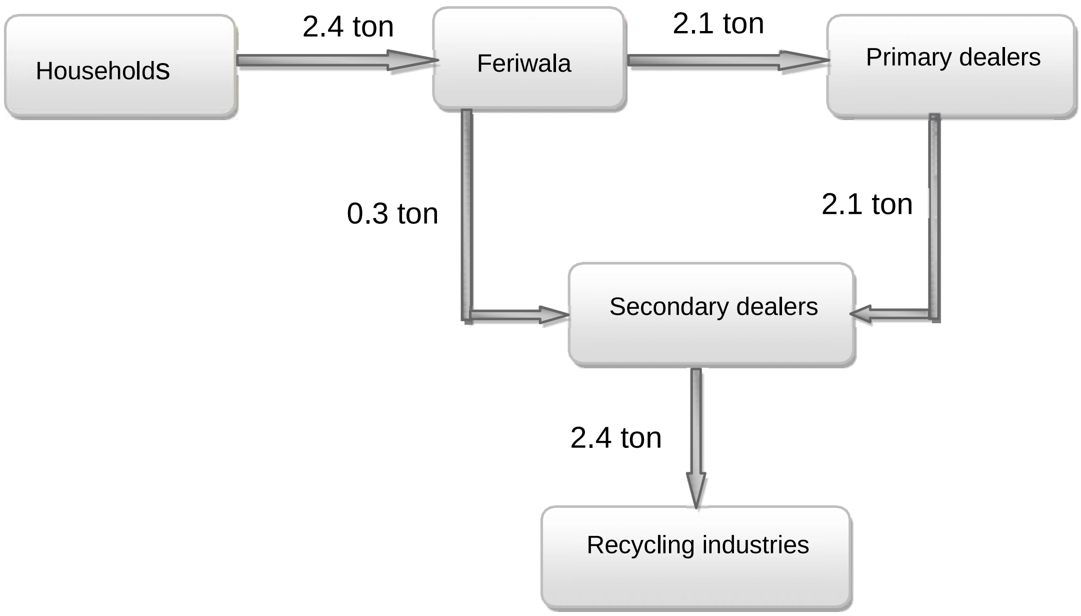

Figure 12: Mass balance of Aluminum waste recycling in Khulna city.

Table 6: Approximate net profit per day for a Feriwala, Primary dealer shop, Secondary dealer shop and Recycling industry.

Aluminum waste collector	Average profit (Tk/Kg)	Amount of waste sell (kg/day)	Net profit (Tk/day)
Feriwala	6.00	40	240
Primary dealer	7.00	80	560
Secondary dealer	7.25	160	1160

INFLUENCE FACTORS

Research has shown that there are some reasons for the Solid waste management system in Khulna city which affects the whole system. In addition to improving waste management, growth and performance, these factors are effective in reducing environmental degradation of household waste. The study found that due to family education, poor supervision, lack of technical and human resources, government policies and lack of government funding, Khulna municipality's poor waste management is among the reasons.

CONCLUSION

Aluminum is valuable at every stage of its life cycle, from production through to end of use. It can be recycled continuously while carrying out the material features. Aluminum recycling requires about 5% of the energy needed to produce it from virgin materials, which reduces greenhouse gas emissions by 95%. Using recycled aluminum reduces the need for primary aluminum and therefore reduces waste, avoids reducing resources and reducing greenhouse gas emissions across the cycle of the product. In this study, aluminum waste recycling process in Khulna City was properly observed. Based on the results, it can be seen that the total amount of aluminum waste collection was 2545 kg / day, where only 3 to 4 percent of aluminum was lost during recycling. Aluminum reusability generally stores significant costs in new aluminum production, even when the cost of collection, separation and recycling is taken into consideration. Capital savings related to international shipping of landfills, mines and raw aluminum are reduced when the national savings are made larger than the long-term period.

ACKNOWLEDGEMENT:

The authors would like to thank Department of Civil Engineering, KUET for this invaluable guidance through research funds. The authors would also like to thank the Feriwala and Shopkeepers and Industry owner for their endless help.

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AN ANALYSIS ON SOLID WASTE MANAGEMENT IN RESIDENTIAL AREAS OF CHITTAGONG CITY CORPORATION, BANGLADESH

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ABSTRACT

Generation of solid waste (SW) is a major problem in urban areas and its management is obligatory functions for both urban local authority and the urban people. The waste collection and disposal does not contend with the amount of waste generated per day as a result garbage are scattered. This study was conducted at three residential Areas named Shanonda, Panchlaish and Chandgaon under Chittagong City Corporation (CCC). Several methods were used to conduct this study including questionnaires, interviews and direct observations. The study involved a questionnaire and encompassed 240 households from three different socio-economic groups (SGs): middle (MSG), upper middle (UMSG) and high (HSG). The households solid waste (HSW) comprised of several categories of wastes like paper, packs, cans, glass, plastics, food, vegetables, bones, textiles, wood etc. The waste generation rate of the study areas is calculated through the study. The existing solid waste management system also observed of the residential areas. The study also revealed several shortcomings in connection with the solid waste managements in the residential areas including low quality, inadequate storage and transportation facilities, an informal dump site, insufficient collection frequency of solid waste, low level of awareness and education of solid waste management and lack of enforcement of regulations by law enforcement. Finally, the research suggests some appropriate recommendations on how a participatory sustainable residential solid waste management system could be developed in the residential areas of CCC to achieve its goals.

Keywords: Solid waste; generation; composition; households solid waste; solid waste management

INTRODUCTION

The rate of generation of solid waste is increasing proportionately with urban growth. The situation is very worse in Chittagong city as the urbanization rate is very high here because of rural migration. Municipal solid waste (MSW) management systems are becoming more complex in many countries with movement from landfill-base systems to resource-recovery-based solutions (Abu-Qdais, 2007) . About 1550 tons solid wastes are generated daily in the Chittagong Urban areas (Berkun, Aras, & Nemlioglu, 2005). The solid waste (HSW) generation rate in household is very much higher compared with the industries and health sectors waste generation (Rahman, Dewan, & Islam, 2001). The amount of domestic wastes is about 80% of total wastes that generated in major cities (Pongrácz, 2009).land pollution, water pollution and air pollution is happened because of the disposal of solid waste of openly dumped, dumped to low laying lands, and burning of wastes respectively. Improper solid waste management in Chittagong city causes the problems of negative impact on human health and animal health which ultimately causes economic, biological and environmental losses (Berkun, Aras, & Nemlioglu, 2005).
The target of the study is to find out the existing Solid waste management condition in residential areas of Chittagong City Corporation by analyzing three major residential areas named Sanonda, Panchlaish and Chandgaon Residential Area and suggest some remedial measures to improve the condition

.

METHODOLOGY

For the study, at first, municipal solid waste related records and documents of CCC are assessed. After that field survey and questionnaire survey was done for identifying the socioeconomic status and solid waste generation scenario of the study areas. The questionnaire also contained especially with the information of sources and sub-sources waste generated, information of physical composition and information about quantity and quality of solid waste (SW).
For the study, total 240 households were selected of the three residential areas by using the random sampling method. Then the information of the households were collected through the secondary data and the prepared questionnaire survey sheet. After analyzing the information at last some remedial recommendation were proposed.

Study Area Profile

Chittagong City Corporation is located between 22°13' and 22°30' north latitudes and between 91°40' and 91°55' east longitudes along the southeast coast of Bangladesh. It is bounded by the Karnaphuli River with the Halda River to the south and east, by the Bay of Bengal to the west and by a range of hills to the north. It is geographically hilly region and the topography is unique currently, the city holds 20, 68,082 people with 178 sq. km., making it the second largest metropolitan city in the country (BBS, 2011)
Among the residential areas of Chittagong City Corporation area, Sunonda, Panchlaish and Chandgaon are regarded as major residential areas based on their population density. They are located under Panchlaish and Chandgaon thana respectively. More than 2,50,000 people are living in these areas. Among them 40,000 inhabitants are in the residential areas. Among them 59.39% are male and 40.61% are female. (BBS, 2011)

Data collection

The waste management facilities of three residential areas of Chittagong City Corporation is presented in the table below:

Table 01: Waste management facilities

Sl no	Particulars	Quantity
1	Dust-bin number	129
2	Amount of Solid Waste	271 ton/day
3	Number of Waste Transport Vehicle	6
4	Schedule time for waste disposal	6 am – 8am
5	Vehicle type	truck and van
6	Number of crew	138
7	Total Houses	180 nos.
8	Total inhabitants	About 40000 nos.
9	Total population of thanas	2,50,000
10	Container number	6 no
11	Rate of Waste Generation	1.084 kg/Cap/Day

The above table describes the waste management facilities in the residential areas of Chittagong City Corporation. There are 129 dustbins in the three residential areas. There are only 6 carrying vehicles for the carrying of wastes and 138 crews are involved in the waste management system of the area. The rate of waste generation rate is 0.684 kg/Cap/Day.
The questionnaire also carried the information about the socio-economic group of the areas, given to the below table:

Table 02: Socioeconomic groups of the households on basis of monthly income

SL.	Socio-economic group	Monthly income	Number of House studied	Number of studied person
1	HSG (High Socioeconomic Group	More than Tk. 50,000	67	210
2	UMSG (Upper Middle Socioeconomic Group)	between 20,000 Tk. to. 50,000 Tk.	96	375
3	MSG (Middle Socioeconomic Group)	between 10,000 Tk. to 20,000 tk	77	336

The table shows that most of the people living in these residential areas are lying in between the middleclass and upper middleclass group.

Table 03: Residential Waste Generation Rate (RWGR)

Socio-economic group	Number of hh studied	RWGR	Number of persons studied	RWGR
		Kg/hh/day		Kg/person/day
HSG	67	3.13	210	0.99
UMSG	96	1.79	375	0.045
MSG	77	1.14	336	0.261
Total	240	2.02	921	1.06

hh = Household; RWGR=Residential Waste Generation Rate

From the above table it is seen that people living in the higher socio-economic group generates the highest residential wastes than the others.

Fig. 01: Variation of Residential wastes Generation Rate of CCC at Residential Areas.

RESULTS AND DISCUSSIONS

Table 4: Physical Composition of RSW Generated by Different Socioeconomic Groups

			Waste Category (%)			
			Non-Compostable			Compostable

Socio-economic group	Paper	Pack	Can	Plastic	Glass	Bones	Textile	Vegetable	Wood
HSG	10	11.6	11	2.35	3.55	2.5	5	51.7	3
UMSG	7.3	8.5	6	2.6	3.2	1.5	4.3	62.3	2.7
MSG	6.4	1.45	4.38	2.82	2.85	0.42	4.6	75	3
GW per day for all SEG	7.9	7.18	7.12	2.57	3.18	1.49	5.3	63	2.9

Table 5: Comparison of Solid Wastes Physical Composition data between Residential Areas and CCC Study

Component	CCC MSWM Household (%)	Residential Areas Assessed Household (%)	CCC MSWGR Kg/Cap/Day	Generation Rate of the thana g/Cap/Day	Sanonda R/A Assessed Generation Rate Kg/Cap/Day
Paper	4.68	7.9	0.920	1.084	1.06
Pack	ND	7.18			
Can	2.65	7.12			
Plastic	8.70	2.57			
Glass	0.00	3.18			
Bones	0.63	1.49			
Textile	2.40	5.3			
Vegetable	70.50	63			
Wood	1.20	2.9			
Compostable	71.70	65.9			
Non Compostable	28.30	34.74			

DATA INTERPRETATION

- CCC RWGR of HSG 0.781 Kg/cap/day which is different from Assessed waste generation rate of the three residential areas, HSG RWGR 1.084 Kg/cap/day but average data of UMSG and MSG RWGR 0.47 Kg/cap/day almost same as CCC RWGR.
- From above analysis it is seen that CCC MSWGR is 0.92 kg/cap/day which has studied on entire Chittagong city which includes not only domestic waste but also commercial and market wastes of composition.
- Panchlaish and Chandgaon thana has a lots of academic institution and press are situated. So waste generation is higher in this areas (1.084 kg/cap/day) compared to the average city data.
- It is mentioned that assessment of our study is based on three socioeconomic level (HSG, UMSG & MSG) whereas CCC also included lower income group. It is also notice that CCC MSWM composition is not similar with Residential Areas.

CONCLUSIONS

Solid waste generation has increased proportionately with the high density of population but support for waste management is inadequate. The purpose of this study is to analyze the existing solid waste management system in Chittagong City Corporation. Moreover, it also evaluates priorities for sector reforms as well as identification of investment projects in the aforementioned urban local bodies. HSWM refers to all activities pertaining to the control, collection, transportation, processing and disposal of waste in accordance with the best principles regarding public health, economics, engineering, conservation, aesthetics and other environmental considerations. The generation of 9 category house hold wastes are paper, packaging materials, cans, plastic, textiles, glass, vegetable, bones/dirt and wood which has 65.9% wastes is compost able & 34.74% waste is no compostable. On the other hand the study also exposed that CCC is not fully capable to properly & regularly handling the wastes from the city without environmental interfere, so MWMS has to be integrate to disposal the solid waste with best practice.

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EFFECTS OF RAW SEWAGE PRETREATMENT USING BAR SCREEN IN KHULNA MUNICIPAL AREA

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ABSTRACT

Direct disposal of raw sewage is common practice in Bangladesh. For developing and underdeveloped countries, installing complete wastewater treatment system everywhere is not possible. Bar screen can be used in separating solid waste from the raw sewage and can play a vital role in improving the environmental condition. Purpose of the study was to observe the effect of bar screen in raw sewage pretreatment. This study was carried out inKhulna city area.An investigation was made involving 47 outfalls. As part of the study, a bar screen was temporarily installedona drain inside Khulna University of Engineering & Technology campus.Capability and effect of the temporarily installed bar screen were observed and studied over a period of time. Furthermore, the difference between raw sewage and bar screen treated sewage were studied; andthe possibilityof using bar screens on every outfall of Khulna city area was discussed.

***Keywords**: bar screen, solid waste,sewage pretreatment.*

INTRODUCTION

Khulna is the third largest city of Bangladesh after Dhaka and Chittagong. Khulna is located in south-western Bangladesh at 22°49′0″N 89°33′0″E. The city is bonded by Rupsha River on east and southSide, Mayur river on west and by Bhairab River by north side. It is the capital of Khulna Division and a major industrial and commercial center. Khulna City Corporation (KCC) covers a total area of 64.78 square kilometers (Bangladesh Bureau of Statistics, 2011). The population of the KCC area is about 0.75 million as of 2011 and the growth rate is 5% which is mainly due to rural-urban migration (Population and Housing Census, 2011).The city is beset with a number of environmental problems. Water logging, solid waste disposal, black smoke from vehicular and industrial emissions, air and noise pollution, pollution of water bodies by industrial discharge (Mujibor et al, 2009). Drainage and waste disposal facilities of Khulna City discharges a high amount of wastewater, domestic sewage, solid wasteevery day.Among all sorts of activities that can pollute a natural water sources, dumping of wastewater and solid waste stands first on the list.The magnitude of the dumping is not just alarming but is almost lethal to the native aquatic life. So much so, that the entire aquatic ecosystem of Khulna can be destroyed with this intensity of careless dumping. Future projections indicate that it can be further affected by salinity intrusion and sea level rise due to climate change (ADB, 2010).

About 11.75 million liters/day effluent is discharged through 47 canals and sewers from Khulna City area to the nearby streams (UK Mridha, 2011). The location of the outlets is shown in Figure 1 below. By visiting a few outlets, it can be stated that the condition of these sewer systems is very substandard, and treatment system is nowhere to be found. At this point, any inexpensive preliminary treatment system can be of great help for the Khulna city.

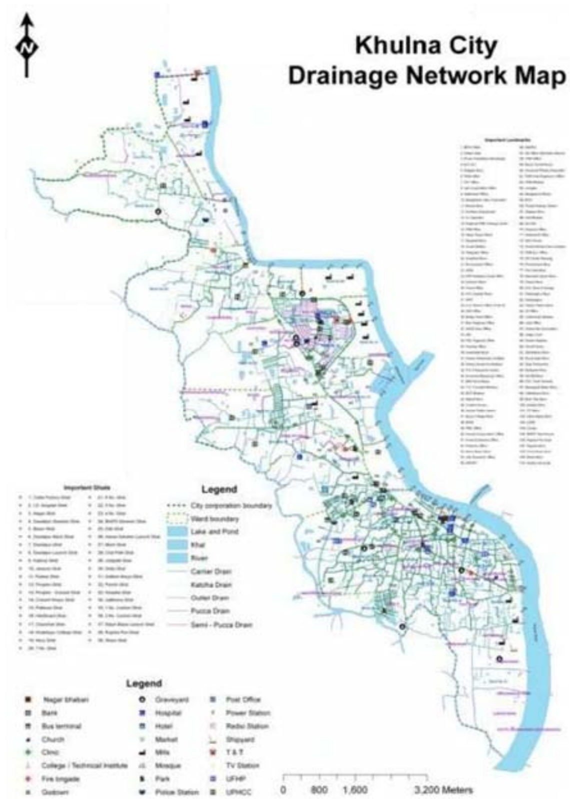

Figure 1Location of the drainage outlets of Khulna City.

The purpose of preliminary treatment is to protect the streams from direct disposal of solid waste. Preliminary treatment devices are, therefore, designed to:

- Remove or to reduce in size the large, entrained, suspended or floating solids. These solids consist of pieces of wood, cloth, paper, plastics, garbage, etc. together with some fecal matter.
- Remove heavy inorganic solids such as sand and gravel as well as metal or glass. These objects are called grit.
- Remove excessive amounts of oils or greases. A number of devices or types of equipment are used to obtain these objectives.

The first step in wastewater treatment is the removal or reduction of coarse solids. The usual procedure is to pass the untreated wastewater through bar racks or screens.Bar screens are normally installed as the first line of defense to remove large objects primarily, rags, woods and rocks that manage to escape and find their way through the sewer systems. Theoretically around 60 to 70percent of solid waste from municipal wastewater could be contained by using bar racks (Metcalf and Eddy, 2003). For Khulna city, instead of dumping the sewage into streams directly,a major part of solid waste can be retained by using bar screens before dumping the sewage into streams. It would certainly make a difference to the quality of a river water where direct disposal of raw sewage happens on a regular basis.

An understanding of the nature of wastewater is essential in the design and operation of treatment, and disposal facilities; in the engineering management of environmental quality. Though, a number of studies have investigated the characteristics of wastewater in Khulna city, no study was conducted to identify the impact of pretreatment system such as bar screen. The specific objectives of the study are: (i) to identify the existing drainage condition and management system of wastewater in Khulna City; (ii) to understand how poor solid waste management affects drainage system in the area and propose how bar screen system can be a great alternative to prevent buildup. (iii) to evaluate the suitability of bar screen for the preliminary treatment of wastewater in Khulna City; (iv) to evaluate the difference in characteristics of untreated and bar screen treated wastewater; and (v) to check the feasibility of installing bar screen on every outfall of Khulna municipal area.

MATERIALS AND METHODS

Before going to a final study, a procedural setup has to be fixed to undertake the possible all work to fulfill the objectives. Criteria fixation, types of data collection, time duration, quantity of data etc. are some major tasks have to be done. This organizational setup and working procedure are called as methodology. The methodological analysis has some certain section in this project concerned.

Selection of the Study Area

The scoping study relied on both primary and secondary information. A field survey within Khulna municipal area was conducted to get the primary data during February 2018 to May 2018. Map of existing drainage system and outfalls were collected from Khulna City Corporation (KCC) and Khulna Development Authority (KDA). Other maps were collected from word book for Khulna city. Other data was collected through reconnaissance survey, direct observation, and community consultations. Secondary data was collected from different sources including published and unpublished literature, different databases, newspapers and the World Wide Web.
Among the observed 47 outfalls, the one near Khulna University of Engineering and Technology found to be one of the easiest to access for the team.That's why the KUETcampus sewer directly connected to theoutfall was considered for the study.Location of the study area in context of Bangladesh and Khulna district is shown in Figure 2. The observed drainage system was found out to be both directly and indirectly linked with the water bodies of Khulna city. The study site was visited to understand and identify the major problems and issues related to solid waste dumping and benefit of solid waste removal using bar screen.

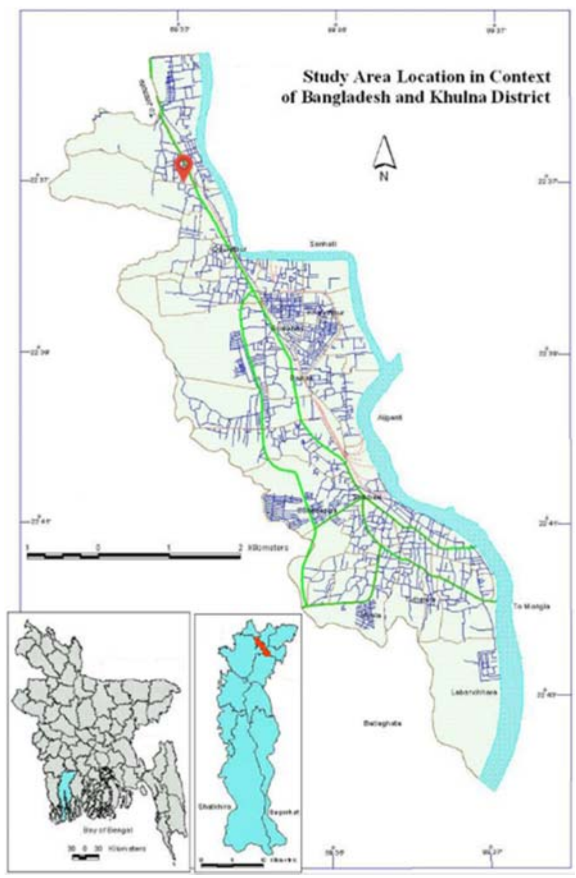

Figure 2 Location of the study area.

Wastewater Characteristics

Municipalities are faced with the problem of disposing of wastes. This includes all solid waste products which are composed wholly or partly of such materials as garbage, sweepings, cleanings, trash, rubbish, litter, industrial solid wastes or domestic solid wastes including organic wastes or residues of animals, meat, fruit, vegetables, grains or fish; animal excreta or carcasses of animals; rubbish including wood, leaves, vegetation, tree trimmings, dead trees and shrubs, branches, sawdust, shavings, grass, paper products, straw, rags, clothing and all other combustibles; waste matter composed of soil, clay, sand, earth, gravel, fill, stones, bricks, plaster, glass, glassware, crockery, ashes, cinders, shells, metal and other non-combustibles; waste debris resulting from the construction, demolition, repair, or alteration of structures or buildings; accumulated waste materials composed of cans, containers, tires, junk, vehicle parts or other substances which may become a nuisance. Condition of the selected drain can be seen in Figure 3.

Figure3Condition of the observed drain.

Selection of Parameters for Wastewater

Each sample of the collected wastewater was tested for various Physio-Chemical parameters. pH, EC, TDS, BOD, COD, and DO were analyzed to test the water quality of selected drain to understand the effectiveness of solid waste removal using bar screen. The results were compared with Department of Environment (DoE) standards.

The characteristics of wastewater and standards are showed in Table 1. From the observation, it can be said that the TDS, EC, COD and BOD of the wastewater is quite high, pH level is acidic and dissolved oxygen is substandard.

Design Parameters of Bar Screen

Bar screens may be hand cleaned or mechanically cleaned. Hand cleaned bar screens are frequently used in small sewer system. That’s why a manual bar screen was considered for this study.It should be noted that manual bar screen must not exceed the distance that can be conveniently raked by hand (approximately 10ft). The rack bars should not be less than 3/8 inch thick by 2 inch deep. They should be welded to spacing bars located at the rear face, out of the way of the tines of the rake (Metcalf and Eddy, 2003). For this study, considering every factor, a 3.3 ft long bar screen made of 0.2 inch thick and 1 inch deep flat bar was used. Characteristics of the constructed manual bar screen is shown in Table 1. Schematic diagram and experimental set-up of the bar screen considered for this study are shown in Figure 4.

Table 1 Characteristics of the considered manual bar screen.

Items	Standard for Manual Bar Screen	Considered Measurement
Bar size:		
Width, in	0.2 - 0.6	0.2
Depth, in	1.0 – 1.5	1.0
Clear spacing between bars, in	1.0 – 2.0	1.0
Slope from vertical, degree	30 - 45	45
Approach velocity, ft/s	1.0 – 2.0	1.5

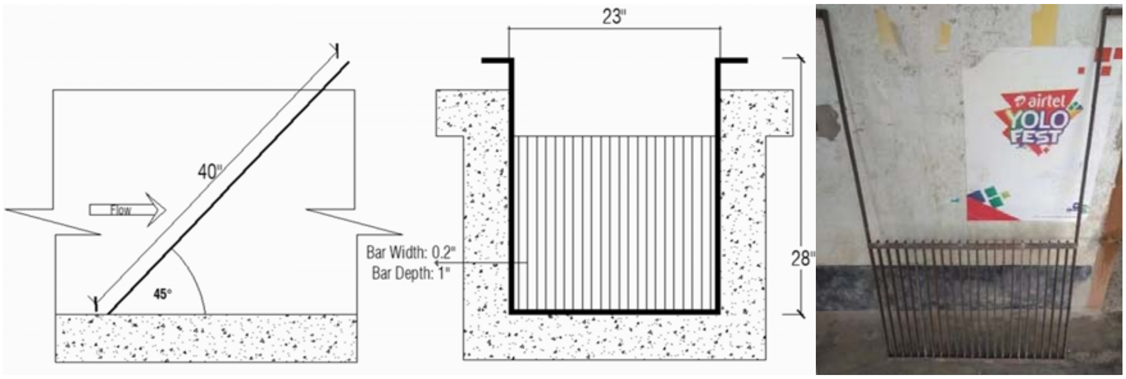

Figure 4Schematic diagram and experimental set-up of the bar screen.

Wastewater Sample Analysis

Samples were collected before installing the bar screen, 1 hour after installation of bar screen and then 4 more times with 6 hours interval.Figure 5 shows the condition of the drain at different times when samples were collected.Collected samples were transported to the environmental engineering lab of Khulna University of Engineering & Technology, where the characteristics of the wastewater were observed.Dissolved oxygen (DO), Electrical Conductivity (EC), and pH were monitored with differentelectrochemical probes. Chemical Oxygen Demand (COD) was measured by using COD digestor and spectrophotometer.The Biochemical Oxygen Demand (BOD_5) test procedure was conducted based on DO concentration and required an accurate DO determination.Total Dissolved Solids (TDS)was calculated by evaporating the sample wastewater and weighing the solid residue. Sample preparation for chemical oxygen demand, suspended solids and total solids are shown in Figure 6 and 7.

Figure 5 Observation of the drain after 1, 12 and 24 hours of installing the bar screen.

Figure6Sample preparation for the calculation of COD.

Figure 7: Sample preparation for suspended solids and total dissolved solids.

RESULTS AND DISCUSSION

Samples of wastewater collected 6 different time within 24 hours from the selected drain and were analyzed for parameters including pH, EC, TDS, BOD, COD, and DO. The results of the analysis of these physical and chemical parameters are shown in Tables 2-6.

Table 2 Results of Physio-chemical parameters of wastewater of the drain after 1 hour of installing the bar screen and its comparison with DoE standard.

Parameter	Unit	DoE Standard	Sewage Without bar screen	Bar screen treated sewage	Sewage at bar screen where waste retained
pH	-	6-9	5.95	6.22	6.08
DO	mg/L	4.5-8	4.9	5.2	4.7
BOD_5	mg/L	250	170.19	112.78	181.70
COD	mg/L	400	395.16	235.56	403.39
EC	µS/cm	1200	795	685	835
TDS	mg/L	2100	1100	800	1190

Table 3Results of Physio-chemical parameters of wastewater of the drain after 6 hours of installing the bar screen and its comparison with DoE standard.

Parameter	Unit	DoE Standard	Sewage Without bar screen	Bar screen treated sewage	Sewage at bar screen where waste retained
pH	-	6-9	5.95	6.20	5.9
DO	mg/L	4.5-8	4.9	5.1	4.5
BOD_5	mg/L	250	170.19	133.15	219.04
COD	mg/L	400	395.16	316.39	478.02
EC	µS/cm	1200	795	639	878
TDS	mg/L	2100	1100	820	1380

Table 4 Results of Physio-chemical parameters of wastewater of the drain after 12hours of installing the bar screen and its comparison with DoE standard.

Parameter	Unit	DoE Standard	Sewage Without bar screen	Bar screen treated sewage	Sewage at bar screen where waste retained
pH	-	6-9	5.95	6.21	5.9
DO	mg/L	4.5-8	4.9	5	4.4
BOD_5	mg/L	250	170.19	135.20	230.38
COD	mg/L	400	395.16	326.56	571.95
EC	µS/cm	1200	795	647	953
TDS	mg/L	2100	1100	830	1450

Table 5 Results of Physio-chemical parameters of wastewater of the drain after 18 hours of installing the bar screen and its comparison with DoE standard.

Parameter	Unit	DoE Standard	Sewage Without bar screen	Bar screen treated sewage	Sewage at bar screen where waste retained
pH	-	6-9	5.95	6.07	5.4
DO	mg/L	4.5-8	4.9	4.7	4.4
BOD_5	mg/L	250	170.19	140.78	245.39
COD	mg/L	400	395.16	341.20	611.48
EC	µS/cm	1200	795	701	1037
TDS	mg/L	2100	1100	890	1500

Table 6. Results of Physio-chemical parameters of wastewater of the drain after 24 hours of installing the bar screen and its comparison with DoE standard.

Parameter	Unit	DoE Standard	Sewage Without bar screen	Bar screen treated sewage	Sewage at bar screen where waste retained
pH	-	6-9	5.95	6.10	5.35
DO	mg/L	4.5-8	4.9	4.8	4.2
BOD_5	mg/L	250	170.19	154.86	298.27
COD	mg/L	400	395.16	349.71	642.53
EC	µS/cm	1200	795	756	1280
TDS	mg/L	2100	1100	940	1670

Table 2-6 shows that the physio-chemical parameters were substandard without bar screen when comparing with the DoE standard, and bar screen treated sewage showed good improvement. In general, the performance of the test bar screen system is satisfactory with high removal efficiencies for organic matter, suspended solids, BOD and COD with slight DO and pH levels improvements.

Performance of Tested Manual Bar Screen

Figure 8and 9 represent the variations of BOD_5 andCOD between the sewage before the installation of bar screen and bar screen treated sewage. Subsequently, Figure 10 and 11representthe variation of EC and TDS between the sewage before the installation of bar screen and bar screen treated sewage.

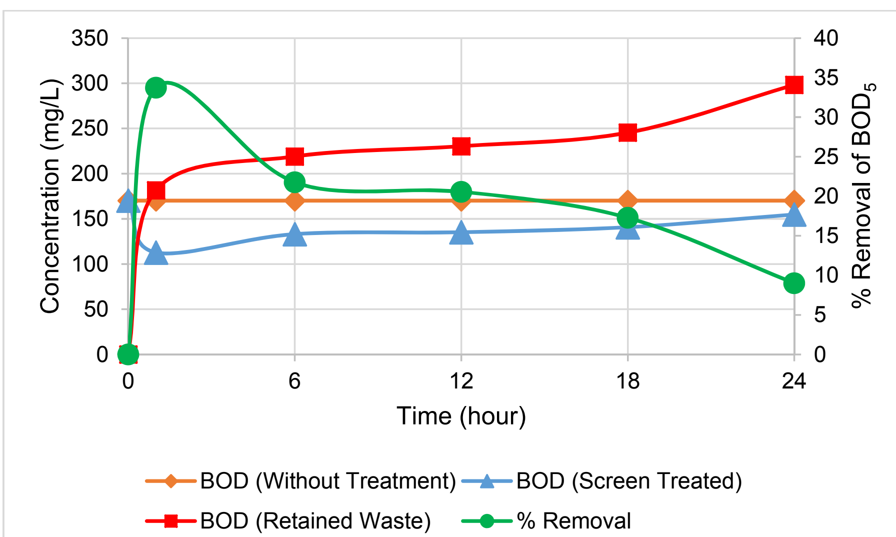

Figure 8 Variations of BOD_5 of the drain within 24 hours of installing the bar screen.

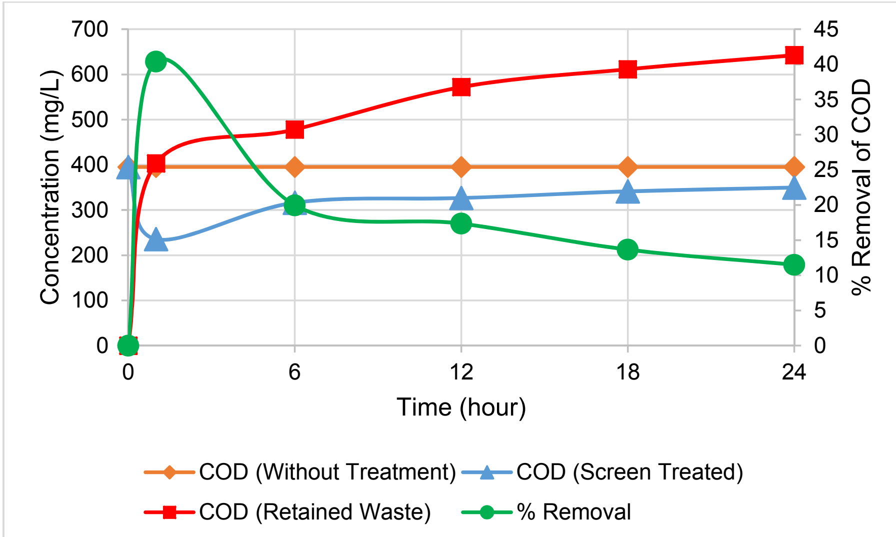

Figure 9Variations of COD of the drain within 24 hours of installing the bar screen.

Observation of Figure 8 and 9 show that, at first hour or just at the time of installing bar screen, the BOD_5 was 170.19 mg/L and COD was about 395.16 mg/L. The BOD_5 level of the treated sewage becomes 112.78 mg/L, and the COD level becomes 235.56 mg/L after 1 hour, which occurred due to decreased number of solid waste and organic matter in the treated sewage. With the time passes, solid waste and organic matter was continuously retained by the bar screen, hence the BOD_5 and COD level of the treated sewage decreases; subsequently BOD_5 and COD level of the sewage where the waste was retained at the bar screen increases. The BOD_5 level of the treated sewage becomes 133.15 mg/L after 6 hours, 135.20 mg/L after 12 hours, 140.78 mg/L after 18 hours and 154.86 mg/L after 24 hours. Subsequently the COD level of the treated sewage becomes 316.39 mg/L after 6 hours, 326.56 mg/L after 12 hours, 341.20 mg/L after 18 hours and 349.71 mg/L after 24 hours.The result shows the gradually increasing level of BOD_5 and COD of the treated sewage especially after 12 hours, which indicates the effectiveness of the bar screen at first 12 hours and the decreasing efficiency of the screen at later hours which occurred due to huge amount of retained solid waste and organic matter at the screen.

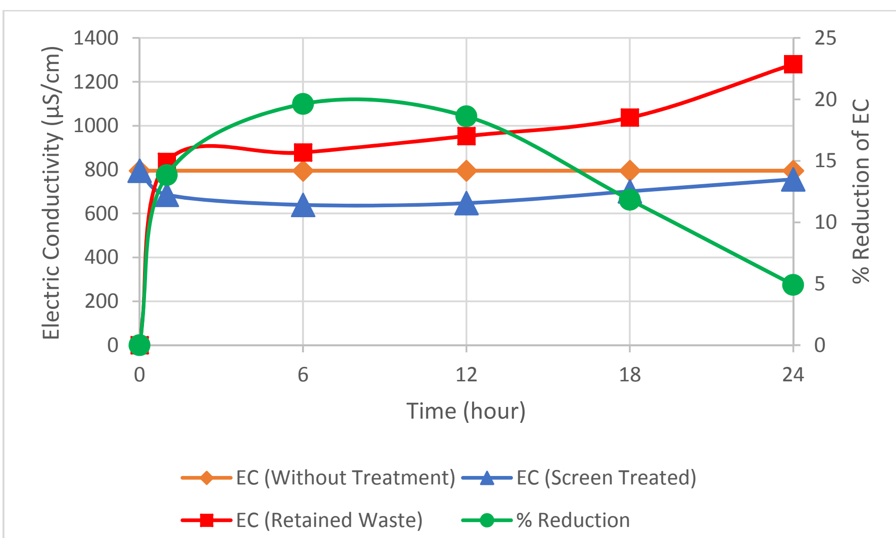

Figure 10 Variations of Electrical Conductivity of the drain within 24 hours of installing the bar screen.

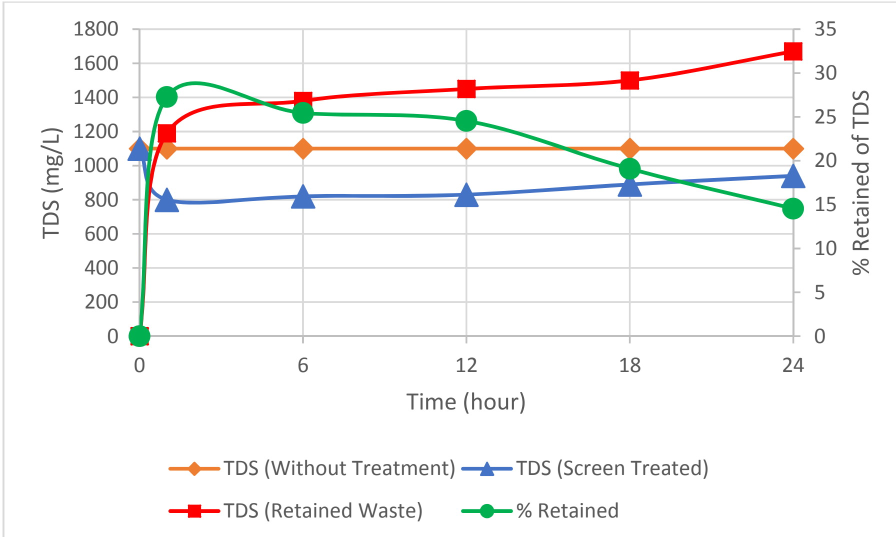

Figure 11 Variations of Total Dissolved Solids of the drain within 24 hours of installing the bar screen.

EC is the capacity of water to conduct current, which is caused by the presence of salts, acids and bases, called electrolytes, capable of producing cations and anions (Goel, 2006). Conductivity is an early indicator of change in a water system. Conductivityand TDS have strong correlation.According to Figure 10 and 11, the EC was 795 µS/cm and TDS was about 1100mg/L at the beginning. After 1 hour, the EC level of the treated sewage reduced to685µS/cm, and the TDS level becomes 800mg/L, which occurred due to decreased number of solid wastes in the treated sewage. As the time passes, solid waste was continuously retained by the bar screen, hence the reduction of EC and TDS level of the treated sewage; subsequently EC and TDS level of the sewage where waste retained at the bar screen increased. The EC level of the treated sewage becomes 639µS/cm after 6 hours, 647µS/cm after 12 hours, 701µS/cm after 18 hours and 756µS/cm after 24 hours. Subsequently the TDS level of the treated sewage becomes 820 mg/L after 6 hours, 830 mg/L after 12 hours, 890 mg/L after 18 hours and 940 mg/L after 24 hours. One of the main sources for TDS of the observed drain is solid waste and that's why their levels were high before the treatment and was highest where the solid waste was retained by the bar screen. The result shows the gradually increasing level of EC and TDS of the treated sewage especially after 12 hours, which indicates the effectiveness of the bar screen at first 12 hours.From the graph, it is observed that the rate of the removal of EC and TDS decrease after 12 hours and the removal rate continued to decrease gradually after that. This indicates the importance of manual cleaning every 12 hours for better result.

Based on the report conducted by UK Mridha in 2011, about 11.75 million liters/day effluent is discharged through 47 canals and sewers from Khulna City area to the nearby streams.Installing bar screen canimprove the BOD and COD level of the sewage by about 20% and reduce the TDS by about 25%, if the screen is cleaned every 12 hours. If it is possible to install bar screen on all 47 outfalls, quality of 11.75 million liter/day of sewage can be improved in the same way. This can greatly benefit the water quality of the streams of Khulna city.

CONCLUSIONS

The main purpose of drains should be collectingmunicipal effluents. But due to lack of awareness, the drains of Khulna city are now used to collect solid wastes of diverse nature. This can be remedied by screening out the solid wastes from sewage by bar screens. The result of this studyshows that detainment of solid wastes by the bar screen exhibited an important potential to reduce COD, BOD_5,EC and TDS. Thus, it provides strong evidence that the drains of Khulna City area can be greatly benefitted by installing bar screen in every major outfall. Therefore, there is an urgent need to take essential steps to install bar screen and remove solid waste before discharging sewage into the waterbodies. So that pollution load can be minimized, natural waterbodies can be preserved and the water can be used for beneficial purposes very efficiently.

RECOMMENDATIONS

Study on the surface and subsurface runoff and effect of climate change on the drainage system will be helpful for better understanding of the situation.A detailed study can be conducted on implementation of the mechanically cleaned bar screen in the Khulna city as well.

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ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

Proceedings of the Waste Safe 2019 – 6th International Conference on Solid Waste Management in South Asian Countries
23-24 February 2019, Khulna, Bangladesh

Community Participation As a Tool For Improving Solid Waste Management: A Case Study On Savar Municipality, Dhaka

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***Key words**: Community Participation, Savar Municipality, Solid waste management, Public Services, Community Empowerment.*

Executive Summary

In the introductory chapter that has a general introduction to explain the importance of the issue and its relevance. It contains background of the study and introduction to the problem, objectives, rationale of the study, scope and limitations of the study and organization of the dissertation. It also presents conceptual framework, theoretical perspective and literature review for the research. It also discussed about the current practice of community participation at municipality level in some developing countries of Asia for the better understanding of the practical-aspect. Then it is consists of methodology which is the base of any research work. The methodology possesses three sub-components, namely - study procedure, survey procedure, analytical procedure. Based on these three paramount components the design of the research will developed which includes numerous micro components like selection of topic and study area, development of goals and objectives, analysis of objectives and operational requirements, reconnaissance survey, enlisting of expected data and relevant sources, selection of sampling technique and sampling size, preparation of questionnaire, primary data collection, secondary data collection, processing of the data, data interpretation and analysis, formulation of sustainable scheme. Indeed, this design of research work provides a systemic view of the overall procedure of the research work. In description of the study area, It describes the study area with focusing on demographic and geographic data, socio-economic condition of the study area. This paper also consists of current practices, problems, constraints and potentialities of community participation at municipality. With the help of few case studies in selected areas of Savar Paurashava this chapter compares the presumed result of the regulations and the ground reality. It also assesses the implication of existing regulations on the solid waste management system. It presents major findings from the study regarding to community participation as a tool for improving solid waste management at Savar Paurashava. This paper proposes improving mechanism for community participation as a tool for improving solid waste management system of Savar Paurashava and recommends policies for development upgrade mechanism and provides conclusions of the research.

ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

ABSTRACT

Community participation is frequently identified by the involvement of people in projects to solve their own problems and develop a sense of ownership with the projects. This article explores how well community participation explains variations in the performance of solid waste management projects in Savar municipality. Case studies of solid waste management in savar, reveal a variety of activities that we categorize into four forms of community participation: mobilizing, decision making, construction and maintenance. Mobilizing and Decision Making are associated with performance in the cases we examined. Our results suggest that participation form as well as community influence are important in providing public services like solid waste management. The hypothesis that increased community empowerment performance is a generalization for solid waste management in savar municipality.

INTRODUCTION

Community partiicpation is a process through which stakeholders influence and share control over development initiatives and the decisions and resources which affect them (World Bank, 1994). Community Participation is a function of information through which people can come to share a development vision, make choices, and manage activities (Williams, 1992) . Public participation can be defined as a continuous, two way communication process which involves promoting full public understanding of the processes and mechanisms through which environmental problems and needs are investigated and solved by the responsible agency; keeping the public fully informed about the status and progress of studies and implications of project, plan, program or policy formulation and evaluation activities and actively soliciting from all concerned citizens, their opinions and their perceptions of objectives and needs and alternative development or management strategies and any other information and assistance relative to the decision (Canter, 1996).

In Savar, Solid waste management systems running, by the participation of the community. They were putting the garbage at the street in a proper way at the right time. At the individual level, residents are responsible as users. This involves actions like storing waste in a proper way in a bag or bin, separate recyclable or organic materials from other waste, offering waste at the right place at the proper time for collection, and cleaning the area around the house. Apart from individual responsibility, people can be collectively responsible in more or less organised activities, like meetings, clean-up campaigns, and awareness-raising activities. Therefore, community participation in savar area may involve making material, financial or physical contributions to activities of solid waste management, for instance working as cart operator or sweeper, and paying fees for waste collection. A step further is actively participating in formulating the project, meaning participation in meetings and expressing opinions and ideas about the objectives and activities of the project, and closely following the project and its progress. The highest level of community participation is community management and this may entail becoming a member of committees, being involved in controlling the project, being accountable to other community members about decisions taken. Often community management is carried out by a smaller group within the community, through for example a newly established committee or an existing community-based organization.

This study is based on two objectives which are to examine the existing level and mechanism of participation of Paurashava citizens in providing and improving solid waste management services in the study area and to evaluate the effectiveness of existing citizen's participation and to recommend ways to improve it, if necessary.

METHODOLOGY

The reasons behind the selection of the paurashava as the study area are:

- This paurashavas are of similar type (class-I);
- Secondary data of this paurashava is available;
- This paurashava is providing solid waste management system by community involvement sand
- As the distance between these two paurashavas is small, primary data collection has been easier.

For the purpose of attaining the objectives of the study, three different indicators for solid waste management service has been selected.

- Waste collection
- Waste bins and;
- Waste disposal

The respondent has been chosen randomly from each household. For the purpose of holding selection, the steps shown below have been performed:

- At first, the list of holdings of the ward was collected from each paurashava and listed with a sequential serial number.
- Then, total holdings N divided by the sample size n gives the sample interval k
- One holding was selected randomly. Suppose it is M.
- Then the sample was selected on the basis of holdings bearing the numbers M, M+k, M+2k, ……, M+(n-1)k.

Data have been collected from primary as well as secondary sources. Primary data have been collected from a questionnaire survey as well as key informants (paurashava personnel, staffs of different projects etc.) interviews.

Data for indicators have been collected through a questionnaire survey of individuals from randomly selected households from a sample of holdings in Savar paurashava. Secondary data were collected from the Paurashava offices, LGED as well as different books, reports and journals.

After collecting necessary data from the survey of individuals and key informants as well as secondary sources, all have been assembled and processed for the next phase.

In the process of analysis for the present study, a comparison of different parameters of solid waste management facilities for Savar paurashavas was established. Some computer software such as SPSS, Microsoft Excel etc. were needed to accomplish the analysis phase and GIS software has been used for the preparation the study area maps and services facilities maps.

STUDY AREA PROFILE

Savar municipality covers the northwest side of Dhaka Metropolitan City. It lies between 23.44° to 24.02° north latitude and 90.11° to 90.22° east longitude. Municipal area is bounded with four rivers- Turag on the east and east west, Dhalesswari and Bangshi on the west and Buriganga on the south. Only the northern side is without any river. So actual boundary of Savar paurashava is:

- At North- Ghoradia, Deogaon, MollikerTek, Modonpur,
- At South- Karnapara
- At East- DhoendaMouza, Bonga Union
- At West - Bonshi River

ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

Climate of Savar is relatively mild in nature. The main features of the climate of this area are incessant rain in the rainy season and high temperature in the summer. More rain occurs between June and September. October to January is the low rain period. Rate of annual rainfall is 80 inches to 90 inches and temperature remains within 50º F. to 95º F (Savar MIDP, 2008).

Madhupur tract area is known to be raised during plasticine area. Due to the scorching sun calcium carbonate ($CaCO3$) is created by oxidization and by the color of soil turns into red. High lands are of alluvial or loamy soil and low lands are of sandy or loamy. But areas on the south of the Paurashava are mostly of alluvial plain.

Savar Paurashava is a residential area. But the most land use of the area is mixed. Mixed land use comprises residential, commercial, industrial, agricultural and institutional land use, open space, water bodies and road network. The mixing type of these land use is seen almost all over the study area. The study area consists of 9 wards and their land use is totally different from each other. The total area of Savar Paurashava is16.67 square kilometers of which 54.85% is residential, 4.56% is commercial, 2.08% industrial, 24.55% is agricultural, 2.93% is institutional, 0.67% road network and others is 10.36% e.g. open space and water bodies (LGED, 2006).

Majidpur, Bank Colony, Bank Town, Karnapara, Rajashan, etc. are the core residential areas of the Paurashava. Both sides of the Dhaka-Aricha Highway, Wapda Road, etc. are used for commercial and industrial purposes. Institutions are established in scattered manner. Commercial establishments and residential buildings are located adjacently in an area. A good number of educational institutions are situated in the ward no. 4. So it can be said that, land use of Savar Paurashava is more or less mixed land use, because there has been no specific land use plan or zoning regulations for the Paurashava (Savar MIDP, 2008).

At present the total population of the Savar Paurashava is 1, 40,300 (BBS, 2001). According to the census report of 1991, this number was 1, 14,200. According to the LGED Population Growth Project, this number of population will increase day by day because of increasing rural urban migration, natural increasing trend, etc. Savar Paurashava projected its population 170536 in 2005 (before the year 2005). In 2011, estimated population of Savar Paurashava will be near about 2 lakhs and it will be more than 4 lakhs in 2021. According to the Census Report 2001, the population density of the Paurashava is about 1000 per sq. km or 40 people per acre. In the central area of the Paurashava this figure is about 1800 per sq. km.

The quantity of solid waste generation is 25 tons/day of which 15 tons (LGED, 2005) are collected and disposed of to the uncontrolled dumping site. At present the Paurashava has 2 garbage truck, 20 rickshaw vans, 40 waste bins and one dumping site at Genda (uncontrolled land fill). There is a provision to collect garbage from the waste bins, every morning by the garbage trucks and rickshaws.

Coverage of Paurashava services in solid waste disposal is 60% for the residential and 50% for the commercial users. Number of households served total is 5000. Recently the Paurashava authorities is planning to arrange 7 new dumping trucks, 16 new rickshaw vans, 9 transfer stations, 42 additional staff, and 50 waste bins, which will cover 90% residential and 65% commercial services in solid waste disposal (Masud, 2013) (MIDP, 2008).

Savar Paurashava mainly consists of 9 wards. Among them ward no three and ward no eight practiced community participation for improving solid waste management system in Savar.

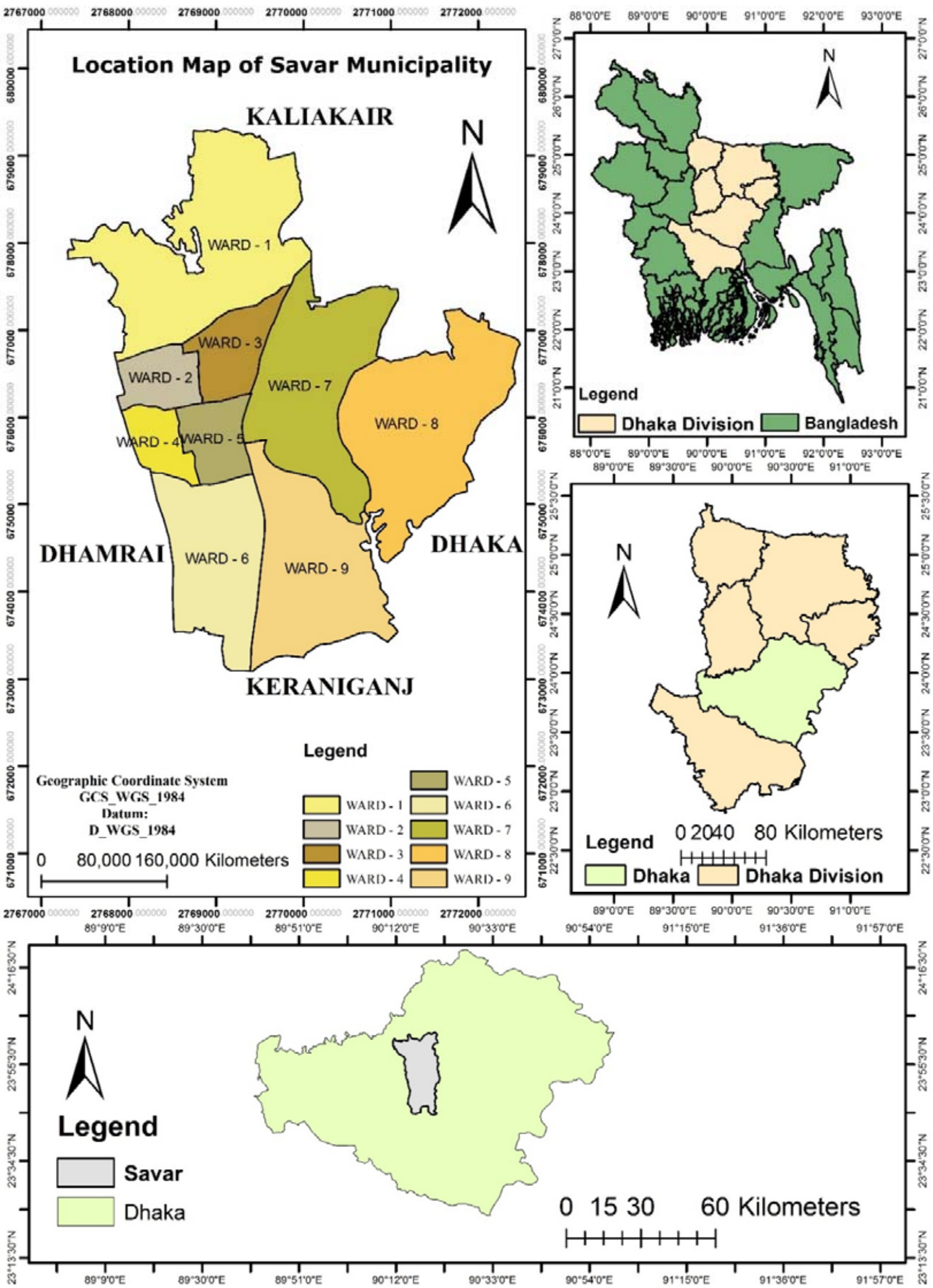

Figure 1: Location Map of Savar Municipality

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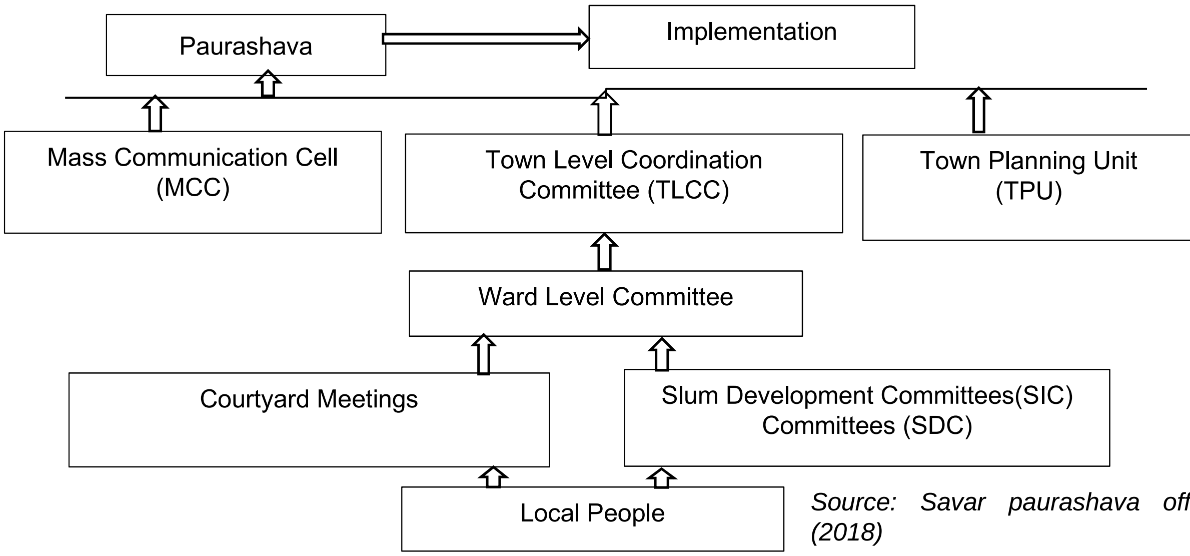
WAY OF PARTICIPATION FOR SOLID WASTE MANAGEMENT

Savar paurashava incorporate people in different service providing activities through different committees.



Source: Savar paurashava office (2018)

Figure 2: Relationship of different committees of Savar paurashava

There are three committees in Savar paurashava namely Mass Communication Cell, Town Level Co-ordination Committee (TLCC), Town Planning Unit (TPU). The main objectives of these committees are to gather opinion of people related to service facilities as well as arrange different kinds of awareness building program. Under Town Level Co-ordination Committee (TLCC) there are nine Ward committees that arrange different courtyard meetings at these nine Wards. Besides, Slum Development Committees (SDC) gather opinion from slum areas that are finally presented to TLCC through WC.

According to UGIAP, the Savar Paurashava has to arrange courtyard meeting quarterly at every Ward. The participants of these meetings should mainly the poor women of that area. But, in practice the situation is different. The courtyard meetings are not arranged regularly. Though, the female ward commissioners are responsible to arrange the courtyard meetings quarterly and submit the minutes of the meetings to the monitoring authority, but they submit the minutes of more than one meetings by arranging a single meeting. Sometimes the female ward commissioners use these meetings as their post-election showdown. For these reasons, the paurashava authority cannot gather the authentic information from poor people by courtyard meetings.

In ward committee, respective ward commissioner is the chairperson and the female ward commissioner is co-chairperson. Sometimes due to personal conflict and lack of coordination between them, the meeting does not hold in every quarter. They both do not want to take the responsibility of arranging the meeting. Some ward commissioner does not participate in ward committee meeting because they think that different issues must be discussed in the meeting and the Paurashava will not be able to solve all the problems and in result the citizen will not vote to that ward commissioner in the next election. The total ward committee member of Savar paurashava is 90.

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Savar Paurashava arrange TLCC meeting in every quarter. But in most cases, among 50 members around 10 to 20 members attend in the meeting. Though all members do not attend the meeting but some effective issues are discussed and the issues are being implemented.

Forms of people's participation means to what extent and how the people are being involved in different kinds of development activities that are implemented by the paurashavas. In Savar paurashava among nine wards participatory approach was applied in ward no. three and eight. And other wards which is ward no. one, two, four, six and nine this approach is not applied at present. In Savar paurashava ward no three and eight are practiced participatory approach and other wards are not included in this approach. In Savar paurashava, other wards except for mobilizing residents, all forms of participation are almost absent. In other wards about 55% people are mobilized which indicate that people are conscious about participation but they do not get the opportunity of it. On the other hand, in Savar paurashava ward no. three and eight take initiative to mobilize people more than that of other wards that result 74.5 % peoples' engagement to participate in mobilizing residents.

Table 1: Percentages of responses with regard to mobilization of people

S.L. no	Forms of Participation	Other Wards		Ward 3 and 8	
		yes	no	yes	no
1	Mobilize other people	55	45	78	22
2	Attend courtyard / WC / TLCC meeting	12.5	87.5	52.3	47.7
3	Discuss about service facilities	30	70	55	45
4	Involved in awareness building program	8.5	91.5	22.5	77.5
5	Respond to questionnaire from authority	40	60	70	30

Source: Field survey (July, 2018)

Table 1 shows that more than 52.3% people of ward no. three and eight attend courtyard meeting arranged by the paurashavas to discuss different kinds of problems and their demands. Generally, these meetings are arranged in poor communities. It also shows that in these two wards, 45% of the surveyed people have experience of discussing with the paurashava authority about service facilities and the corresponding figure is 20% for other wards in Savar paurashava. The table also shows that the rates of participation in awareness building programs and responding to questionnaires by inhabitants of ward no three and eight are higher than those wards of Savar paurashava.

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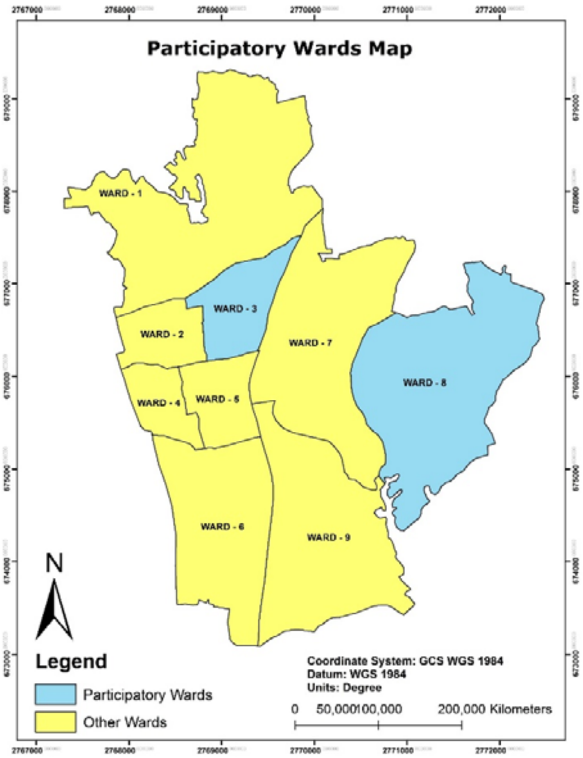


Figure 2: Participatory Wards Map of Savar Paurashava

Table 2: Percentages of responses with regard to contribution of people in construction work

S.L. no	Forms of Participation	Other Wards		Ward three and eight	
		yes	no	yes	no
1	Contribute by labor, money, property etc.	25	75	33	67
2	Construct dumping zone	79.5	20.5	88.7	11.3

Source: Field survey (July, 2018)

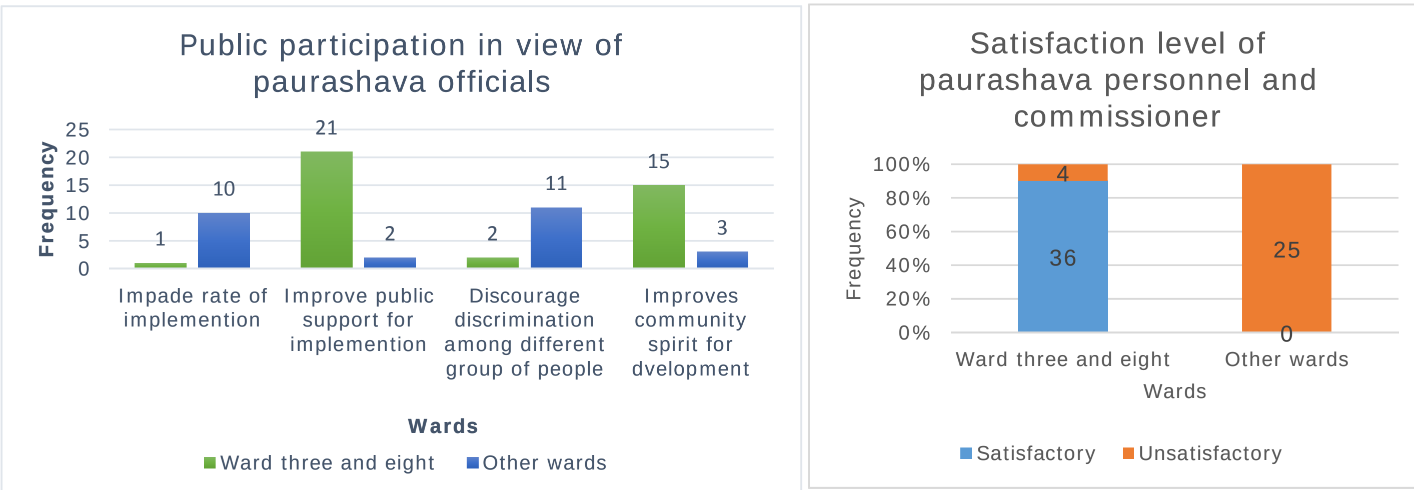
One of the main achievements of effective community participation is to encourage people to contribute something for the betterment of the project. These contributions may take different forms such as donations of money, portions of property, labor, monitoring the project etc. From these points of view, the people of ward no three and eight in Savar paurashava are more advanced than the people of other wards in Savar paurashava. Table 2 shows that 33% people of ward three and eight of Savar paurashava have contributed or are willing to contribute these sorts of help and other wards the figure is 22.0%. The table also explains that more than 88.7% people of Savar paurashava ward three and eight have constructed their road and drain to improve the quality of service facility and in other wards the figure is below 80%.

Table 3: Percentages of responses with regard to participation of people in maintenance work

S.L. no	Form of Participation	Other Wards		Ward three and eight	
		yes	no	yes	no
1	Participation in management work	21	79	47.5	52.5

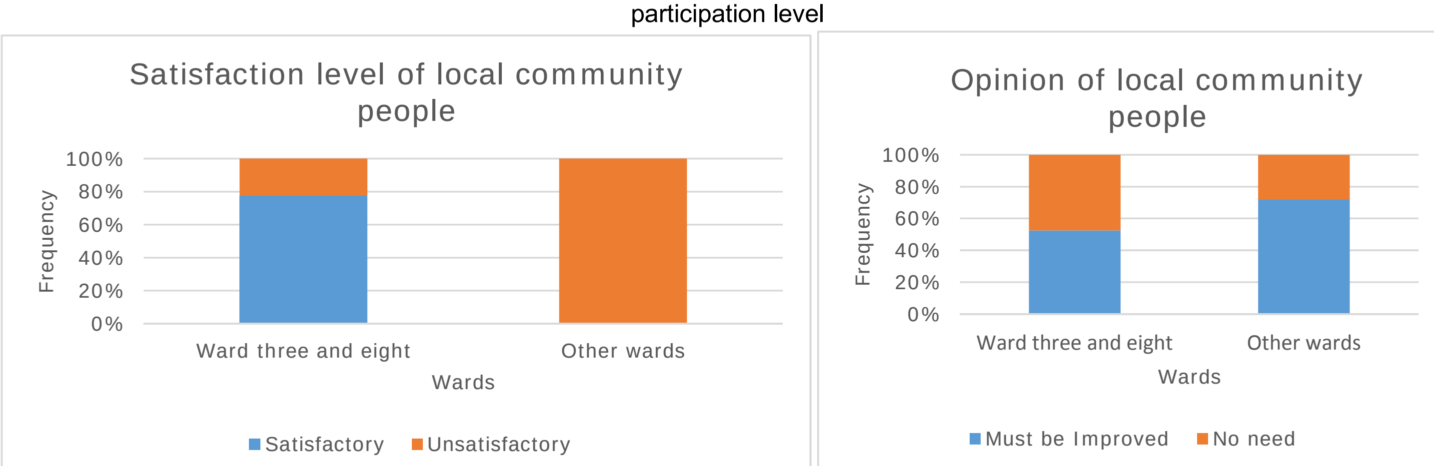
Source: Field survey (July, 2018)

Proper maintenance of services is very much needed for their sustainability. Generally, it is very difficult for any authority to repair all sorts of damages immediately. In this circumstance, the local people can be involved to maintain the services for minor problems. If a participatory approach is followed during provision of service people are motivated to take these responsibilities. Table 3 demonstrates that the people of Savar Paurashava ward number three and eight (47.5.5%) are more conscious about maintenance of services by their own effort than that of other wards people of Savar Paurashava (52.5%).



Source: Field survey (July, 2018)

Figure 3: Opinion and Satisfaction level of paurashava personnel and commissioners about present participation level



Source: Field survey (July, 2018)

Figure 4: Satisfaction level and Comments of community people about present participation level

Figure 3 shows that in Savar paurashava, 90% respondents of ward no. three and eight are satisfied and the rest are not satisfied. On the other hand, in other wards of Savar paurashava, almost every respondent is dissatisfied about present participation level. In response, 95% (Figure 3) respondents of other wards in Savar paurashava suggested to improve it. On the other hand, 65% respondents of ward no. three and eight in Savar paurashava gave opinion in support of improving it and 35% (Figure 3) respondents did not feel about the necessity of people's participation. Figure 4 shows that in other wards people of Savar paurashava, almost every people are dissatisfied. On the other hand, in Participatory wards of Savar paurashava, 75% people are satisfied and only 25% are not satisfied. In response, 70% (Figure 4) people of other wards in Savar paurashava suggested to improve it. On the other hand, 55% respondents of ward no. three and eight in Savar paurashava gave opinion in support of improving it and 45% (Figure 4) people did not feel about the necessity of people's participation.

PEOPLES OPINION ABOUT SOLID WASTE MANAGEMENT

The scores of each of three indicators under solid waste management service facilities were summed up for participated and non-participated wards in Savar paurashavas separately. Then the score of each indicator was added to achieve the total score. Next, the total score was divided by the maximum possible score of 3000 for each service and multiplied by hundred to get the satisfaction score scaled to a range of 0-100. Finally, the satisfaction score was measured to the level of very poor, poor, fair, good and very good according to TUGI Index.

Table 4: Score of solid waste service of Savar paurashava

Wards	Frequency	Score				Maximum Possible Score	Satisfaction Score
		Waste Collection	Waste Bins	Waste Disposal	Total		
Other Wards	200	459	355	395	1209	3000	40.3
Ward no three and eight	200	664	601	660	1925	3000	64.17

Source: Field survey (July, 2018)

Table 4 presents all the three indicators of solid waste facilities which in participated Wards in Savar Paurashava bear higher score than those of non-participated wards in Savar paurashava. It is clear from the table that regularity in waste collection and disposal is as require as adequate numbers of dustbins to improve this service. The respondent of Ward no three and eight in Savar paurashava reported 156 higher score to dustbin facilities than that of other wards. But the score of waste disposal in participated wards in Savar paurashava is almost 265 higher than other wards. It indicates that it is possible to satisfy people with solid waste services by limited number of dustbins if coordination between paurashava authority and paurashava people can be ensured. Eventually the table shows the total score of satisfaction level with solid waste management system of Savar paurashavas which is 64.17 in participated wards and 40.30 in other wards. It indicates that the inhabitants of participated wards is more satisfied with the present system of providing service compared with non-participated wards.

Table 5: Satisfaction score and level of Savar paurashavas at a glance

S.L. no	Indicators	Other Wards		Ward no three and eight	
		Satisfaction score	Satisfaction level	Satisfaction score	Satisfaction level
1	Solid waste Management	40.3	Poor	64.17	Fair

Source: Field survey (July, 2018)

Table 5 shows that in participated wards satisfaction level is fair and non-participated wards satisfaction level is poor. Because of community participation satisfaction level in participated wards in Savar Paurashava is better than other wards in Savar Paurashava. Satisfaction level is providing according to TUGI index.

RECMMENDATION AND CONCLUSION

- Increasing more participatory technique in Savar paurashava
- Both men and women should be invited to the Courtyard meetings as well as Gender and Environment committee
- Monitoring solid waste management of the activities of these committees should be increased.
- To ensure more effective participation the paurashava authority should formulate ward level committee with the coordination with other govt. agency or private agency.
- Community approval should be displayed in the paurashava ground and the authority must preserve the right in favor of citizens to make query about any service provision activities.

Moreover, after distinguishing among different forms of people's participation, it is found that not all forms of participation are equally practiced in delivering service facilities in the Savar paurashavas. It is also found that people's involvement for providing and improving solid waste management service facility is treating as an optional activity. Paurashavas are generally controlled by Pourashava Ordinance 1977. So if people's participation is included in the ordinance and makes the participatory approach as a mandatory task, it is expected that the solid waste management service facility would be improved in Savar paurashava area.

ACKNOWLDGEMENT

I express my profound gratitude and indebtedness to our course teacher Mr. Rashedul Hasan Udoy, Assistant Professor, Department of Urban and Regional Planning (URP), Chittagong University of Engineering and Technology for his cordial encouragement, constant guidance, inspiration and valuable suggestion to prepare this works.

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Savar MIDP (Municipal Infrastructure Development Plan)

ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

AN ANALYSIS ON SOLID WASTE MANAGEMENT IN RESIDENTIAL AREAS OF CHITTAGONG CITY CORPORATION, BANGLADESH

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ABSTRACT

Generation of solid waste (SW) is a major problem in urban areas and its management is obligatory functions for both urban local authority and the urban people. The waste collection and disposal does not contend with the amount of waste generated per day as a result garbage are scattered. This study was conducted at three residential Areas named Shanonda, Panchlaish and Chandgaon under Chittagong City Corporation (CCC). Several methods were used to conduct this study including questionnaires, interviews and direct observations. The study involved a questionnaire and encompassed 240 households from three different socio-economic groups (SGs): middle (MSG), upper middle (UMSG) and high (HSG). The households solid waste (HSW) comprised of several categories of wastes like paper, packs, cans, glass, plastics, food, vegetables, bones, textiles, wood etc. The waste generation rate of the study areas is calculated through the study. The existing solid waste management system also observed of the residential areas. The study also revealed several shortcomings in connection with the solid waste managements in the residential areas including low quality, inadequate storage and transportation facilities, an informal dump site, insufficient collection frequency of solid waste, low level of awareness and education of solid waste management and lack of enforcement of regulations by law enforcement. Finally, the research suggests some appropriate recommendations on how a participatory sustainable residential solid waste management system could be developed in the residential areas of CCC to achieve its goals.

Keywords: Solid waste; generation; composition; households solid waste; solid waste management

INTRODUCTION

The rate of generation of solid waste is increasing proportionately with urban growth. The situation is very worse in Chittagong city as the urbanization rate is very high here because of rural migration. Municipal solid waste (MSW) management systems are becoming more complex in many countries with movement from landfill-base systems to resource-recovery-based solutions (Abu-Qdais, 2007) . About 1550 tons solid wastes are generated daily in the Chittagong Urban areas (Berkun, Aras, & Nemlioglu, 2005). The solid waste (HSW) generation rate in household is very much higher compared with the industries and health sectors waste generation (Rahman, Dewan, & Islam, 2001). The amount of domestic wastes is about 80% of total wastes that generated in major cities (Pongrácz, 2009).land pollution, water pollution and air pollution is happened because of the disposal of solid waste of openly dumped, dumped to low laying lands, and burning of wastes respectively. Improper solid waste management in Chittagong city causes the problems of negative impact on human health and animal health which ultimately causes economic, biological and environmental losses (Berkun, Aras, & Nemlioglu, 2005).
The target of the study is to find out the existing Solid waste management condition in residential areas of Chittagong City Corporation by analyzing three major residential areas named Sanonda, Panchlaish and Chandgaon Residential Area and suggest some remedial measures to improve the condition

.

METHODOLOGY

For the study, at first, municipal solid waste related records and documents of CCC are assessed. After that field survey and questionnaire survey was done for identifying the socioeconomic status and solid waste generation scenario of the study areas. The questionnaire also contained especially with the information of sources and sub-sources waste generated, information of physical composition and information about quantity and quality of solid waste (SW).

For the study, total 240 households were selected of the three residential areas by using the random sampling method. Then the information of the households were collected through the secondary data and the prepared questionnaire survey sheet. After analyzing the information at last some remedial recommendation were proposed.

Study Area Profile

Chittagong City Corporation is located between 22°13' and 22°30' north latitudes and between 91°40' and 91°55' east longitudes along the southeast coast of Bangladesh. It is bounded by the Karnaphuli River with the Halda River to the south and east, by the Bay of Bengal to the west and by a range of hills to the north. It is geographically hilly region and the topography is unique currently, the city holds 20, 68,082 people with 178 sq. km., making it the second largest metropolitan city in the country (BBS, 2011)

Among the residential areas of Chittagong City Corporation area, Sunonda, Panchlaish and Chandgaon are regarded as major residential areas based on their population density. They are located under Panchlaish and Chandgaon thana respectively. More than 2,50,000 people are living in these areas. Among them 40,000 inhabitants are in the residential areas. Among them 59.39% are male and 40.61% are female. (BBS, 2011)

Data collection

The waste management facilities of three residential areas of Chittagong City Corporation is presented in the table below:

Table 01: Waste management facilities

Sl no	Particulars	Quantity
1	Dust-bin number	129
2	Amount of Solid Waste	271 ton/day
3	Number of Waste Transport Vehicle	6
4	Schedule time for waste disposal	6 am – 8am
5	Vehicle type	truck and van
6	Number of crew	138
7	Total Houses	180 nos.
8	Total inhabitants	About 40000 nos.
9	Total population of thanas	2,50,000
10	Container number	6 no
11	Rate of Waste Generation	1.084 kg/Cap/Day

The above table describes the waste management facilities in the residential areas of Chittagong City Corporation. There are 129 dustbins in the three residential areas. There are only 6 carrying vehicles for the carrying of wastes and 138 crews are involved in the waste management system of the area. The rate of waste generation rate is 0.684 kg/Cap/Day.

The questionnaire also carried the information about the socio-economic group of the areas, given to the below table:

Table 02: Socioeconomic groups of the households on basis of monthly income

SL.	Socio-economic group	Monthly income	Number of House studied	Number of studied person
1	HSG (High Socioeconomic Group	More than Tk. 50,000	67	210
2	UMSG (Upper Middle Socioeconomic Group)	between 20,000 Tk. to. 50,000 Tk.	96	375
3	MSG (Middle Socioeconomic Group)	between 10,000 Tk. to 20,000 tk	77	336

The table shows that most of the people living in these residential areas are lying in between the middleclass and upper middleclass group.

Table 03: Residential Waste Generation Rate (RWGR)

Socio-economic group	Number of hh studied	RWGR	Number of persons studied	RWGR
		Kg/hh/day		Kg/person/day
HSG	67	3.13	210	0.99
UMSG	96	1.79	375	0.045
MSG	77	1.14	336	0.261
Total	240	2.02	921	1.06

hh = Household; RWGR=Residential Waste Generation Rate

From the above table it is seen that people living in the higher socio-economic group generates the highest residential wastes than the others.

Fig. 01: Variation of Residential wastes Generation Rate of CCC at Residential Areas.

RESULTS AND DISCUSSIONS

Table 4: Physical Composition of RSW Generated by Different Socioeconomic Groups

			Waste Category (%)			
			Non-Compostable			Compostable

Socio-economic group	Paper	Pack	Can	Plastic	Glass	Bones	Textile	Vegetable	Wood
HSG	10	11.6	11	2.35	3.55	2.5	5	51.7	3
UMSG	7.3	8.5	6	2.6	3.2	1.5	4.3	62.3	2.7
MSG	6.4	1.45	4.38	2.82	2.85	0.42	4.6	75	3
GW per day for all SEG	7.9	7.18	7.12	2.57	3.18	1.49	5.3	63	2.9

Table 5: Comparison of Solid Wastes Physical Composition data between Residential Areas and CCC Study

Component	CCC MSWM Household (%)	Residential Areas Assessed Household (%)	CCC MSWGR Kg/Cap/Day	Generation Rate of the thana g/Cap/Day	Sanonda R/A Assessed Generation Rate Kg/Cap/Day
Paper	4.68	7.9	0.920	1.084	1.06
Pack	ND	7.18			
Can	2.65	7.12			
Plastic	8.70	2.57			
Glass	0.00	3.18			
Bones	0.63	1.49			
Textile	2.40	5.3			
Vegetable	70.50	63			
Wood	1.20	2.9			
Compostable	71.70	65.9			
Non Compostable	28.30	34.74			

DATA INTERPRETATION

- CCC RWGR of HSG 0.781 Kg/cap/day which is different from Assessed waste generation rate of the three residential areas, HSG RWGR 1.084 Kg/cap/day but average data of UMSG and MSG RWGR 0.47 Kg/cap/day almost same as CCC RWGR.
- From above analysis it is seen that CCC MSWGR is 0.92 kg/cap/day which has studied on entire Chittagong city which includes not only domestic waste but also commercial and market wastes of composition.
- Panchlaish and Chandgaon thana has a lots of academic institution and press are situated. So waste generation is higher in this areas (1.084 kg/cap/day) compared to the average city data.
- It is mentioned that assessment of our study is based on three socioeconomic level (HSG, UMSG & MSG) whereas CCC also included lower income group. It is also notice that CCC MSWM composition is not similar with Residential Areas.

CONCLUSIONS

Solid waste generation has increased proportionately with the high density of population but support for waste management is inadequate. The purpose of this study is to analyze the existing solid waste management system in Chittagong City Corporation. Moreover, it also evaluates priorities for sector reforms as well as identification of investment projects in the aforementioned urban local bodies. HSWM refers to all activities pertaining to the control, collection, transportation, processing and disposal of waste in accordance with the best principles regarding public health, economics, engineering, conservation, aesthetics and other environmental considerations. The generation of 9 category house hold wastes are paper, packaging materials, cans, plastic, textiles, glass, vegetable, bones/dirt and wood which has 65.9% wastes is compost able & 34.74% waste is no compostable. On the other hand the study also exposed that CCC is not fully capable to properly & regularly handling the wastes from the city without environmental interfere, so MWMS has to be integrate to disposal the solid waste with best practice.

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ASSESSMENT ON SMALL PLASTIC PACKET WASTE PRODUCTION RATE IN KUET CAMPUS WITH POSSIBILITIES OF FURTHER USES

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ABSTRACT

Waste management or waste disposals are all the activities and actions required to manage waste from its inception to its final disposal.Huge solid wastes like small pack wastes of shampoo, chips, tomato ketchup packets etc. are deposited everyday which are not yet recyclable for further uses. A survey in KUET campus was conducted for finding the percentage of mini pack waste produced daily. About 400 kg -600 kg solid wastes are produced in whole KUET campus daily where 200 kg-300 kg dry wastes are produced by students, staff and from academic building and residential area of KUET. About 1-10% of them are small pack wastes. After the survey it was found out that in Friday and Saturday these wastes are large in amount comparing to the other days of the week. The purpose of this survey is to find the possibilities of recycling mini pack wastes for the further uses.

Keywords:*solid wastes,small packet waste, waste generation, production rate, recycling.*

INTRODUCTION

The propagation of solid waste is increasing day by day in Bangladesh as well as in Khulna. The average solid wastes which generated in KUET campus is about 700 kg/day. Among them 1% or less mini packs wastes are generated in KUET campus everyday. Solid waste come off a significant environmental threats. Recycling of solid waste can be a helpful way to diminish environmental hazards.

This mini pack wastes are not environmentally useable because these do not easily mix with soil.According to Diamadopoluset.al.(1995) if solid wastes are not recycled, the landfills will very fast exhausted and necessitate the construction of new ones. Furthermore, this mini packs wastes jammed the sewage systems and plumbing system. So, most of wastes have to burn which produce air pollution and other

environmental pollution. Kaseva and Gupta (1996) reported that solid waste recycling reduces environmental damage and is an import-substitution economic activity.

Small packet wastes are generally is a small bag or pouch, made from paper, foil, plastic film or another type of packing material, often used to contain single-use quantities of foods or consumer goods such as ketchup or shampoo. In KUET campus, the uses of these mini pack products like chips,shampoo, ketchup, coffee etc. generated at a percentage of 1% or less than 1% of total wastes produced in KUET campus. This paper gives a concept about the producing number of mini pack wastes and different ways of reusing or further uses of these wastes.

WHAT IS MINI PACK WASTES?

Mini pack waste means, the waste of mini packet which generally contain goods like chips, ketchup, shampoo, coffee, chocolates etc. Generally mini pack waste is one kind of solid waste. It produced by the company who are providing the food items or other essential daily useable goods which are small in amount. These packets contain only a little amount of products like 5mg-200gm. Some packets contain liquid good like ketchup, shampoo etc. These items and packets transferred to waste when the goods or food are used and the packet are thrown away.

COLLECTION OF MINI PACK WASTE

An interview has been taken to the waste collectors of KUET campus, they gave information about the collection of these waste process. Generally they collect these wastes from dustbin, drain etc. Besides the also collect these waste from other area like residential area, academic building, student's hall, cafeteria, central field, road side drain etc. After collecting those wastes, all the wastes are carried in a van and carried to waste management plant for further treatment of wastes. The mini packet wastes and other packet wastes are not generally recyclable. So waste collectors burned those packets which cause air pollution.

WASTE SURVEY

A survey has also taken in the KUET campus where the amount or quantity of mini pack wastes are measured. The wastes varies with the day of the week. It seen that, Friday and Saturday generated most number of mini pack wastes. It should be for the off day of academic activities and Jumma prayer. Besides, the normal people outside KUET area come to visit campus and enjoy the beauty of the green campus of KUET. As a result, the foods which are they eaten and the packets those contain the food and other goods are also threw in to the dustbin which also one of the reason of increasing the number of waste packet in Friday and Saturday. Sometimes, the monthly feast occur at student's hall. At that day, the number of ice-cream packet, coffee, pan masala etc. food items and the packet wastes also produced a great number In different cultural program arranged by many associations of KUET, the visitors and the students produced more packet waste than normal day.

(A) Small packet wastes.

(B) Weighting the wastes.

(C) Shampoo packet wastes.	(D) Separating the packet wastes into sizes.

Figure 1: Collecting, weighting and separating the small packet wastes

Mini pack waste generation rate in campus area varies from 1.5kg/cap/day 5.5 kg/cap/day. The generation rate is higher in students' hall area, where as lower at academic area. Average waste generation rateis 3.9 kg/capita/day. On this basis, the solid waste generated in this campus is about 700 kg per day and the total min pack waste produced in a year is about 1425 kg or 1.57 ton/year. Total collections of waste from the whole campus area are given below in Table 1.

Table 1: Amount of total waste weight and mini pack waste (weight) in KUET campus.

Days	Weight (kg)					
	Department	Residential		Hall		Mini pack waste
		Wet	Dry	Wet	Dry	
Sunday	85	110	75	280	145	4.30
Monday	80	110	70	285	140	3.95
Tuesday	80	105	60	290	155	3.78
Wednesday	85	105	65	300	145	2.52
Thursday	85	110	70	282	135	4.40
Friday	95	110	70	270	140	5.18
Saturday	70	120	70	275	150	6.20

The size of mini packs varies from 35cm^2 to 300cm^2. The unit weight of each packet are calculated by measuring the packet weight in weight machine. The unit weight of these wastes varies in 1.00 mg/cm^2 to 4.5 mg/cm^2. The size of packets and their unit weight is given below in Table 2 with some examples of the products of those packets.

Table 2: Different size of mini packs with weights, unit weights & some examples according to size.

Size of products (cm)	Weight of product(gm/unit)	Unit Weight (mg/cm^2)	Examples of products
17x13	3.55	1.60	Honeycomb
15x12.5	2.65	1.41	Jhalmuri
16x5.5	1.35	1.53	Ice-Cream
24x11	4.00	1.51	Noodles(big pack)
20x7	2.45	1.02	All time bon
11x7	1.35	1.75	Biscuits
13x9.5	2.32	1.88	All time cake
10x7	1.50	2.14	Games
18x8.5	2.15	1.40	Dan cake
12x14	2.67	1.28	Noodles(small pack)
10x16	3.12	1.95	Dalmut
6.5x5	0.80	2.46	Mini pack shampoo
9x5	2.00	4.44	Tomato ketchup (mini)
8x7	1.27	2.26	Tea/Saline pack
7x5.5	0.85	2.20	Tang (mini pack)
11.5x6	1.45	2.10	Surf Excel (mini pack)
15x20	6.00	2.00	Chips
7x5.5	1.170	3.12	Pan Masala

12.5x4	1.200	2.40	Dairy milk chocolate (mini)
4x2.5	0.250	2.50	Chocolate
7x7	1.270	2.60	Coffee/Glucose
16x12	1.500	0.78	Handwash packet

The amount of waste produced in a week varies 1.9 kg to 5.3 kg. It has been found out that wastes generated are large in number at the weekend days of the weeks. The highest weight determined at Saturday. The amount of wastes produced are measured at different days of the week. The amount of the solid waste generated in different days of the weeks is given in Table 3.

Table 3: Weight of mini packs produced in a week with size

Size of products(cm)	Days						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Weight	Weight	Weight	Weight	Weight	Weight	Weight
17x13	142.00	81.65	120.70	74.55	92.30	578.65	202.35
15x12.5	185.50	365.70	323.30	10.60	673.10	162.70	185.50
16x5.5	0.00	24.30	59.40	27.00	36.45	195.75	10.80
24x11	44.00	180.00	60.00	0.00	212.00	12.00	76.00
20x7	497.35	372.40	220.50	313.60	423.65	382.20	622.30
11x7	263.25	263.25	260.55	18.90	276.75	58.05	229.50
13x9.5	113.68	27.84	160.08	97.44	204.16	164.20	122.96
10x7	34.50	31.50	60.00	19.50	88.50	15.00	69.00
18x8.5	0.00	98.90	139.75	36.55	17.20	27.95	83.85
12x14	348.34	80.10	120.15	34.71	149.52	18.69	96.12
10x16	848.64	202.80	240.24	127.92	249.60	433.68	1017.12
6.5x5	298.40	229.60	150.40	198.40	268.80	332.80	208.00
9x5	224.00	244.00	304.00	34.00	204.00	154.00	120.00
8x7	68.36	58.42	80.00	0.00	83.82	19.05	44.45
7x5.5	107.95	130.05	122.40	80.75	106.25	78.20	28.90
11.5x6	53.65	39.15	59.45	31.50	68.15	75.40	31.90
15x20	1134.00	1302.00	456.00	684.00	1026.00	2160.00	1608.00
7x5.5	29.25	38.61	39.78	28.08	33.93	28.08	211.77
12.5x4	0.00	12.00	60.00	0.00	0.00	4.80	18.00
4x2.5	3.00	4.75	3.00	3.25	4.75	3.00	2.25
7x7	44.45	0.00	0.00	30.48	76.20	106.68	39.37
16x12	0.00	0.00	0.00	7.50	37.50	0.00	25.50
Total=	4440.32	3787.02	3039.70	1858.73	4332.63	5010.88	5255.99

In Figure 2 shows the weight vs days where the peak or highest weight 5.3 kg generated at Saturday and lowest weight 1.9 kg at Wednesday.

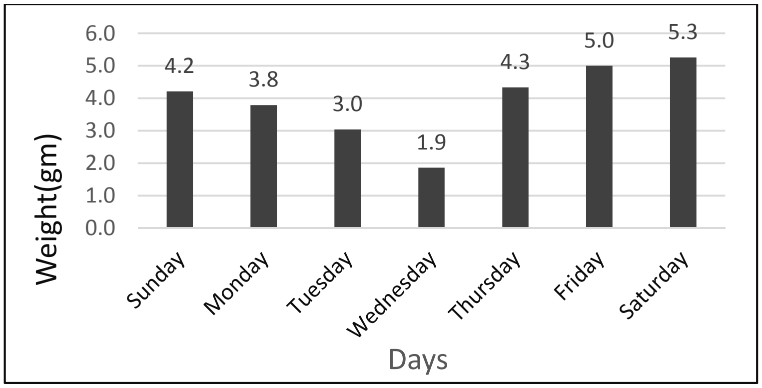

Figure 2: Weight vs Day graph

Figure 3 shows the percentage of waste generated in a week comparing to days. In total weekly waste, 19% wastes generated in Saturday which a off day in KUET academic activities and 18% wastes generated in Friday which is national weekend day. In Thursday, the wastes are large in number also because of day before Friday. In that day, many students of hall cooked inside the rooms which produced large number of wastes. So the value of that day is also around the largest amount of waste of the week.

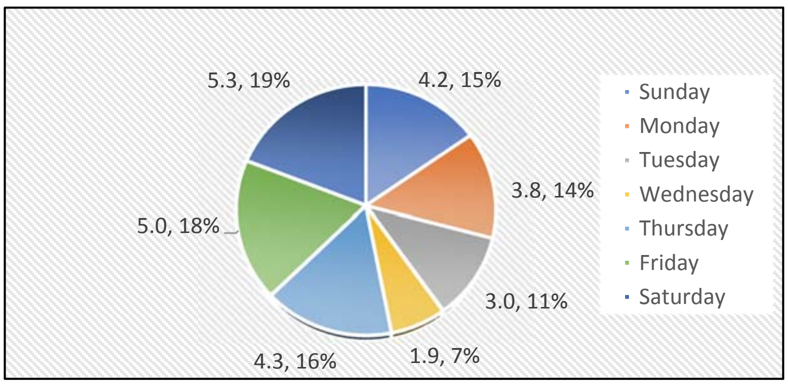

Figure 3: Percentage of waste produced in a week.

Figure 4 shows comparison between average waste weight produced in a week with respect to daily waste produced. The average waste generated in a week is 3.9 kg.

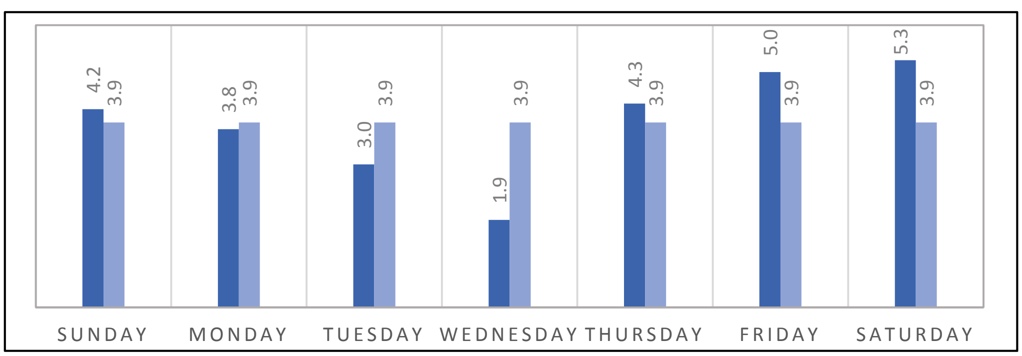

Figure 4: Average weight vs Day weight graph

RECYCLING AND ECONOMIC GAIN

Recycling is the process by which solid waste can be utilized again and again. It is the method where the wastes are reprocessed either into the same products or to different products. Solid waste recycling has been found to be recently acceptable and a sustainable by solid waste management. It is getting more appreciation from environmental, economical and social points of view. The solid waste recycling decrease environmental damage and is an import-substitution economic activities which also saves energy, conserves resources and saves waste collection and disposal costs (Kaseva and Gupta 1996).
Any waste management method, by which wastes beingenergy converting or recycling or composting, it is not cost effective, but it has great influencedon environment. So any type of recycling activity, which can bring waste management to economic gain, has a great significance. When solid waste can separate in generation point, income will increase by selling reusable or recyclable these wastes. The authority will have some money for selling the recyclable and reusable wastes or can use these wastes to converting in other useable ways. Wastes collectors are required to separate these waste into three categories; organic, reusable and recyclable and should store in separately. Authority of KUET campus should ensure to collect the waste separately. As a result, disposable wastes may decrease and cost of waste management will reduce.

POSSIBLE OF FURTHER USES

These small packet can be erosive to soil fertilization and burning of these small packets effect in air constituents and increase the carbon-di-oxide and other gases which effect global warming. So these wastes should be recyclable if possible. There are many possible ways to reduced these wastes and utilizing them into productive contents. Some of the possible ways are given below:

- The inside of the packet is shiny and looks like foil, it is in fact a metallized plastic film. This type of material can be recycled.
- PET(Polyethylene Terephthalate),HDPE(High Density Polyethylene),PVC(Polyvinyl Chloride),LDPE(Low-Density Polyethylene),PP (Polypropylene),PS (Polystyrene) etc. these types of plastic packet can be recyclable to generate new packets.
- Used as landfill in dumpy area .
- Chips packets can used as crafting, wrapping paper, home craft, as a bag etc.

CONCLUSION

Solid waste is an important issues in a country. Many wastes can be recyclable and reusable if those can use in particular ways. Small packet wastes hamper the beauty of nature. In KUET campus , these waste also hamper or reduce the beauty of green campus . For maintaining KUET campus as a green campus small packet wastes should be taken care of under solid waste management. The production rate of small packet waste will increase by the time flows. Every year the students of KUET is increasing a significant way. This large number students will generate more small packet wastes. So the management should be taken as soon as possible.

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Waste Water related Issues in Pabna Municipality (A Case Study on Ward No. 07, Pabna Municipality, Bangladesh)

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Abstract:

Wastewater treatment in developing countries is a major concern and solution has become challenging for various unfavorable conditions. Inadequate education and low economic perspective are causing difficulties in implementing advanced treatment methods. Similar to other developing countries, Bangladesh is also facing several waste water related problems both in the urban and rural region. Pabna is an old city of Bangladesh. The population rate of Pabna municipality is increasing rapidly. Ward no. 07 is selected for this paper which is efficient in residential, industrial, commercial areas resulting in a huge amount of waste water daily and many problems related with wastewater mismanagement. This paper consists of the existing scenario of waste water management of Ward no. 07 of Pabna Municipality including the major issues related with waste water management and some possible recommendations are also included in this paper.

Keywords: Waste water, Waste water management, Sanitation system, Treatment, ETP

Chapter One: Introduction

Water is essential for life, clean water is one of the most important natural resources on the planet. Wastewater, which is basically used water, is also a valuable resource, especially with recurring droughts and water shortages in many areas of the world. Wastewater refers to all effluent from household, commercial establishments and institutions, hospitals, industries and so on. It also includes storm water and urban runoff, agricultural, horticultural and aquaculture effluent. However, wastewater contains many harmful substances and cannot be released back into the environment until it is treated. [1]

Pabna municipality was established in 1876 as a sequel of the various acts and charter passed by the British Parliament in Kolkata, Madras and Bombay, the consolidated act no. 4 of 1876 gave away to the beginning of Pabna as an ULB. It is located in the middle of the great flood prone area of the braided river system known as the Brahma-Gangetic-Jamuna Plains. It is now classified as an “A” category municipality, covering an area of 27.20 sq. km. with 15 wards. [2] Pabna has expanded into a very important urban center in the whole north Bengal with many mills, factories and manufacturing units. It is also the trading center for all the agro-based and finished products. Huge number of houses, industrial centers, medical collage/university, cadet collage, vocational institutes along with various other government and private offices have their premises located in this municipality generating huge amount of waste water. This paper has been developed to analyze waste water management of Ward no. 07 of Pabna Municipality.

Types of waste water:

1. Domestic Wastewater (from homes, offices, hotels, institutions) comprises sewage (human waste)) and grey water from bathrooms, kitchens, laundries which is called sullage. [1]
2. Industrial Wastewater is the liquid discharge from manufacturing processes; for example soft drink and beer companies; sugar processing; metal processing; photo finishing. [1]

Waste water management:

Waste water management includes generation, collection, treatment and disposal of wastewater. In this Paper, mainly the scenario and issues related with waste water management in Ward no. 07 of Pabna Municipality have been discussed briefly.

Objectives of the study:

- To analysis existing scenario of waste water generation in ward no. 07;
- To identify the existing treatment system and disposal lay out of wastewater;
- To identify the major issues related with waste water generation, treatment in the study area;
- To recommend better treatment and mitigation measures to get rid of the issues.

Scope of the study:

- To understand existing scenario of waste water management of Pabna Municipality.
- To identify proper treatment system of waste water in order to remove pathogenic (disease causing) organisms and to remove organic and inorganic matter which would otherwise cause pollution.
- In order to protect:
  - The Environment;
  - Human Health.

Chapter Two: Profile of the Study Area

The Pabna Municipality is between $23^0 53''$ N and $24^0 05''$ N Latitude and $89^0 09''$ E and 89^0 25" E Longitudes. It is bounded by Shalgaria and Laskorpur beyond the river Ichamoti on the North, Dakshin Ramchandrapur on the South, Arifpur-Mahendrapur-Madarbaria on the East and Hemayetpur and Pailanpur on the West part of the Municipality. The Ichamoti River is passing through the middle of the Municipality. In this paper, study area is middle part of Pabna municipality in ward no. 07.

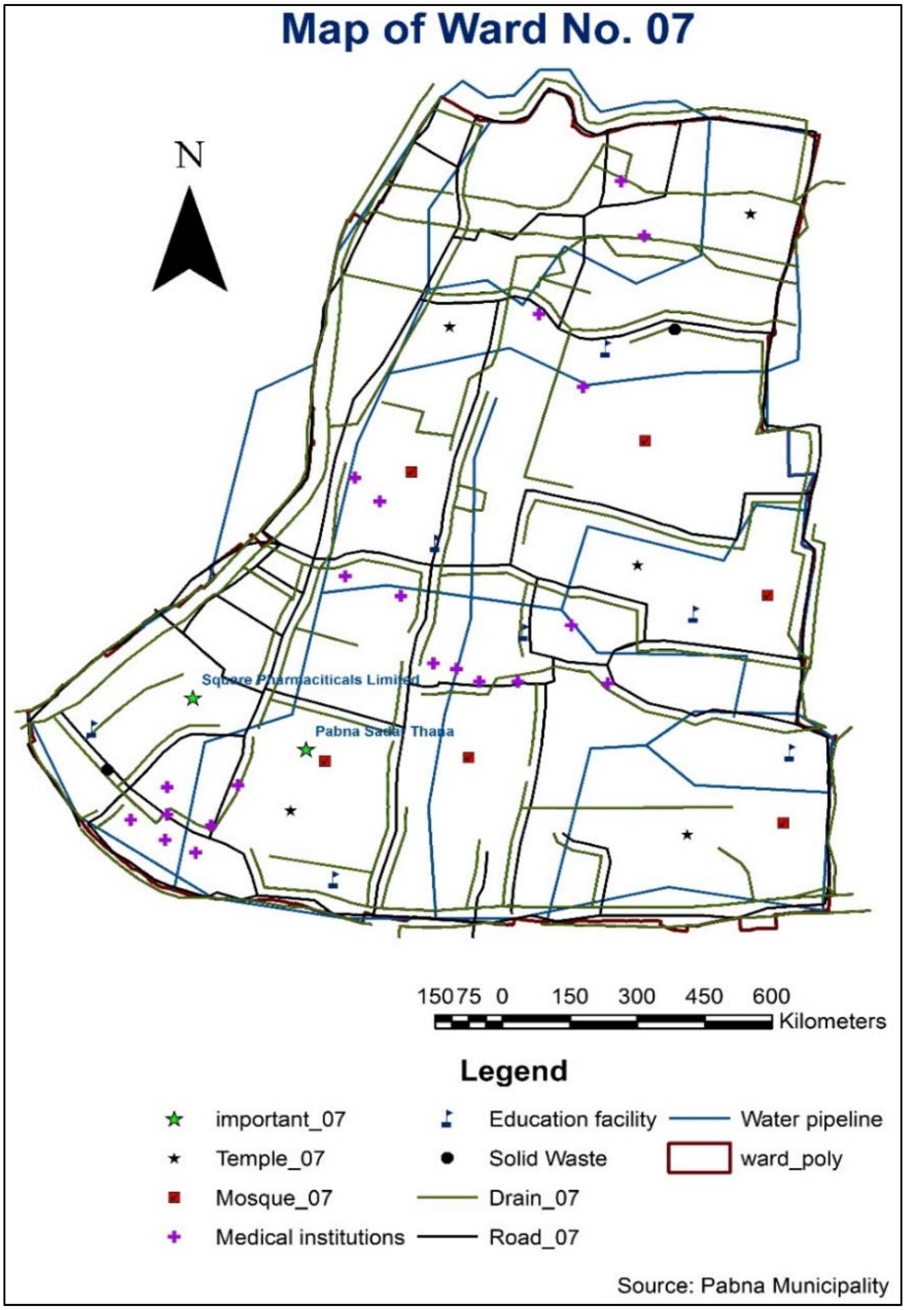
Boundary of Paurashava:

Pabna Paurashava is bounded by the following Mauza:

- ☑ North: Radhanagar, Shalgaria and Loskorpur Mauza.
- ☑ South: Luxmikol, Shadhupara and Dakshin Ramchandrapur Mauza.
- ☑ East: Arifpur, Madarbaria and Mohendrapur Mauza.
- ☑ West: Pailanpur, Chatiani, Hemayetpur and Kismotprotappur Mauza.

Total Area of Ward no. 07 is about 255.681 acres. Total population in this area is about 10216. Approximately 1446 households are located in this ward.

There are six academic institutions, six mosques, five temples, about twenty-two medical institutions (i.e. clinics, diagnostic centers, hospitals etc.) in this ward. This ward is located nearly the central business district area and for this reason there are several trading shops and offices, banks are available in this ward.



Main branch of Square Pharmaceuticals Limited is located in this area. Sadar Thana of Pabna Municipality is located in this ward. In this paper, the existing scenario of wastewater generation, treatment and its related issues have been discussed briefly.

Chapter Three: Methodology

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

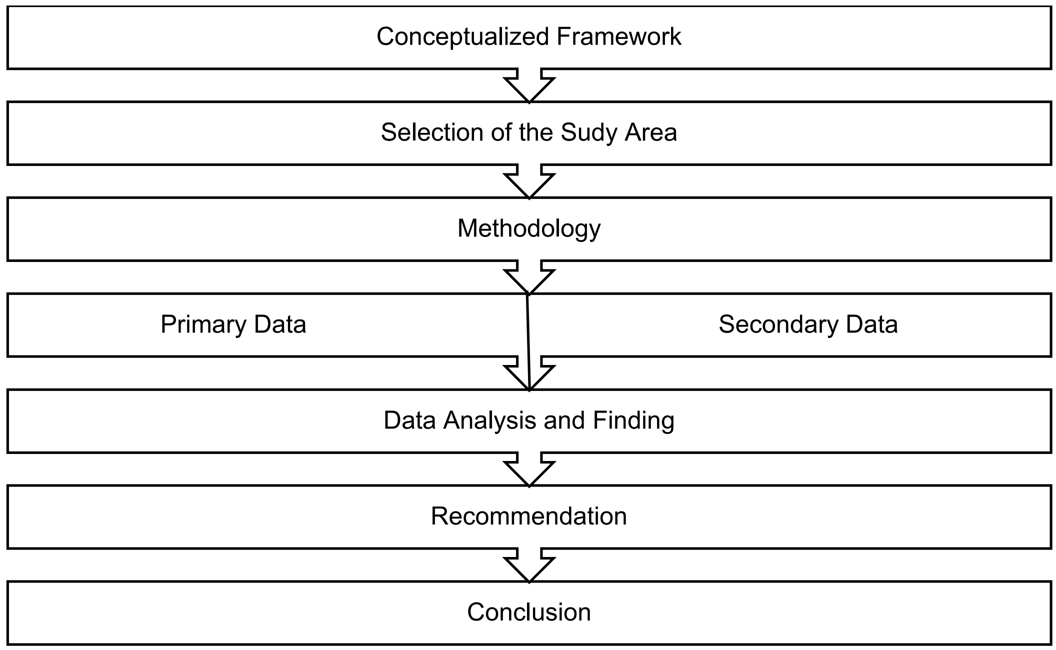


Figure 3.1: Flow chart of Research Methodology

Conceptualized Framework:

- Creative process of generating, developing and communicating new ideas.
- Involves taking that already exists and changing it.
- Existing condition can be developed by different way.

Selection of the Study Area:

Proposed site is Ward Number 07 of Pabna Municipality. The total area of ward no 07 is 255.681 acres approximately. Details of the study area has already been stated before in this paper.

Data collection:

Two types of data were collected during revitalization survey. They are:

1. Primary data;
2. Secondary data.

Primary data: Primary data refers to that data types which are collected directly by field survey.
Secondary data: Secondary data refers to the data types which are collected from different sources, records that is stored before.
Primary data has been collected through field work. Primary data such as the demographic information about the ward including information related with wastewater in that ward (i.e., dimension of wastewater generation, treatment process, issues related with it and disposal scenario of wastewater etc) by questionnaires, observation and group discussion. Secondary data has been collected from Pabna Municipality office.

Data Analysis and Findings:

After data Collection, the data will be analyzed and major findings will be stated in this paper.

Recommendation:

- To state possible recommendation to solve this problem.
- Making alternative plan.

Conclusion:

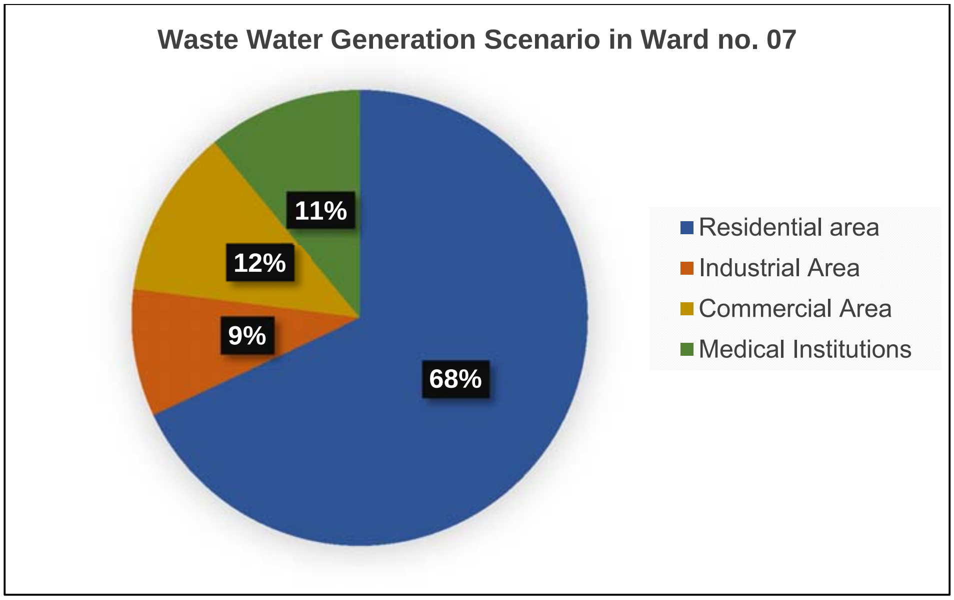
After analysis the area, some problems are found but it is possible to solve the problems with necessary initiations and operations. A short review of whole survey is included in this part.

Chapter Four: Data Analysis

Different information and data have been collected from Ward no. 07 which are related with waste water management of this area. For example, the amount of total waste water generated from this entire ward including its ratio in different sectors, the collection process, available treatment methods and disposal of waste water.

4.1: Waste water Generation:

In this ward, there are approximately 1416 households, one industry, six schools, one collage, six mosques, five temples, twenty-two medical institutions, numerous shops and offices, banks. About 2150 cubic meters waste water is generated per day in this ward.



Above chart explains the ratio of waste water generation in different sectors of landuse. For example, about 12% of total waste water of ward no. 07 is generated from commercial areas (including all shops, offices, banks, schools, religious places etc.).

The largest part of waste water is generated from households which includes human waste, sullage. Smallest part of waste water is generated from industrial areas.

Waste-water generation from households:

About 1000 liters of waste water (mainly as sullage) is generated per household. In average there are about 7 members per household. So, amount of sullage generated per capita per day is approximately (1000/7) = 141.52 liters.

Table 4.1: Amount of waste water generation per capita per day:

Types of waste water	Amount
Sullage	141.51 liters
Urines	1-1.4 liters
Faeces	130-520 gram (0.33 liters)
Total	143.045 liters

Source: Pabna Municipality

Total population of this area is approximately 10218 and 143.045 liters of waste water is generated daily per capita, so total waste water generation (including human waste, sullage, other purposes) is = (10218*143.045 *.001) cubic meters= 1462 cubic meters.

Waste-water generation from Industries:

About 9% of total waste water is generated from industries in this ward. As there is only one industry available in this ward (Square Pharmaceuticals Limited), according to them, about 192.67 cubic meters of waste water is generated from this industry.

Waste-water generation from Commercial areas:

In total, about 258 cubic meters of waste water is generated from this area. About 46% of this waste water which is about 119 cubic meters is generated from schools. About 87.8 cubic meters of waste water which is approximately 34% of total, is generated from offices, banks. About 43.86 cubic meters of waste water is generated from religious places (mosques, temple etc.). And the rest of total (about 7.74 cubic meters) is generated from shops, trading centers, shopping malls.

Waste-water generation from medical institutions:

About 236.5 cubic meters of waste water generated from this ward's medical institutions.

4.2: Waste Water Collection:

Wastewater collection systems gather the used water from our homes, businesses and industries and convey it to a wastewater treatment plant. This type of system is also called a sanitary sewer. A similar system known as a storm water collection system conveys water resulting from runoff of rain and snow from buildings and paved and unpaved areas to a natural watercourse or body of water, usually without treatment. This type of system is also known as a storm sewer. Usually, there are two types of collection system available for waste water [3]:

On-site collection system: In this area, maximum waste water is collected by on-site collection system as this water is treated on the generated site. Maximum households have ventilated improved pit latrines and septic tank system (rarely used) in which the waste water is collected.

The effluent of industry (Square Pharmaceuticals Limited) is also collected on the generation site and treated on the site by specific process in their own Effluent Treatment Plant.

Off-site collection system: Rest of the waste water is collected off-site by open drains where simple pit latrines are used and directly disposed into the Ichamoti River which remains untreated.

4.3: Waste Water Treatment:

Waste water of this area is treated by following means:

Septic tank: In un-sewered rural and urban areas septic tanks are suitable for disposal of night soil. The size of the septic tank is so designed that the sewage is retained in the tank for 24hrs during which certain biological decomposition by the action of anaerobic bacteria takes place which liquefies and breaks the night soil leaving small quantity of soil which is known as sludge and settles at the bottom of the tank and clear water known as effluent flows out of the tank. [3]

The effluent is discharged to the municipal drainage lines existing in the area. Maximum10% of total waste water is treated by this means.

ETP (Effluent Treatment Plant) [4]:

The ETP Plant works at various levels and involves various physical, chemical, biological and membrane processes to treat waste water from different industrial sectors like chemicals, drugs, pharmaceutical, refineries, dairy, ready mix plants & textile etc. Industrial effluent treatment plant process include the following stages:

1. Preliminary Treatment: Screening, Sedimentation, Grit chamber, Clarifiers.

2. Primary Treatment: Flocculation, Coagulation, Neutralization, Primary Clarifiers.
3. Secondary or Biological Treatment: Activated Sludge Process, Aerated Lagoons, Trickling Filters, Rotating Biological Contactor.
4. Tertiary/advanced/disinfection treatment: Chemical Coagulation and sedimentation, Filtration, Reverse Osmosis, UV Disinfection.

(Source: Field Survey, 2018)

Figure 4.1: Off-site Collected and Untreated Waste Water

In this area of Pabna Municipality, 90 percent of all wastewater goes into water untreated. As town outgrows its sanitation systems, wastewater can go straight into Ichamoti River.

4.4: Waste Water Disposal:

There is no specific disposal site in Pabna Municipality. All of its wastewater is disposed to Ichamoti River. This river is flowing at the left side of the ward no. 07 and all off effluents generated from this area are being disposed to the river.

Chapter Five: Major Findings

5.1: Scenario of Waste Water Mismanagement:

Mainly in low-income areas of cities and towns within developing countries, a large proportion of wastewater is discharged directly into the closest surface water drain or informal drainage channel, sometime without or with very little treatment. In addition to household effluent and human waste, urban-based hospitals and industries such as small-scale mining and motor garages, often dump highly toxic chemicals and medical waste into the wastewater system. [5]

Even in cities where wastewater is collected and treated, the efficiency of treatment may vary according to the system used. However, some facts of waste water mismanagement is listed below:

No sewerage system: There are no sewerage system in this ward. As a result, waste waters are flowing in the open drains which are not treated and resulting several negative impacts.

Poor maintenance of septic tank: Though septic tanks rarely used, poor maintenance of septic tank is another mismanagement in waste water treatment and collection which result in different pathogen borne diseases and other related pollutions.

Energy consumption: One of the largest issues facing wastewater management facilities is energy consumption. Sifting through wastewater and storm water consumes almost 3% of electrical power annually. That means it's one of the largest expenses in the entire wastewater industry. It might not seem like a lot, but truly the number is exceedingly large.

Insufficient resource:

1. **Unskilled workforce:** When it comes to wastewater treatment, it's important to have highly skilled individuals who have the necessary training and education to get the job done right. These individuals are responsible for everything from pipe leaks to electrical malfunctions. And unfortunately, there aren't enough of them.
2. **Poor infrastructure:** Aging infrastructure, which includes pipelines, tunnels, dams, pumping, storage and treatment facilities, and specifically buried assets
3. **Funding concerns:** Treatment process and appropriate collection system is very expensive which needs huge funding and the permitted funding for management from authority is not sufficient in Pabna Municipality and Square Pharmaceuticals Limited.

Increasing/expanding regulations: Increasing regulations which relate to spending, most utilities with large-scale programs that gain funding are those required by federal or state regulations, such as nutrient removal and drinking water quality requirements. The challenge becomes balancing these expenses with deferred infrastructure maintenance.

Technology changes: Information technology refers to cloud computing, virtualization and hosted applications, which improve operations and potentially reduce costs. But with these advancements come security concerns that could potentially dampen the positive effects of new technology. Energy recovery is becoming much more important for wastewater treatment, which means those entities are shifting in function.

Negligence of authority: The municipal authority is not so much concerned about waste water management which is resulting in various negative impacts.

Lack of awareness: The general people are not aware of the problems related with mismanagement of waste water which results in never solving problems of waste water mismanagement.

Inefficient authority: The authority is not efficient in directing waste water mismanagement which is a large obstacle for solving the major issues.

Indistinctive disposal site: Open disposal in Ichamoti River is one of the biggest part of mismanagement in this area.

Inadequate scheme for medical effluents: Medical effluents contain most dangerous viruses, bacteria, pathogens etc and for the medical effluents, there are no such arrangements. In most cases, maximum effluents are disposed to the open drains without being treated. It is one of the most dangerous threat for the environment and human health in this area.

5.2: Issues Related With Waste Water Mismanagement:

In certain parts of the world, especially in developing countries, wastewater is pumped directly into fresh water bodies without any form of treatment. In our study area, lack of adequate wastewater treatment infrastructure, maintenance and outdated systems heavily compromise wastewater treatment efforts. As well as the untreated waste water is directly disposed to the nearest water body, Ichamoti River by open drains has been creating one of the biggest threat to environment and public health. The effects of this (either treated or partly treated) can be classified in the following:

Water pollution: Water pollution is the most important concern due to waste water mismanagement in this area. Main ways by which water pollution is taking place in this area are:

a) Water pollution, by the discharge of wastewater from commercial and industrial waste (intentionally or through spills) into surface waters;
b) Discharges of untreated domestic sullage, and chemical contaminants, such as chlorine;
c) Release of waste and contaminants into surface runoff flowing to surface waters (including urban runoff and agricultural runoff, which may contain chemical fertilizers and pesticides; also including human feces from open defecation;
d) Groundwater pollution from waste disposal and leaching into the ground, including from pit latrines and septic tanks;
e) Eutrophication and littering.

Effects on physical properties of water (taste, color, odor, turbidity, density etc.): Wastewater discharged on lands surrounding Ichamoti River can leach into underground water tables and potentially contaminate aquifers and underground water. Waste water is being discharged in freshwater bodies, it renders water sources unsuitable for use in the area specially ground water.

Degradation of Ecosystem: All ecosystems are connected and they all ultimately depended on water. Similarly, all water (surface and underground) is connected. This means careless wastewater discharge have some serious ripple effect. One common effect of wastewater is the eutrophication of fresh water bodies. If one part of the ecosystem chain is destroyed, it can upset its entire food chain.

Effects on Agriculture / Fisheries: Wastewater for irrigation contains unsuitable chemicals and higher concentrations of nutrients needed for crops. This is resulting in delayed and under yielding. Wastewater used for animal farming also contain harmful things and chemicals dissolved in them. Animals are dying, and there is a chance that humans that eat such animals may be harmed too. Fecal sewage is discharged directly into the Ichamoti River. The discharge contains pathogens and harmful dissolved chemicals which can affect fishing in that area.

Health Problems: Feces and urine from both humans and animals carry many disease-causing organisms. Wastewater also contain harmful chemicals and heavy metals known to cause a variety of environmental and health problems. Disease-causing organisms (pathogens) from humans enters into wastewater from patients at hospitals, or from anyone who is sick or a carrier of disease. Carriers may not have symptoms or even know they have a disease. Animal wastes often enter from farms, meat packing and processing facilities, and from rats and other animals found in or around open drains. [6] In this area, where wastewater treatment is inadequate or nonexistent, the opportunities for people to become infected seem endless. For example, people have become ill by doing the following:

Blockage of drainage: Irregular and uncontrolled disposal of untreated waste water (including sludge, scum and also residential waste) causes blockage of drainage.

Soil pollution: Soil contamination occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, MTBE, herbicides, pesticides and chlorinated hydrocarbons. Oils around the VIP latrines and Ichamoti river is being polluted more and more gradually which will result in serious threat to the environment.

Environmental Footprint: Wastewater management facilities produce sludge; it’s the product of pulling all of the waste out of our water supply. Unfortunately, producing this sludge also means cleaning it up, which means there’s a huge footprint left on the environment.

Chapter Six: Recommendation and Conclusion

In developed countries, water use is commonly high and the sewage therefore greatly diluted; effluents are treated in municipal treatment plants and no significant health risks should be expected, even without further specific treatment of these effluents. In developing countries, where there may be no connection to municipal sewage networks, discharge of untreated or inadequately treated sewage to the environment will inevitably pose major health risks. The toxic effects of any chemical pollutants contained in wastewater on the active bacteria of the sewage purification process may give rise to additional hazards. For our study area, some possible recommendations are listed below:

1. Effective Wastewater management: The basic principle underlying effective wastewater management is a strict limit on the discharge of hazardous liquids to sewers. At First, Providing basic facilities of sewerage system (conventional or open sewers) along with drains and ensuring maximum quality. Secondly, Establishment of sewerage treatment plant in a suitable location and it should be ensured that the plant is in safe distance from the municipality. Thirdly, Connection to a municipal sewage treatment plant

2. On-site treatment or pretreatment of wastewater: On site treatment system is must for medical and industrial effluents. The medical institutions and industries should have their own treatment plant, so that they can first treat their effluents and then dispose the treated waste to the sewerage system towards the plant for further treatment. [7]

3. Reuse of wastewater and sludge in agriculture and aquaculture
4. Options for establishments that apply minimal waste management programmes (Lagooning, Minimal safety requirements)

Conclusion:

The primary problems concerning waste water in this area are the depletion and degradation of the resource caused by various anthropogenic activities. Over-utilization, particularly through tube wells, is another major problem affecting ground water resources. Except for pipe-borne water supply, irrigation and hydropower schemes, in general water resources are managed very poorly. Regulations are available to control most water related problems but enforcement of these regulations is lacking. The ultimate result of degradation and depletion of water resources is the increasing health hazards. Water-borne and vector-borne diseases are prevalent, particularly amongst urban low-income communities with poor sanitary facilities and drainage. Despite government initiatives and legislation, very slow progress has been made towards combating water pollution.

Acknowledgement:

At first we would like to thank Almighty of Allah for completing this report. Some people coordinated with us. Without their kind help & support it would have been difficult for us to complete the report. Firstly we would like to acknowledge our Course teacher KAMRUL HASAN KANAK sir, Lecturer, Department of URBAN &REGIONAL PLANNING, AT PABNA UNIVERSITY OF SCIENCE & TECHNOLOGY (PUST). His continuous acknowledgement & guidance help us to accomplish the work. He gave us him valuable time. So we greatly indebted to him.

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IMPACT OF PLASTIC DEBRIS ON MARINE ENVIRONMENT OF BANGLADESH: A REVIEW

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Keywords: Plastic debris; Pollution; Marine environment, Bangladesh.

ABSTRACT

Plastic debris is one of the obstacles which hasnegative impact on marine environment. Plastic debris dispatched to fish, sea birds, marine reptiles and marine mammals through ingestion and entanglement. The deleterious effects of plastic debris on the marine environment were reviewed by bringing together most of the literature published so far on the topic. A large number of marine species is known to be harmed and/or killed by plastic debris, which could jeopardize their survival, especially since many are already endangered by other forms of anthropogenic activities.Bangladesh has many attractivetourist places for foreigners and local visitors. The world largest sea-beach Cox's Bazar, Saint Martine and Kuakata are one of them. People come to see these places each and every year. Throughout the time of passing a good mausoleum, People useplastic things like bottle, polythene, chips packet, plastic bags, balloons, cigarette lighters, beer, juice, fishing net, clean containers and many of others.Basically this kind of plastic goes to the water and effect both ocean environment and marine species. The Research focuses on the impact of plastic debris on marine environment, besides it can be perceived how plastic does effect on ocean environment and how it can be impeded as well as how to increase a huge apprehension among the people. The research is also for promoting a more sustainable lifestyle and educate people about the prevalence of plastic debris on oceans and attractive places that how deadly it can be to marine life.

INTRODUCTION

Marine animals are mostly affected through entanglement in and ingestion of plastic litter. Other less known threats include the use of plastic debris by ‘‘invader’’ species and the absorption of polychlorinated biphenyls from ingested plastics. Less conspicuous forms, such as plastic pellets and ‘‘scrubbers’’ are also hazardous. Human activities are responsible for a major declineof the world’s biological diversity, and the problem is socritical that combined human impacts could have accelerated present extinction rates to 1000–10,000 timesthe natural rate (Lovejoy, 1997). In the oceans, thethreat to marine life comes in various forms, such asoverexploitation and harvesting, dumping of waste, pollution, alien species, land reclamation, dredging andglobal climate change (Beatley, 1991; National Research Council, 1995; Irish and Norse, 1996; Ormond et al.,1997; Tickel, 1997; Snelgrove, 1999). One particularform of human impact constitutes a major threat tomarine life: the pollution by plastic debris. To address the problem of plastic debris in the oceans is a difficult task, and a variety of approaches are urgently required. Some of the ways to mitigate the problem are discussed.

PLASTIC DEBRIS

Plastic debris is defined as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great lake. Plastics are synthetic organic polymers, and thoughthey have only existed for just over a century (Gorman,1993), by 1988 in the United States alone, 30 milliontons of plastic were produced annually (O’Hara et al.,1988). The versatility of these materials has lead to a great increase in their use over the past three decades and they have rapidly moved into all aspects of everyday life (Hansen, 1990; Laist, 1987). Plastics are lightweight, strong, durable and cheap (Laist, 1987), characteristics that make them suitable for the manufacture of a verywide range of products. These same properties happento be the reasons why plastics are a serious hazard to the environment (Pruter, 1987; Laist, 1987). Since they arealso buoyant, an increasingload of plastic debris is beingdispersed over longdistances, and when they finallysettle in sediments they may persist for centuries (Hansen, 1990; Ryan, 1987b; Goldberg, 1995, 1997).The threat of plastics to the marine environment hasbeen ignored for a long time, and its seriousness hasbeen only recently recognised (Stefatos et al., 1999).Fergusson (1974) for instance, then a member of theCouncil of the British Plastics Federation and a Fellowof the Plastics Institute, stated that ‘‘plastics litter is avery small proportion of all litter and causes no harm tothe environment except as an eyesore’’. His commentsnot only illustrates how the deleterious environmentaleffects of plastics were entirely overlooked, but also that,apparently, even the plastics industry failed to predictthe great boom in the production and use of plasticsof the past 30 years. In the marine environment, theperceived abundance of marine life and the vastnessof the oceans have lead to the dismissal of the proliferation of plastic debris as a potential hazard (Laist,1987)The literature on marine debris leaves no doubt thatplastics make-up most of the marine litter worldwide(Table 1). Though the methods were not assessed toensure that the results were comparable, Table 1 clearlyindicates the predominance of plastics amongst themarine litter, and its proportion consistently varies between 60% and 80% of the total marine debris (Gregoryand Ryan, 1997).It is not possible to obtain reliable estimates of theamount of plastic debris that reaches the marine environment, but the quantities are nevertheless quite substantial. In 1975 the world’s fishing fleet alone dumped into the sea approximately 135,400 tons of plastic fishinggear and 23,600 tons of synthetic packaging material (Cawthorn, 1989; DOC, 1990). Horsman (1982) estimated that merchant ships dump 639,000 plastic containers each day around the world, and ships aretherefore, a major source of plastic debris (Shaw, 1977; Shaw and Mapes, 1979). Recreational fishingand boatsare also responsible for dumpinga considerable amountof marine debris, and accordingto the US Coast Guardthey dispose approximately 52% of all rubbish dumpedin US waters (UNESCO, 1994).Plastic materials also end up in the marine environment when accidentally lost, carelessly handled (Wilber,1987) or left behind by beachgoers (Pruter, 1987). Theyalso reach the sea as litter carried by rivers and municipal drainage systems (Pruter, 1987; Williams and Simmons, 1997). There are major inputs of plastic litterfrom land-based sources in densely populated or industrialized areas (Pruter, 1987; Gregory, 1991)

Table 1. Proportion of plastics among marine debris worldwide (per number of items)(Sciences & Zealand, 2002)

Locality	Litter type	Percentage of debris items represented by plastics	Source
1992 International Coastal Cleanups	Shoreline	59	Anon (1990)
St. Lucia, Caribbean	Beach	51	Corbin and Singh (1993)
Dominica, Caribbean	Beach	36	Corbin and Singh (1993)
Curacao, Caribbean	Beach	40/64	Debrot et al. (1999)
Bay of Biscay, NE Atlantic	Seabed	92	Galgani et al. (1995a)
NW Mediterranean	Seabed	77	Galgani et al. (1995b)
French Mediterranean Coast	Deep sea floor	>70	Galgani et al. (1996)
European coasts	Sea floor	>70	Galgani et al. (2000)
Caribbean coast of Panama	Shoreline	82	Garrity and Levings (1993)
Georgia, USA	Beach	57	Gilligan et al. (1992)
5 Mediterranean beaches	Beach	60–80	Golik (1997)
50 South African beaches	Beach	>90	Gregory and Ryan (1997)
88 sites in Tasmania	Beach	65	Gregory and Ryan (1997)
Argentina	Beach	37–72	Gregory and Ryan (1997)
9 Sub-Antarctic Islands	Beach	51–88	Gregory and Ryan (1997)
South Australia	Beach	62	Gregory and Ryan (1997)
Kodiak Is, Alaska	Seabed	47–56	Hess et al. (1999)
Tokyo Bay, Japan	Seabed	80–85	Kanehiro et al. (1995)
North Pacific Ocean	Surface waters	86	Laist (1987)
Mexico	Beach	60	Lara-Dominguez et al. (1994)
Transkei, South Africa	Beach	83	Madzena and Lasiak (1997)
National Parks in USA	Beach	88	Manski et al. (1991)
Mediterranean Sea	Surface waters	60–70	Morris (1980)
Cape Cod, USA	Beach/harbour	90	Ribic et al. (1997)
4 North Atlantic harbors, USA	Harbour	73–92	Ribic et al. (1997)
Is. Beach State Park, New Jersey, USA	Beach	73	Ribic (1998)
Halifax Harbour, Canada	Beach	54	Ross et al. (1991)
Price Edward Is., Southern Ocean	Beach	88	Ryan (1987b)
Gough Is., Southern Ocean	Beach	84	Ryan (1987b)
Heard Is., Southern Ocean	Beach	51	Slip and Burton (1991)
FogBay, N. Australia	Beach	32	Whiting(1998)
South Wales, UK	Beach	63	Williams and Tudor (2001)

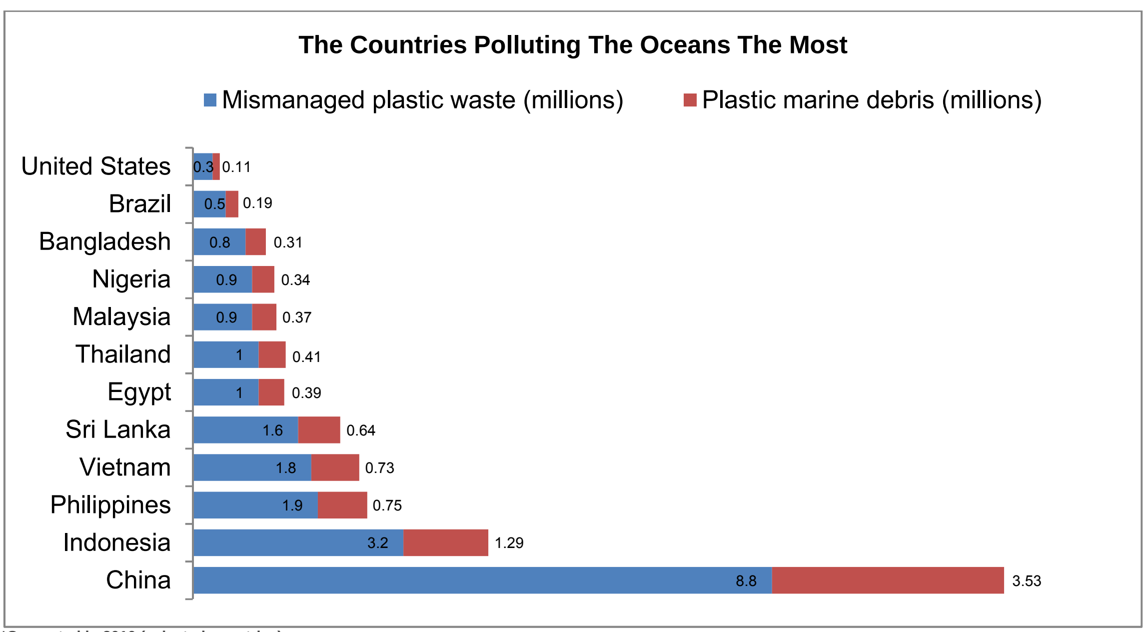
Results are arranged in alphabetical order by author.

[a]76% of total consisted of synthetic line for long-line fisheries.

most in the form of packaging. A study on Halifax Harbourin Canada, for instance, showed that 62% of the totallitter in the harbour originated from recreation andland-based sources (Ross et al., 1991). In contrast, inbeaches away from urban areas (e.g. Alaska) most of thelitter is made up of fishing debris. Not only the aesthetically distasteful plastic litter, but also less conspicuous small plastic pellets and granulesare a threat to marine biota. The latter are found inlarge quantities on beaches (Gregory, 1978, 1989; Shiber, 1979, 1982, 1987; Redford et al., 1997), and are theraw material for the manufacture of plastic productsthat end up in the marine environment through accidental spillage during transport and handling, not aslitter or waste as other forms of plastics (Gregory, 1978; Shiber, 1979; Redford et al., 1997). Their sizes usuallyvary from 2–6 mm, though occasionally much largerones can be found (Gregory, 1977, 1978).Plastic pellets can be found across the SouthwestPacific in surprisingly high quantities for remote andnon-industrialised places such as Tonga, Rarotonga and Fiji (Gregory, 1999). In New Zealand beaches they arefound in quite considerable amounts, in counts of over100,000 raw plastic granules per meter of coast (Gregory, 1989), with greatest concentration near importantindustrial centres (Gregory, 1977). Their durability inthe marine environment is still uncertain but they seemto last from 3 to 10 years, and additives can probablyextend this period to 30–50 years (Gregory, 1978).Unfortunately, the dumpingof plastic debris into theocean is an increasingproblem. For instance, surveyscarried out in South African beaches 5 years apart, showed that the densities of all plastic debris have increased substantially (Ryan and Moloney, 1990). InPanama, experimentally cleared beaches regained about50% of their original debris load after just 3 months (Garrity and Levings, 1993). Even sub antarctic islands are becoming increasingly affected by plastic debris, especially fishinglines (Walker et al., 1997). Benton (1995) surveyed islands in the South Pacific and got to the alarming conclusion that beaches in remote areas hada comparable amount of garbage to a beach in the industrialized western world.

Bangladesh a major polluter of the world's oceans

Bangladesh has been listed among the top polluters of the world's oceans. The country ranked 10th in polluting the oceans in 2010, said a report compiled by a team of researchers based in the United States and Australia, who analyzed plastic waste levels in the world's seas. The team of researchers was led by Jenna Jambeck, an environmental engineer at the University of Georgia. Bangladesh dumped 0.79 million metric tons of plastic waste in to the oceans in 2010, the Statista Portal reports. (Study: Bangladesh a major polluter of the world's oceans, 2018)



***Generated in 2010 (selected countries)**
Source: The Wall Street Journal
Originally this infographic incorrectly labelled the total amount of mismanaged plastic waste as the amount found in the water.

Figure 1. Countries polluting the oceans the most.

The threats from plastics pollution to marine biota

There is still relatively little information on the impactof plastics pollution on the ocean's ecosystems (Quayle, 1992; Wilber, 1987). There is however an increasingknowledge about their deleterious impacts on marinebiota (Goldberg, 1995). The threats to marine life areprimarily mechanical due to ingestion of plastic debrisand entanglement in packaging bands, synthetic ropesand lines, or drift nets (Laist, 1987, 1997; Quayle, 1992).Since the use of plastics continues to increase, so doesthe amount of plastics pollutingthe marine environment. Robards et al. (1995) examined the gut content ofthousands of birds in two separate studies and foundthat the ingestion of plastics by seabirds had significantly increased duringthe 10–15 years interval betweenstudies. A study done in the North Pacific (Blight andBurger, 1997) found plastic particles in the stomachs of8 of the 11 seabird species caught as bycatch. The list ofaffected species indicates that marine debris are affectinga significant number of species (Laist, 1997). It affects atleast 267 species worldwide, including86% of all seaturtle species, 44% of all seabird species, and 43% of allmarine mammal species (Laist, 1997). The problem maybe highly underestimated as most victim are likely to goundiscovered over vast ocean areas, as they either sinkor are eaten by predators (Wolfe, 1987).There is also potential danger to marine ecosystemsfrom the accumulation of plastic debris on the seafloor. According to Kanehiro et al. (1995) plasticsmade up 80–85% of the seabed debris in Tokyo Bay, animpressive figure considering that most plastic debrisare buoyant. The accumulation of such debris can inhibit the gas exchange between the overlying watersand the pore waters of the sediments, and the resultinghypoxia or anoxia in the benthos can interfere with thenormal ecosystem functioning, and alter the make-upof life on the sea floor (Goldberg, 1994). Moreover, asfor pelagic organisms, benthic biota is likewise subjected to entanglement and ingestion hazards (Hesset al., 1999)

Ingestion of plastics

A study done on 1033 birds collected off the coast ofNorth Carolina in the USA found that individuals from55% of the species recorded had plastic particles in theirguts (Moser and Lee, 1992). The authors obtained evidence that some seabirds select specific plastic shapes and colors, mistaking them for potential prey items.Shaw and Day (1994) came to the same conclusions, asthey studied the presence of floating plastic particles of different forms, colors and sizes in the North Pacific,findingthat many are significantly under-represented.Carpenter et al. (1972) examined various species of fishwith plastic debris in their guts and found that onlywhite plastic spherules had been ingested, indicating thatthey feed selectively. A similar pattern of selective ingestion of white plastic debris was found for loggerhead sea turtles (Carettacaretta) in the Central Mediterranean (Gramentz, 1988). Amongseabirds, the ingestionof plastics is directly correlated to foraging strategiesand technique, and diet (Azzarello and Van-Vleet, 1987; Ryan, 1987a; Moser and Lee, 1992; Laist, 1987, 1997).For instance, planktivores are more likely to confuseplastic pellets with their prey than do piscivores, therefore the former have a higher incidence of ingested plastics (Azzarello and Van-Vleet, 1987). Ryan (1988) performed an experiment with domestic chickens (Gallus domesticus) to establish the potentialeffects of ingested plastic particles on seabirds. Theywere fed with polyethylene pellets and the results indicated that ingested plastics reduce meal size by reducingthe storage volume of the stomach and the feedingstimulus. He concluded that seabirds with large plasticloads have reduced food consumption, which limits theirability to lay down fat deposits, thus reducingfitness.Connors and Smith (1982) had previously reached thesame conclusion, as their study indicated that the ingestion of plastic particles hindered formation of fatdeposits in migrating red phalaropes (Phalaropusfulicarius), adversely affecting long-distance migration andpossibly their reproductive effort on breedinggrounds.Spear et al. (1995) however, provided probably the firstsolid evidence for a negative relationship betweennumber of plastic particles ingested and physical condition (body weight) in seabirds from the tropicalPacific.Other harmful effects from the ingestion of plasticsinclude blockage of gastric enzyme secretion, diminishedfeedingstimulus, lowered steroid hormone levels, delayed ovulation and reproductive failure (Azzarello andVan-Vleet, 1987). The ingestion of plastic debris bysmall fish and seabirds for instance, can reduce fooduptake, cause internal injury and death followingblockage of intestinal tract (Carpenter et al., 1972; Rothstein, 1973; Ryan, 1988; Zitko and Hanlon, 1991).The extent of the harm, however, will vary amongspecies. Procellariiformes for example, are more vulnerabledue to their inability to regurgitate ingested plastics (Furness, 1985; Azzarello and Van-Vleet, 1987). Laist (1987) and Fry et al. (1987) observed that adultsthat manage to regurgitate plastic particles could passthem onto the chicks duringfeeding. The chicks of Laysan albatrosses (Diomedeaimmutabilis) in the Hawaiian Islands for instance, are unable to regurgitatesuch materials which accumulate in their stomachs, becoming a significant source of mortality, as 90% of thechicks surveyed had some sort of plastic debris in their upper GI tract (Fry et al., 1987). Even Antarctic and sub-Antarctic seabirds are subjected to this hazard (Slip et al., 1990). Wilson's storm-petrels (Oceanitesoceanicus) for instance, pick up plastic debris while wintering in other areas (Van Franeker and Bell, 1988). A whitefaced storm-petrel (Pelagodroma marina) found dead at the isolated Chatham Islands (New Zealand) at a breedingsite, had no food in its stomach while its gizzard was packed with plastic pellets (Bourne and Imber, 1982). The harm from ingestion of plastics is nevertheless not restricted to seabirds. Polythene bags drifting in ocean currents look much like the prey items targeted by turtles (Mattlin and Cawthorn, 1986; Gramentz, 1988; Bugoni et al., 2001). There is evidence that their survival is beinghindered by plastic debris (Duguy et al., 1998), with youngsea turtles beingparticularly vulnerable (Carr, 1987). A youngmale pygmy sperm whale (Kogiabreviceps) stranded alive in Texas, USA, died in a holding tank 11 days later (Tarpley and Marwitz, 1993). The necropsy showed that the first two stomach compartments were completely occluded by plastic debris (garbage can liner, a bread wrapper, a corn chip bag and two other pieces of plastic sheeting). The death of an endangered West Indian manatee (Trichechusmanatus) in 1985 in Florida was apparently caused by a large piece of plastic that blocked its digestive tract (Laist, 1987). Deaths of the also endangered Florida manatee (Trichechusmanatuslatirostris) have too been blamedon plastic debris in their guts (Beck and Barros, 1991). Secchi and Zarzur (1999) blamed the fate of a dead Blainville's beaked whale (Mesoplodondensirostris) washed ashore in Brazil to a bundle of plastic threads found in the animals' stomach. Coleman and Wehle(1984) and Baird and Hooker (2000) cited other cetaceans that have been reported with ingested plastics, such as the killer whale (Orcinus orca). Some species of fish off the British coast were found to contain plastic cups within their guts that would eventually lead to their death (Anon, 1975). In the Bristol Channel in the summer of 1973, 21% of the flounders (Platichthyesflesus) were found to contain polystyrene spherules (Kartar et al., 1976). The same study found, that in some areas, 25% of sea snails (Liparisliparis) (a fish, despite its common name) were heavily contaminated by such debris. In the New England coast, USA, the same type of spherules were found in 8 out of 14 fish species examined, and in some species 33% of individuals were contaminated (Carpenter et al., 1972).

Plastics ingestion and polychlorinated biphenyls

Over the past 20 years polychlorinated biphenyls (PCBs) have increasingly polluted marine food webs, and are prevalent in seabirds (Ryan et al., 1988). Though their adverse effects may not always be apparent, PCBs lead to reproductive disorders or death, they increase risk of diseases and alter hormone levels (Ryan et al., 1988; Lee et al., 2001). These chemicals have a detrimental effect on marine organisms even at very low levels and plastic pellets could be a route for PCBs intomarine food chains (Carpenter and Smith, 1972; Carpenter et al., 1972; Rothstein, 1973; Zitko and Hanlon, 1991; Mato et al., 2001). Ryan et al. (1988) studyinggreat shearwaters (Puffinus gravis), obtained evidence that PCBs in the birds' tissues were derived from ingested plastic particles. Their study presented the first indication that seabirds can assimilate chemicals from plastic particles in their stomachs, indicatinga dangerous pathway for potentially harmful pollutants. Bjorndal et al. (1994) worked with sea turtles and came to a similar conclusion, that the absorption of toxins as sublethal effects of debris ingestion has an unknown, but potentially great negative effect on their demography. Plastic debris can be a source of other contaminants besides PCBs. Accordingto Zitko (1993) low molecular weight compounds from polystyrene particles are leached by seawater, and the fate and effects of such compounds on aquatic biota are not known.

Entanglement in plastic debris

Entanglement in plastic debris, especially in discarded fishinggear, is a very serious threat to marine animals. According to Schrey and Vauk (1987) entanglement accounts for 13–29% of the observed mortality of gannets (Sula bassana) at Helgoland, German Bight.Entanglement also affects the survival of the endangered sea turtles (Carr, 1987), but it is a particular problem for marine mammals, such as fur seals, which are both curious and playful (Mattlin and Cawthorn, 1986). Youngfur seals are attracted to floatingdebris and dive and roll about in it (Mattlin and Cawthorn, 1986). They will approach objects in the water and often poke their heads into loops and holes (Fowler, 1987; Laist, 1987). Though the plastic loops can easily slip onto their necks, the lie of the longguard hairs prevents the strapping from slipping off (Mattlin and Cawthorn, 1986). Many seal pups grow into the plastic collars, and in time as it tightens, the plastic severs the seal's arteries or strangles it (Weisskopf, 1988). Ironically, once the entangled seal dies and decomposes, the plastic band is free to be picked up by another victim (DOC, 1990; Mattlin and Cawthorn, 1986), as some plastic articles may take 500 years to decompose (Gorman, 1993; UNESCO, 1994). Once an animal is entangled, it may drown, have its ability to catch food or to avoid predators impaired, or incur wounds from abrasive or cuttingaction of attached debris (Laist, 1987, 1997; Jones, 1995). According to Feldkamp et al. (1989) entanglement can greatly reduce fitness, as it leads to a significant increase in energetic costs of travel. In the PribiloffIslands alone, in the BeringSea west of Alaska, the percentage of northern fur seals returning to rookeries entangled in plastic bands rose from nil in 1969 to 38% in 1973 (Mattlin and Cawthorn, 1986). The population in 1976 was decliningat a rate of 4–6% a year, and scientists estimated that up to 40,000 fur seals a year were beingkilled by plastic entanglement (Weisskopf, 1988). A decline due to entanglement also seems to be occurringwith Antarctic fur seals (Arctocephalusgazella) (Croxall et al., 1990). Pemberton et al. (1992) and Jones (1995) both reported similar concern for Australian fur seals (Arctocephaluspusillusdoriferus). At South-east Farallon Island, Northern California, a survey from 1976–1988 observed 914 pinnipeds entangled in or with body constrictions from synthetic materials (Hanni and Pyle, 2000). Lost or abandoned fishing nets pose a particular greatrisk (Jones, 1995). These ''ghost nets'' continue to catch animals even if they sink or are lost on the seabed (Laist, 1987). In 1978, 99 dead seabirds and over 200 dead salmon were counted during the retrieval of a 1500 m ghost net south of the Aleutian Islands (DeGange and Newby, 1980). In a survey done in 1983/84 off the coast of Japan, it was estimated that 533 fur seals were entangled and drowned in nets lost in the area (Laist, 1987). Whales are also victims, as ''they sometimes lunge for schools of fish and surface with netting caught in their mouths or wrapped around their heads and tails'' (Weisskopf, 1988).

Plastic ''scrubbers''

Studies (Gregory, 1996; Zitko and Hanlon, 1991) have drawn attention to an inconspicuous and previously overlooked form of plastics pollution: small fragments of plastic (usually up to 0.5 mm across) derived from hand cleaners, cosmetic preparations and air blast cleaning media. The environmental impact of these particles, as well as similar sized flakes from degradation of larger plastic litter, has not been properly established yet. In New Zealand and Canada, polyethylene and polystyrene scrubber grains respectively were identified in the cleansing preparations available in those markets, sometimes in substantial quantities (Gregory, 1996). In air blasting technology, polyethylene particles are used for stripping paint from metallic surfaces and cleaning engine parts, and can be recycled up to 10 times before they have to be discarded, sometimes significantly contaminated by heavy metals (Gregory, 1996). Once discarded they enter into foul water or reticulate sanitary systems, and though some may be trapped during sewage treatment, most will be discharged into marine waters; and as they float, they concentrate on surface waters and are dispersed by currents (Gregory, 1996). There are many possible impacts of these persistent particles on the environment (Zitko and Hanlon, 1991). For instance, heavy metals or other contaminants could be transferred to filter feedingorganisms and other invertebrates, ultimately reachinghigher trophic levels (Gregory, 1996).

DISCUSSION AND RECOMMENDATIONS

Though the seas cover the majority of our planet's surface, far less is known about the biodiversity of marine environments then that of terrestrial systems (Ormond et al., 1997). Irish and Norse (1996) examined all 742 papers published in the journal Conservation Biology and found that only 5% focused on marine ecosystems and species, compared with 67% on terrestrial and 6% on freshwater. As a result of this disparity, marine conservation biology severely lags behind the terrestrial counterpart (Murphy and Duffus, 1996), and this gap of knowledge poses major problems for conservation of marine biodiversity and must be addressed. This study shows that there is overwhelmingevidence that plastic pollution is a threat to marine biodiversity, already at risk from overfishing, climate change and other forms of anthropogenic disturbance. So far however, that evidence is basically anecdotal. There is a need for more research (especially longterm monitoring) to assess the actual threat posed by plastic debris to marine species. The research information would provide input for conservation management, strengthen the basis for educational campaigns, and also provide marine scientists with better evidence that could be used to demand from the authorities more effort to mitigate the problem. Due to the longlife of plastics on marine ecosystems, it is imperative that severe measures are taken to address the problem at both international and national levels, since even if the production and disposal of plastics suddenly stopped, the existingdebris would continue toharm marine life for many decades.

PLASTICS POLLUTION AND LEGISLATION

There have been nevertheless some attempts to promote the conservation of the world's oceans through international legislation, such as the establishment of the 1972 Convention on the Prevention of Marine Pollution by DumpingWastes and Other Matter (the London DumpingConvention or LDC). The most important legislation addressing the increasing problem of marine pollution is probably the 1978 Protocol to the International Convention for the Prevention of Pollution from Ships (MARPOL), which recognised that vessels present a significant and controllable source of pollution into the marine environment (Lentz, 1987). The Annex V of MARPOL is the key international authority for controllingship sources of marine debris (Ninaber, 1997), and came into effect in 1988 (Clark, 1997). It ''restricts at sea discharge of garbage and bans at sea disposal of plastics and other synthetic materials such as ropes, fishing nets, and plastic garbage bags with limited exceptions'' (Pearce, 1992). More importantly, the Annex V applies to all watercraft, includingsmallrecreational vessels (Nee, 1990). Seventy-nine countries have so far ratified the Annex V (CMC, 2002), and the signatory countries are required to take steps to fully implement it. Annex V also refers to ''special areas'', includingthe Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea and the ''Gulfs'' areas, where discharge regulations are far more strict (Lentz, 1987). Nevertheless, the legislation is still widely ignored, and ships are estimated to discard 6.5 million tons per year of plastics (Clark, 1997). Observers on board foreign fishing vessels within Australian waters, for instance, found that at least one-third of the vessels did not comply with the MARPOL regulations on the disposal of plastics (Jones, 1995). As Kirkley and McConnell (1997) pointed out, the compliance of individuals with laws is partly a question of economics. They believe most people (or companies) would not change their attitude if stopping the dumping of plastics into the ocean were economically costly. Legislation at the national level also plays an important role. Individual countries can be effective through their own legislation, such as laws that require degradability standards or that encourage recycling (Bean, 1987). In the USA, for instance, the Marine Plastics Pollution Research and Control Act of 1987 not only adopted Annex V, but also extended its application to US Navy vessels (Nee, 1990; Bentley, 1994). Ports and ocean carriers have to adapt to these regulations prohibitingthe disposal of plastics at sea (Nee, 1990). The biggest difficulty however when it comes to legislation, is to actually enforce it in an area as vast as the world's oceans. It is therefore essential that neighbouringcountries work together in order to ensure that all vessels comply with Annex V.

FINAL REMARKS

Ultimately, all sectors of the community should taketheir individual steps. Thinking globally and acting locallyis a fundamental attitude to reduce such an environmental threat. A combination of legislation and the enhancement of ecological consciousness through education is likely to be the best way to solve such environmental problems. The general public and the scientific community have also the responsibility of ensuring that governments and businesses change their attitudes towards the problem. It is nevertheless certain that the environmental hazards that threaten the oceans' biodiversity, such as the pollution by plastic debris, must be urgently addressed. ''The last fallen mahogany would lie perceptibly on the landscape, and the last black rhino would be obvious in its loneliness, but a marine species may disappear beneath the waves unobserved and the sea would seem to roll on the same as always'' (Ray, 1988, p. 45).

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IMPACT OF PLASTIC DEBRIS ON MARINE ENVIRONMENT OF BANGLADESH: A REVIEW

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Keywords: Plastic debris; Pollution; Marine environment, Bangladesh.

ABSTRACT

Plastic debris is one of the obstacles which hasnegative impact on marine environment. Plastic debris dispatched to fish, sea birds, marine reptiles and marine mammals through ingestion and entanglement. The deleterious effects of plastic debris on the marine environment were reviewed by bringing together most of the literature published so far on the topic. A large number of marine species is known to be harmed and/or killed by plastic debris, which could jeopardize their survival, especially since many are already endangered by other forms of anthropogenic activities.Bangladesh has many attractivetourist places for foreigners and local visitors. The world largest sea-beach Cox's Bazar, Saint Martine and Kuakata are one of them. People come to see these places each and every year. Throughout the time of passing a good mausoleum, People useplastic things like bottle, polythene, chips packet, plastic bags, balloons, cigarette lighters, beer, juice, fishing net, clean containers and many of others.Basically this kind of plastic goes to the water and effect both ocean environment and marine species. The Research focuses on the impact of plastic debris on marine environment, besides it can be perceived how plastic does effect on ocean environment and how it can be impeded as well as how to increase a huge apprehension among the people. The research is also for promoting a more sustainable lifestyle and educate people about the prevalence of plastic debris on oceans and attractive places that how deadly it can be to marine life.

INTRODUCTION

Marine animals are mostly affected through entanglement in and ingestion of plastic litter. Other less known threats include the use of plastic debris by ‘‘invader’’ species and the absorption of polychlorinated biphenyls from ingested plastics. Less conspicuous forms, such as plastic pellets and ‘‘scrubbers’’ are also hazardous. Human activities are responsible for a major declineof the world’s biological diversity, and the problem is socritical that combined human impacts could have accelerated present extinction rates to 1000–10,000 timesthe natural rate (Lovejoy, 1997). In the oceans, thethreat to marine life comes in various forms, such asoverexploitation and harvesting, dumping of waste, pollution, alien species, land reclamation, dredging andglobal climate change (Beatley, 1991; National Research Council, 1995; Irish and Norse, 1996; Ormond et al.,1997; Tickel, 1997; Snelgrove, 1999). One particularform of human impact constitutes a major threat tomarine life: the pollution by plastic debris. To address the problem of plastic debris in the oceans is a difficult task, and a variety of approaches are urgently required. Some of the ways to mitigate the problem are discussed.

PLASTIC DEBRIS

Plastic debris is defined as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great lake. Plastics are synthetic organic polymers, and thoughthey have only existed for just over a century (Gorman,1993), by 1988 in the United States alone, 30 milliontons of plastic were produced annually (O’Hara et al.,1988). The versatility of these materials has lead to a great increase in their use over the past three decades and they have rapidly moved into all aspects of everyday life (Hansen, 1990; Laist, 1987). Plastics are lightweight, strong, durable and cheap (Laist, 1987), characteristics that make them suitable for the manufacture of a verywide range of products. These same properties happento be the reasons why plastics are a serious hazard to the environment (Pruter, 1987; Laist, 1987). Since they arealso buoyant, an increasingload of plastic debris is beingdispersed over longdistances, and when they finallysettle in sediments they may persist for centuries (Hansen, 1990; Ryan, 1987b; Goldberg, 1995, 1997).The threat of plastics to the marine environment hasbeen ignored for a long time, and its seriousness hasbeen only recently recognised (Stefatos et al., 1999).Fergusson (1974) for instance, then a member of theCouncil of the British Plastics Federation and a Fellowof the Plastics Institute, stated that ‘‘plastics litter is avery small proportion of all litter and causes no harm tothe environment except as an eyesore’’. His commentsnot only illustrates how the deleterious environmentaleffects of plastics were entirely overlooked, but also that,apparently, even the plastics industry failed to predictthe great boom in the production and use of plasticsof the past 30 years. In the marine environment, theperceived abundance of marine life and the vastnessof the oceans have lead to the dismissal of the proliferation of plastic debris as a potential hazard (Laist,1987)The literature on marine debris leaves no doubt thatplastics make-up most of the marine litter worldwide(Table 1). Though the methods were not assessed toensure that the results were comparable, Table 1 clearlyindicates the predominance of plastics amongst themarine litter, and its proportion consistently varies between 60% and 80% of the total marine debris (Gregoryand Ryan, 1997).It is not possible to obtain reliable estimates of theamount of plastic debris that reaches the marine environment, but the quantities are nevertheless quite substantial. In 1975 the world’s fishing fleet alone dumped into the sea approximately 135,400 tons of plastic fishinggear and 23,600 tons of synthetic packaging material (Cawthorn, 1989; DOC, 1990). Horsman (1982) estimated that merchant ships dump 639,000 plastic containers each day around the world, and ships aretherefore, a major source of plastic debris (Shaw, 1977; Shaw and Mapes, 1979). Recreational fishingand boatsare also responsible for dumpinga considerable amountof marine debris, and accordingto the US Coast Guardthey dispose approximately 52% of all rubbish dumpedin US waters (UNESCO, 1994).Plastic materials also end up in the marine environment when accidentally lost, carelessly handled (Wilber,1987) or left behind by beachgoers (Pruter, 1987). Theyalso reach the sea as litter carried by rivers and municipal drainage systems (Pruter, 1987; Williams and Simmons, 1997). There are major inputs of plastic litterfrom land-based sources in densely populated or industrialized areas (Pruter, 1987; Gregory, 1991)

Table 1. Proportion of plastics among marine debris worldwide (per number of items)(Sciences & Zealand, 2002)

Locality	Litter type	Percentage of debris items represented by plastics	Source
1992 International Coastal Cleanups	Shoreline	59	Anon (1990)
St. Lucia, Caribbean	Beach	51	Corbin and Singh (1993)
Dominica, Caribbean	Beach	36	Corbin and Singh (1993)
Curacao, Caribbean	Beach	40/64	Debrot et al. (1999)
Bay of Biscay, NE Atlantic	Seabed	92	Galgani et al. (1995a)
NW Mediterranean	Seabed	77	Galgani et al. (1995b)
French Mediterranean Coast	Deep sea floor	>70	Galgani et al. (1996)
European coasts	Sea floor	>70	Galgani et al. (2000)
Caribbean coast of Panama	Shoreline	82	Garrity and Levings (1993)
Georgia, USA	Beach	57	Gilligan et al. (1992)
5 Mediterranean beaches	Beach	60–80	Golik (1997)
50 South African beaches	Beach	>90	Gregory and Ryan (1997)
88 sites in Tasmania	Beach	65	Gregory and Ryan (1997)
Argentina	Beach	37–72	Gregory and Ryan (1997)
9 Sub-Antarctic Islands	Beach	51–88	Gregory and Ryan (1997)
South Australia	Beach	62	Gregory and Ryan (1997)
Kodiak Is, Alaska	Seabed	47–56	Hess et al. (1999)
Tokyo Bay, Japan	Seabed	80–85	Kanehiro et al. (1995)
North Pacific Ocean	Surface waters	86	Laist (1987)
Mexico	Beach	60	Lara-Dominguez et al. (1994)
Transkei, South Africa	Beach	83	Madzena and Lasiak (1997)
National Parks in USA	Beach	88	Manski et al. (1991)
Mediterranean Sea	Surface waters	60–70	Morris (1980)
Cape Cod, USA	Beach/harbour	90	Ribic et al. (1997)
4 North Atlantic harbors, USA	Harbour	73–92	Ribic et al. (1997)
Is. Beach State Park, New Jersey, USA	Beach	73	Ribic (1998)
Halifax Harbour, Canada	Beach	54	Ross et al. (1991)
Price Edward Is., Southern Ocean	Beach	88	Ryan (1987b)
Gough Is., Southern Ocean	Beach	84	Ryan (1987b)
Heard Is., Southern Ocean	Beach	51	Slip and Burton (1991)
FogBay, N. Australia	Beach	32	Whiting(1998)
South Wales, UK	Beach	63	Williams and Tudor (2001)

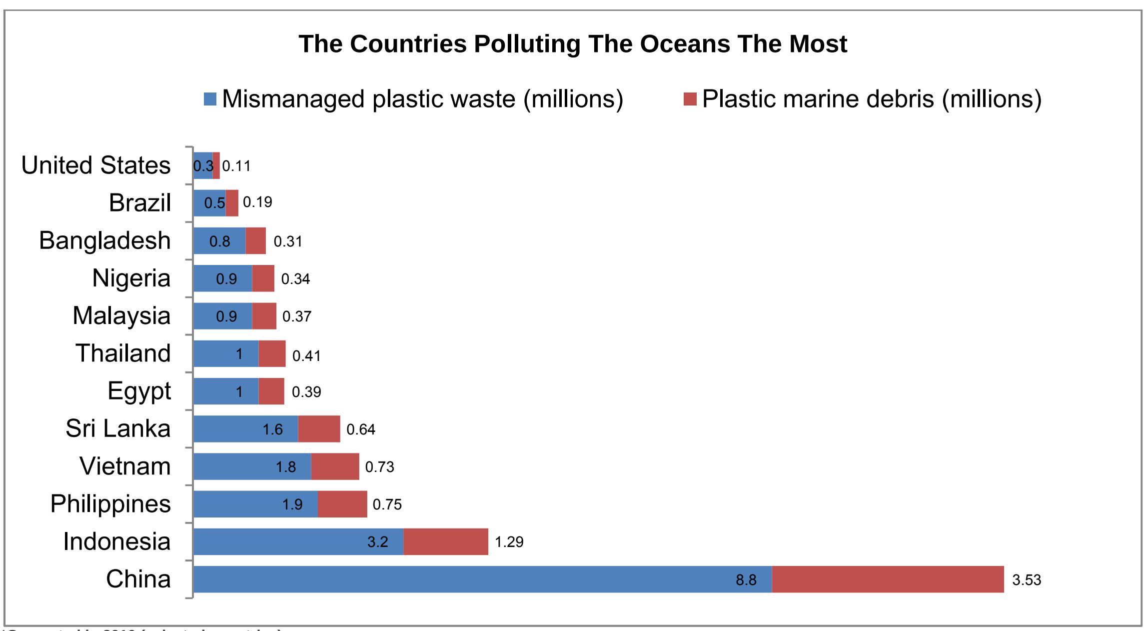
Results are arranged in alphabetical order by author.

[a]76% of total consisted of synthetic line for long-line fisheries.

most in the form of packaging. A study on Halifax Harbourin Canada, for instance, showed that 62% of the totallitter in the harbour originated from recreation andland-based sources (Ross et al., 1991). In contrast, inbeaches away from urban areas (e.g. Alaska) most of thelitter is made up of fishing debris. Not only the aesthetically distasteful plastic litter, but also less conspicuous small plastic pellets and granulesare a threat to marine biota. The latter are found inlarge quantities on beaches (Gregory, 1978, 1989; Shiber, 1979, 1982, 1987; Redford et al., 1997), and are theraw material for the manufacture of plastic productsthat end up in the marine environment through accidental spillage during transport and handling, not aslitter or waste as other forms of plastics (Gregory, 1978; Shiber, 1979; Redford et al., 1997). Their sizes usuallyvary from 2–6 mm, though occasionally much largerones can be found (Gregory, 1977, 1978).Plastic pellets can be found across the SouthwestPacific in surprisingly high quantities for remote andnon-industrialised places such as Tonga, Rarotonga and Fiji (Gregory, 1999). In New Zealand beaches they arefound in quite considerable amounts, in counts of over100,000 raw plastic granules per meter of coast (Gregory, 1989), with greatest concentration near importantindustrial centres (Gregory, 1977). Their durability inthe marine environment is still uncertain but they seemto last from 3 to 10 years, and additives can probablyextend this period to 30–50 years (Gregory, 1978).Unfortunately, the dumpingof plastic debris into theocean is an increasingproblem. For instance, surveyscarried out in South African beaches 5 years apart, showed that the densities of all plastic debris have increased substantially (Ryan and Moloney, 1990). InPanama, experimentally cleared beaches regained about50% of their original debris load after just 3 months (Garrity and Levings, 1993). Even sub antarctic islands are becoming increasingly affected by plastic debris, especially fishinglines (Walker et al., 1997). Benton (1995) surveyed islands in the South Pacific and got to the alarming conclusion that beaches in remote areas hada comparable amount of garbage to a beach in the industrialized western world.

Bangladesh a major polluter of the world's oceans

Bangladesh has been listed among the top polluters of the world's oceans. The country ranked 10th in polluting the oceans in 2010, said a report compiled by a team of researchers based in the United States and Australia, who analyzed plastic waste levels in the world's seas. The team of researchers was led by Jenna Jambeck, an environmental engineer at the University of Georgia. Bangladesh dumped 0.79 million metric tons of plastic waste in to the oceans in 2010, the Statista Portal reports. (Study: Bangladesh a major polluter of the world's oceans, 2018)



***Generated in 2010 (selected countries)**
Source: The Wall Street Journal
Originally this infographic incorrectly labelled the total amount of mismanaged plastic waste as the amount found in the water.

Figure 1. Countries polluting the oceans the most.

The threats from plastics pollution to marine biota

There is still relatively little information on the impactof plastics pollution on the ocean's ecosystems (Quayle, 1992; Wilber, 1987). There is however an increasingknowledge about their deleterious impacts on marinebiota (Goldberg, 1995). The threats to marine life areprimarily mechanical due to ingestion of plastic debrisand entanglement in packaging bands, synthetic ropesand lines, or drift nets (Laist, 1987, 1997; Quayle, 1992).Since the use of plastics continues to increase, so doesthe amount of plastics pollutingthe marine environment. Robards et al. (1995) examined the gut content ofthousands of birds in two separate studies and foundthat the ingestion of plastics by seabirds had significantly increased duringthe 10–15 years interval betweenstudies. A study done in the North Pacific (Blight andBurger, 1997) found plastic particles in the stomachs of8 of the 11 seabird species caught as bycatch. The list ofaffected species indicates that marine debris are affectinga significant number of species (Laist, 1997). It affects atleast 267 species worldwide, including86% of all seaturtle species, 44% of all seabird species, and 43% of allmarine mammal species (Laist, 1997). The problem maybe highly underestimated as most victim are likely to goundiscovered over vast ocean areas, as they either sinkor are eaten by predators (Wolfe, 1987).There is also potential danger to marine ecosystemsfrom the accumulation of plastic debris on the seafloor. According to Kanehiro et al. (1995) plasticsmade up 80–85% of the seabed debris in Tokyo Bay, animpressive figure considering that most plastic debrisare buoyant. The accumulation of such debris can inhibit the gas exchange between the overlying watersand the pore waters of the sediments, and the resultinghypoxia or anoxia in the benthos can interfere with thenormal ecosystem functioning, and alter the make-upof life on the sea floor (Goldberg, 1994). Moreover, asfor pelagic organisms, benthic biota is likewise subjected to entanglement and ingestion hazards (Hesset al., 1999)

Ingestion of plastics

A study done on 1033 birds collected off the coast ofNorth Carolina in the USA found that individuals from55% of the species recorded had plastic particles in theirguts (Moser and Lee, 1992). The authors obtained evidence that some seabirds select specific plastic shapes and colors, mistaking them for potential prey items.Shaw and Day (1994) came to the same conclusions, asthey studied the presence of floating plastic particles of different forms, colors and sizes in the North Pacific,findingthat many are significantly under-represented.Carpenter et al. (1972) examined various species of fishwith plastic debris in their guts and found that onlywhite plastic spherules had been ingested, indicating thatthey feed selectively. A similar pattern of selective ingestion of white plastic debris was found for loggerhead sea turtles (Carettacaretta) in the Central Mediterranean (Gramentz, 1988). Amongseabirds, the ingestionof plastics is directly correlated to foraging strategiesand technique, and diet (Azzarello and Van-Vleet, 1987; Ryan, 1987a; Moser and Lee, 1992; Laist, 1987, 1997).For instance, planktivores are more likely to confuseplastic pellets with their prey than do piscivores, therefore the former have a higher incidence of ingested plastics (Azzarello and Van-Vleet, 1987). Ryan (1988) performed an experiment with domestic chickens (Gallus domesticus) to establish the potentialeffects of ingested plastic particles on seabirds. Theywere fed with polyethylene pellets and the results indicated that ingested plastics reduce meal size by reducingthe storage volume of the stomach and the feedingstimulus. He concluded that seabirds with large plasticloads have reduced food consumption, which limits theirability to lay down fat deposits, thus reducingfitness.Connors and Smith (1982) had previously reached thesame conclusion, as their study indicated that the ingestion of plastic particles hindered formation of fatdeposits in migrating red phalaropes (Phalaropusfulicarius), adversely affecting long-distance migration andpossibly their reproductive effort on breedinggrounds.Spear et al. (1995) however, provided probably the firstsolid evidence for a negative relationship betweennumber of plastic particles ingested and physical condition (body weight) in seabirds from the tropicalPacific.Other harmful effects from the ingestion of plasticsinclude blockage of gastric enzyme secretion, diminishedfeedingstimulus, lowered steroid hormone levels, delayed ovulation and reproductive failure (Azzarello andVan-Vleet, 1987). The ingestion of plastic debris bysmall fish and seabirds for instance, can reduce fooduptake, cause internal injury and death followingblockage of intestinal tract (Carpenter et al., 1972; Rothstein, 1973; Ryan, 1988; Zitko and Hanlon, 1991).The extent of the harm, however, will vary amongspecies. Procellariiformes for example, are more vulnerabledue to their inability to regurgitate ingested plastics (Furness, 1985; Azzarello and Van-Vleet, 1987). Laist (1987) and Fry et al. (1987) observed that adultsthat manage to regurgitate plastic particles could passthem onto the chicks duringfeeding. The chicks of Laysan albatrosses (Diomedeaimmutabilis) in the Hawaiian Islands for instance, are unable to regurgitatesuch materials which accumulate in their stomachs, becoming a significant source of mortality, as 90% of thechicks surveyed had some sort of plastic debris in their upper GI tract (Fry et al., 1987). Even Antarctic and sub-Antarctic seabirds are subjected to this hazard (Slip et al., 1990). Wilson's storm-petrels (Oceanitesoceanicus) for instance, pick up plastic debris while wintering in other areas (Van Franeker and Bell, 1988). A whitefaced storm-petrel (Pelagodroma marina) found dead at the isolated Chatham Islands (New Zealand) at a breedingsite, had no food in its stomach while its gizzard was packed with plastic pellets (Bourne and Imber, 1982). The harm from ingestion of plastics is nevertheless not restricted to seabirds. Polythene bags drifting in ocean currents look much like the prey items targeted by turtles (Mattlin and Cawthorn, 1986; Gramentz, 1988; Bugoni et al., 2001). There is evidence that their survival is beinghindered by plastic debris (Duguy et al., 1998), with youngsea turtles beingparticularly vulnerable (Carr, 1987). A youngmale pygmy sperm whale (Kogiabreviceps) stranded alive in Texas, USA, died in a holding tank 11 days later (Tarpley and Marwitz, 1993). The necropsy showed that the first two stomach compartments were completely occluded by plastic debris (garbage can liner, a bread wrapper, a corn chip bag and two other pieces of plastic sheeting). The death of an endangered West Indian manatee (Trichechusmanatus) in 1985 in Florida was apparently caused by a large piece of plastic that blocked its digestive tract (Laist, 1987). Deaths of the also endangered Florida manatee (Trichechusmanatuslatirostris) have too been blamedon plastic debris in their guts (Beck and Barros, 1991). Secchi and Zarzur (1999) blamed the fate of a dead Blainville's beaked whale (Mesoplodondensirostris) washed ashore in Brazil to a bundle of plastic threads found in the animals' stomach. Coleman and Wehle(1984) and Baird and Hooker (2000) cited other cetaceans that have been reported with ingested plastics, such as the killer whale (Orcinus orca). Some species of fish off the British coast were found to contain plastic cups within their guts that would eventually lead to their death (Anon, 1975). In the Bristol Channel in the summer of 1973, 21% of the flounders (Platichthyesflesus) were found to contain polystyrene spherules (Kartar et al., 1976). The same study found, that in some areas, 25% of sea snails (Liparisliparis) (a fish, despite its common name) were heavily contaminated by such debris. In the New England coast, USA, the same type of spherules were found in 8 out of 14 fish species examined, and in some species 33% of individuals were contaminated (Carpenter et al., 1972).

Plastics ingestion and polychlorinated biphenyls

Over the past 20 years polychlorinated biphenyls (PCBs) have increasingly polluted marine food webs, and are prevalent in seabirds (Ryan et al., 1988). Though their adverse effects may not always be apparent, PCBs lead to reproductive disorders or death, they increase risk of diseases and alter hormone levels (Ryan et al., 1988; Lee et al., 2001). These chemicals have a detrimental effect on marine organisms even at very low levels and plastic pellets could be a route for PCBs intomarine food chains (Carpenter and Smith, 1972; Carpenter et al., 1972; Rothstein, 1973; Zitko and Hanlon, 1991; Mato et al., 2001). Ryan et al. (1988) studyinggreat shearwaters (Puffinus gravis), obtained evidence that PCBs in the birds' tissues were derived from ingested plastic particles. Their study presented the first indication that seabirds can assimilate chemicals from plastic particles in their stomachs, indicatinga dangerous pathway for potentially harmful pollutants. Bjorndal et al. (1994) worked with sea turtles and came to a similar conclusion, that the absorption of toxins as sublethal effects of debris ingestion has an unknown, but potentially great negative effect on their demography. Plastic debris can be a source of other contaminants besides PCBs. Accordingto Zitko (1993) low molecular weight compounds from polystyrene particles are leached by seawater, and the fate and effects of such compounds on aquatic biota are not known.

Entanglement in plastic debris

Entanglement in plastic debris, especially in discarded fishinggear, is a very serious threat to marine animals. According to Schrey and Vauk (1987) entanglement accounts for 13–29% of the observed mortality of gannets (Sula bassana) at Helgoland, German Bight.Entanglement also affects the survival of the endangered sea turtles (Carr, 1987), but it is a particular problem for marine mammals, such as fur seals, which are both curious and playful (Mattlin and Cawthorn, 1986). Youngfur seals are attracted to floatingdebris and dive and roll about in it (Mattlin and Cawthorn, 1986). They will approach objects in the water and often poke their heads into loops and holes (Fowler, 1987; Laist, 1987). Though the plastic loops can easily slip onto their necks, the lie of the longguard hairs prevents the strapping from slipping off (Mattlin and Cawthorn, 1986). Many seal pups grow into the plastic collars, and in time as it tightens, the plastic severs the seal's arteries or strangles it (Weisskopf, 1988). Ironically, once the entangled seal dies and decomposes, the plastic band is free to be picked up by another victim (DOC, 1990; Mattlin and Cawthorn, 1986), as some plastic articles may take 500 years to decompose (Gorman, 1993; UNESCO, 1994). Once an animal is entangled, it may drown, have its ability to catch food or to avoid predators impaired, or incur wounds from abrasive or cuttingaction of attached debris (Laist, 1987, 1997; Jones, 1995). According to Feldkamp et al. (1989) entanglement can greatly reduce fitness, as it leads to a significant increase in energetic costs of travel. In the PribiloffIslands alone, in the BeringSea west of Alaska, the percentage of northern fur seals returning to rookeries entangled in plastic bands rose from nil in 1969 to 38% in 1973 (Mattlin and Cawthorn, 1986). The population in 1976 was decliningat a rate of 4–6% a year, and scientists estimated that up to 40,000 fur seals a year were beingkilled by plastic entanglement (Weisskopf, 1988). A decline due to entanglement also seems to be occurringwith Antarctic fur seals (Arctocephalusgazella) (Croxall et al., 1990). Pemberton et al. (1992) and Jones (1995) both reported similar concern for Australian fur seals (Arctocephaluspusillusdoriferus). At South-east Farallon Island, Northern California, a survey from 1976–1988 observed 914 pinnipeds entangled in or with body constrictions from synthetic materials (Hanni and Pyle, 2000). Lost or abandoned fishing nets pose a particular greatrisk (Jones, 1995). These ‘‘ghost nets’’ continue to catch animals even if they sink or are lost on the seabed (Laist, 1987). In 1978, 99 dead seabirds and over 200 dead salmon were counted during the retrieval of a 1500 m ghost net south of the Aleutian Islands (DeGange and Newby, 1980). In a survey done in 1983/84 off the coast of Japan, it was estimated that 533 fur seals were entangled and drowned in nets lost in the area (Laist, 1987). Whales are also victims, as ‘‘they sometimes lunge for schools of fish and surface with netting caught in their mouths or wrapped around their heads and tails’’ (Weisskopf, 1988).

Plastic ‘‘scrubbers’’

Studies (Gregory, 1996; Zitko and Hanlon, 1991) have drawn attention to an inconspicuous and previously overlooked form of plastics pollution: small fragments of plastic (usually up to 0.5 mm across) derived from hand cleaners, cosmetic preparations and air blast cleaning media. The environmental impact of these particles, as well as similar sized flakes from degradation of larger plastic litter, has not been properly established yet. In New Zealand and Canada, polyethylene and polystyrene scrubber grains respectively were identified in the cleansing preparations available in those markets, sometimes in substantial quantities (Gregory, 1996). In air blasting technology, polyethylene particles are used for stripping paint from metallic surfaces and cleaning engine parts, and can be recycled up to 10 times before they have to be discarded, sometimes significantly contaminated by heavy metals (Gregory, 1996). Once discarded they enter into foul water or reticulate sanitary systems, and though some may be trapped during sewage treatment, most will be discharged into marine waters; and as they float, they concentrate on surface waters and are dispersed by currents (Gregory, 1996). There are many possible impacts of these persistent particles on the environment (Zitko and Hanlon, 1991). For instance, heavy metals or other contaminants could be transferred to filter feedingorganisms and other invertebrates, ultimately reachinghigher trophic levels (Gregory, 1996).

DISCUSSION AND RECOMMENDATIONS

Though the seas cover the majority of our planet's surface, far less is known about the biodiversity of marine environments then that of terrestrial systems (Ormond et al., 1997). Irish and Norse (1996) examined all 742 papers published in the journal Conservation Biology and found that only 5% focused on marine ecosystems and species, compared with 67% on terrestrial and 6% on freshwater. As a result of this disparity, marine conservation biology severely lags behind the terrestrial counterpart (Murphy and Duffus, 1996), and this gap of knowledge poses major problems for conservation of marine biodiversity and must be addressed. This study shows that there is overwhelmingevidence that plastic pollution is a threat to marine biodiversity, already at risk from overfishing, climate change and other forms of anthropogenic disturbance. So far however, that evidence is basically anecdotal. There is a need for more research (especially longterm monitoring) to assess the actual threat posed by plastic debris to marine species. The research information would provide input for conservation management, strengthen the basis for educational campaigns, and also provide marine scientists with better evidence that could be used to demand from the authorities more effort to mitigate the problem. Due to the longlife of plastics on marine ecosystems, it is imperative that severe measures are taken to address the problem at both international and national levels, since even if the production and disposal of plastics suddenly stopped, the existingdebris would continue toharm marine life for many decades.

PLASTICS POLLUTION AND LEGISLATION

There have been nevertheless some attempts to promote the conservation of the world's oceans through international legislation, such as the establishment of the 1972 Convention on the Prevention of Marine Pollution by DumpingWastes and Other Matter (the London DumpingConvention or LDC). The most important legislation addressing the increasing problem of marine pollution is probably the 1978 Protocol to the International Convention for the Prevention of Pollution from Ships (MARPOL), which recognised that vessels present a significant and controllable source of pollution into the marine environment (Lentz, 1987). The Annex V of MARPOL is the key international authority for controllingship sources of marine debris (Ninaber, 1997), and came into effect in 1988 (Clark, 1997). It ''restricts at sea discharge of garbage and bans at sea disposal of plastics and other synthetic materials such as ropes, fishing nets, and plastic garbage bags with limited exceptions'' (Pearce, 1992). More importantly, the Annex V applies to all watercraft, includingsmallrecreational vessels (Nee, 1990). Seventy-nine countries have so far ratified the Annex V (CMC, 2002), and the signatory countries are required to take steps to fully implement it. Annex V also refers to ''special areas'', includingthe Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea and the ''Gulfs'' areas, where discharge regulations are far more strict (Lentz, 1987). Nevertheless, the legislation is still widely ignored, and ships are estimated to discard 6.5 million tons per year of plastics (Clark, 1997). Observers on board foreign fishing vessels within Australian waters, for instance, found that at least one-third of the vessels did not comply with the MARPOL regulations on the disposal of plastics (Jones, 1995). As Kirkley and McConnell (1997) pointed out, the compliance of individuals with laws is partly a question of economics. They believe most people (or companies) would not change their attitude if stopping the dumping of plastics into the ocean were economically costly. Legislation at the national level also plays an important role. Individual countries can be effective through their own legislation, such as laws that require degradability standards or that encourage recycling (Bean, 1987). In the USA, for instance, the Marine Plastics Pollution Research and Control Act of 1987 not only adopted Annex V, but also extended its application to US Navy vessels (Nee, 1990; Bentley, 1994). Ports and ocean carriers have to adapt to these regulations prohibitingthe disposal of plastics at sea (Nee, 1990). The biggest difficulty however when it comes to legislation, is to actually enforce it in an area as vast as the world's oceans. It is therefore essential that neighbouringcountries work together in order to ensure that all vessels comply with Annex V.

FINAL REMARKS

Ultimately, all sectors of the community should taketheir individual steps. Thinking globally and acting locallyis a fundamental attitude to reduce such an environmental threat. A combination of legislation and the enhancement of ecological consciousness through education is likely to be the best way to solve such environmental problems. The general public and the scientific community have also the responsibility of ensuring that governments and businesses change their attitudes towards the problem. It is nevertheless certain that the environmental hazards that threaten the oceans' biodiversity, such as the pollution by plastic debris, must be urgently addressed. ''The last fallen mahogany would lie perceptibly on the landscape, and the last black rhino would be obvious in its loneliness, but a marine species may disappear beneath the waves unobserved and the sea would seem to roll on the same as always'' (Ray, 1988, p. 45).

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"Household Solid Waste Management in Khulna City: Environment and Health concern"

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ABSTRACT:

The more a country's population, the more generation of solid wastes, especially Household Solid Wastes. Like other developing countries, Bangladesh is facing problem to manage solid wastes as it is going through high urbanization and Industrialization processes. 1.5 million People live here and Khulna is the third largest city of Bangladesh. Many areas, there are insufficient amount of dustbins. If there are dustbins, there is lacking in monitoring and maintenance, irregular cleaning and lack of public awareness. This situation is creating a lot of environmental pollution and health problems like Air Pollution, Water Pollution, and different kinds of diseases. The present scenario is investigated, Problems are found out concerning environment and health, and effective recommendations are delivered from this study. Number of Dustbins and authorized dump sites should be increased. People should be made aware and regular waste collecting system must be exercised.

Introduction:

Current goal of environmental sustainability is to create balance between economic growth that means development and environmental protection so that no environmental elements faced harm in a way which may lead to damage directly or indirectly to human beings, earth components and living organisms. In case of solid waste management system, this an integrated system having some interrelated components like collecting wastes from different sources. In the sdeveloping countries there are a lot of cities that are facing serious health and environmental problems due to pollution from solid waste. (P. T. Nguyen, 2011) Already many studies has been conducted to see the health and environment problem due to pollution from solid waste & the result shows that there is an effective relation between solid waste management and its health and environmental impacts. The end from this and different examinations has prompted an expanding enthusiasm of analysts in the investigation identifying with ecological contamination and in addition its impacts on plants and creatures. Maybe a couple of these examinations inspected the ecological and wellbeing ramifications of strong waste transfer to individuals living in nearness of squanders dumpsites. (Nabegu, 2010). Waste that is not well managed, mainly excreta and other liquid and strong waste from families and the community, are a serious fitness threat and cause the spread of infectious sicknesses. Unattended waste lying round attracts flies, rats, and different creatures that in flip spread sickness. Generally it's far the wet waste that decomposes and releases a bad odor. This leads to unhygienic situations and thereby to an upward thrust in the health troubles. The plague outbreak in surat is a superb instance of a metropolis struggling because of the callous mind-set of the nearby frame in keeping cleanliness in the metropolis. Plastic waste is some other motive for sick fitness. Hence immoderate stable waste that is generated should be managed through taking sure preventive measures.(edugreen, n.d.) The people live beside or close to waste dumping site are generally face various health diseases from the industrial waste because those contains huge amount of chemicals leads to chemical poisoning and medical wastes to infectious diseases. (Rushton, 2003) Leachates from refuge dumps percolates into the soil and contaminate underground water. Scavengers and stray animals invade the roadside garbage and litter the waste over large area causing much aesthetic damage to the atmosphere. Waste products when burnt like plastic and rubber pollute the atmosphere with noxious fumes. Organic solid wastes emits obnoxious odor on their decomposition and make the environment polluted. (Bhattacharya BC) Certain squanders smell more awful than others. For instance, muck squanders are high in dampness and may have a high sulfur content, gypsum etc. Which can also create problems.(The National Solid Wastes Management Association (NSWMA) , 20008)

So that it is clear that improper Solid waste management can create different types of health hazards and different pollution like water pollution, soil pollution, air pollution, Odor pollution etc. Water pollution from leaching unscientifically stored solid wastes. That can contaminate pond, river, and lake water. This study is about to find out the environmental and health impacts of solid waste in Khulna city. The objective of this study is to investigate the present scenario of solid wastes in Khulna city concerning environment and health of the citizens.

The study Area: Khulna is the third largest city of Bangladesh. Khulna city is established around the intersection of latitude 22.49 degree north and longitude 89.34 degree east. 1.5 million People live in this city. The area of Khulna City is about 47 square kilometers. This city has local truck stand, port and railway station, bus stands. Rounding those points, business centered zones are built for any export import business. (Quazi H.Bari, 2012) For this study, Moilapota, Daulatpur, Dakbangla, Rail way Bazar area including Ward 6, 7, 19, 27 etc. were studied.

Methodology:

At first related secondary data was collected from different sources including government and non-government authorities. Numerous books, journals, newspapers, conference papers, electronic sources, activities both published and un-published were reviewed for gathering concerned information. Then, a field supervision was done in person to observe the health and environmental impacts of solid wastes in Khulna City. Several influential and documentary pictures were captured. Next, a social and user opinion survey (questionnaire survey) were conducted (after questionnaire development) to understand the situation and taking their opinion in participatory planning method. Residents of our study area, Road users, Passersby, households' residents in the surrounding of the dumpsites were involved.

Results and Discussion:

Relationship between socio-economic characteristics of Respondents and Environment and Health impact of Solid Waste Disposal in Khulna City
Income and Educational Status were studied for this research. Majorly of people of our study area are illiterate or less educated people. There is a relationship between the two. In our study area, generally less educated peoples are low income people. Majority of respondents of our study area has primary level education (40%). 31% people are kind of illiterate, 22% people has secondary education, the other 7% has higher education. Most of people's income level is 5000- 10000 taka per month here. They basically live near the disposal site. Generally, those people of less education work in the hotels, restaurants, some has personal tea stall, some are labors and some women of them work in other houses of people. Stall keepers do business roadside just beside the dustbins and dumping sites.

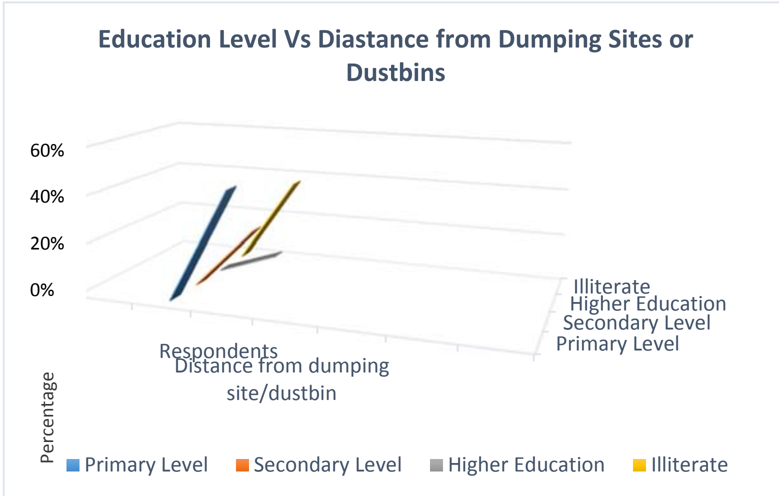


Figure 1: Relationship between education level and distance from dumping site or dustbin.

Some of them collects wastes like polybags, bottles, plastics, chips packets for their livelihood. Bio-medical wastes can lead to remarkable risk on infections and other health problems.

How many times in a time duration disposal sites or dustbins are cleaned:

The dustbins are not located properly. Many of them are not properly designed or insufficient against the increasing demand. According to the field survey and user opinion survey, Majority said that there is no regular basis cleaning of those dustbins.

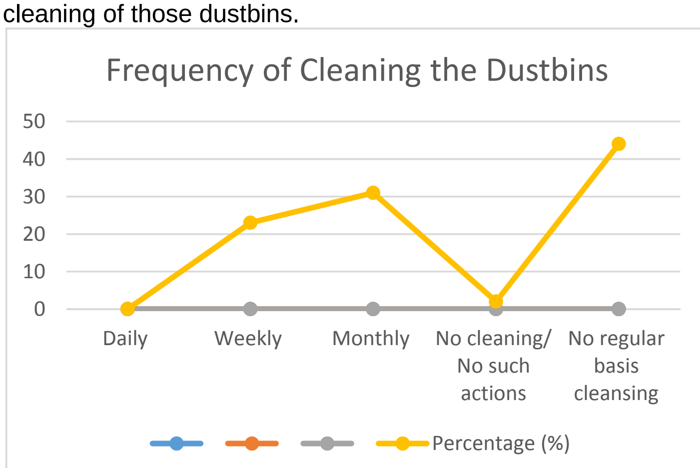


Figure 2: Frequency of dustbin cleanliness

As the dustbins are not cleaned properly and regular basis most of the time they are filled up. Solid wastes are dumped, stored for a long time as there is no regular collection or other treatment. Air pollution, Water pollution, Soil pollution etc. cause a lot of uncomfortableness and health hazards to the road users, passersby, road side shop and stall keepers who are near to the dumpsite and dustbins. s

Relation between nearby community and diseases:

According to the field survey and user opinion survey we have found that most of the people who live or work near the dumpsites or dustbins are mostly affected by the bad effects of improper solid waste management. They have faced different health problems due to this reason. Almost 56% of the total respondents have suffered diseases because of improper solid waste management and pollution tho or three times.

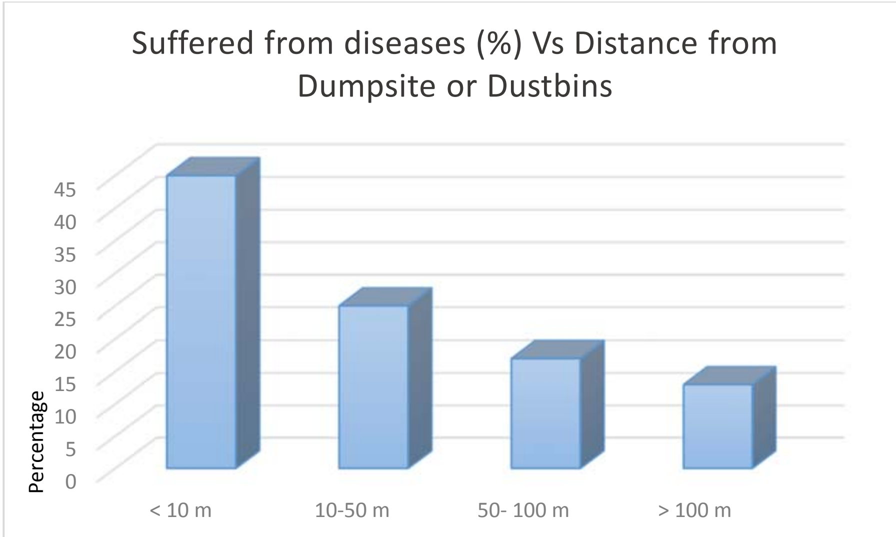
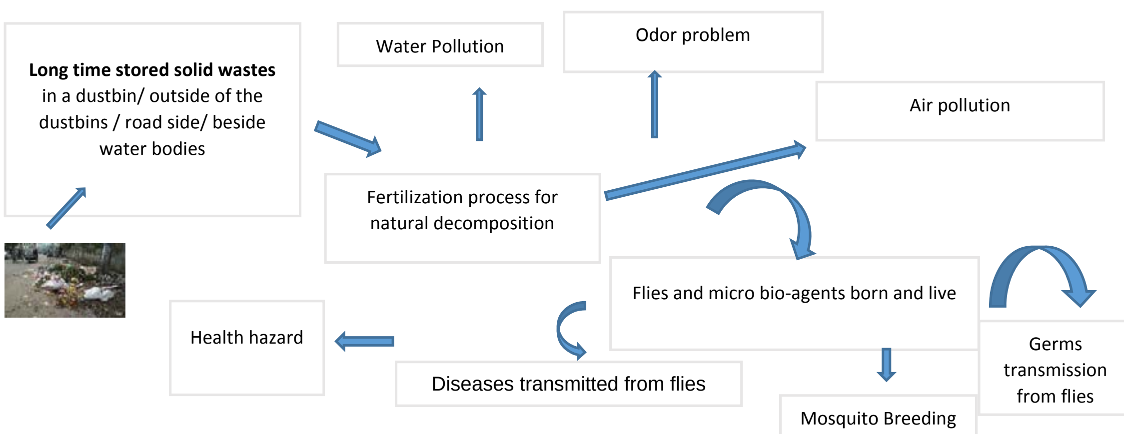


Figure 3: Relation between nearby community and diseases

The study shows that, the people who are the nearest from dustbins are more experienced and suffered one from various health problems or diseases. Mainly the dumpsites and dustbins are not cleaned well and regularly. Almost all the time those are filled up with wastes especially solid wastes and the fertilization process creates odor, germs and heath damage agents. The people who pass through the sites are also faced various health problems like the staying others: Respiratory problems, Transmitted diseases from flies, Bites of the animals feeding from the dump sites, Skin and eye irritating and infection, Headache etc.



Types of diseases people generally suffer from here because of pollution and improper solid waste management:

The surrounding areas of the dumpsites or dustbins are very much involved in Environmental pollution: Air Pollution, Water Pollution, and Soil Pollution etc. People who live in those area, who business or work in those areas, who collect wastes or the passersby and road users are highly affected in various health problems.

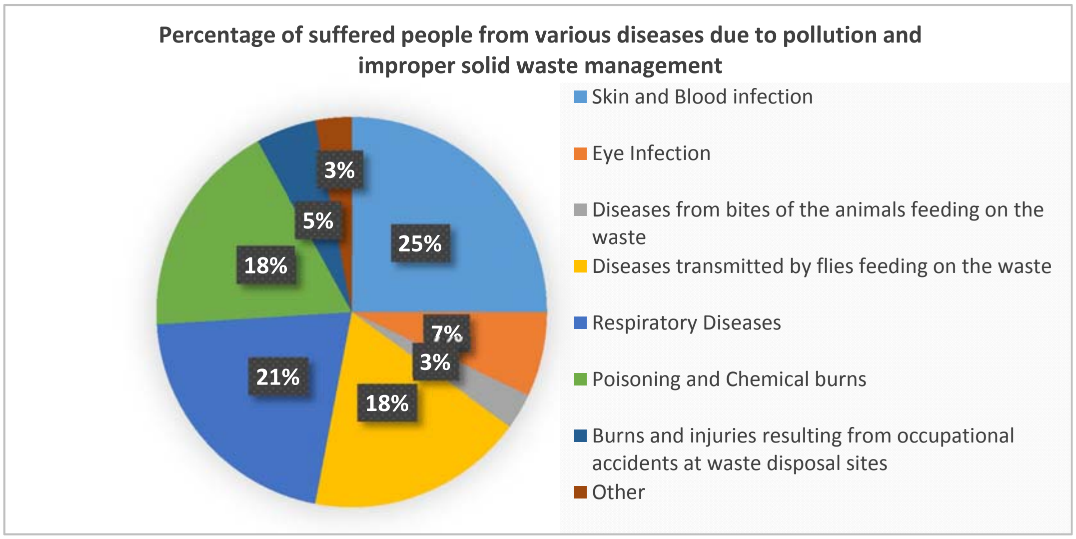
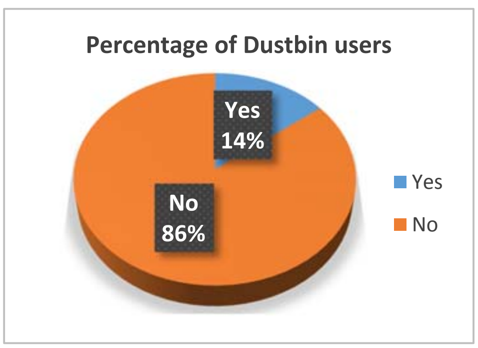


Figure 4: Percentage of suffered diseases in this community

Reason behind not using Dustbins: People don't use dustbins in maximum areas according to field investigation:



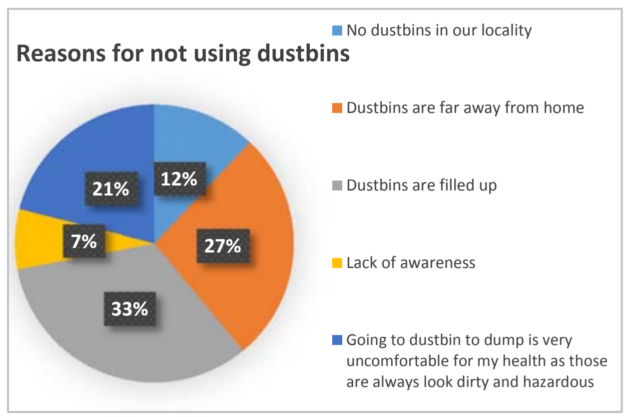


Figure 5: Reasons for not using Dustbins

Only 14% people always use dustbins. Huge amount of people said that the dustbins are filled up with wastes so where they will dump their wastes? Though the dustbins are already filled up or stay as filled up, no regular collection so, people dumps outside of the dustbins. Majority of them dump wastes road side and one of them dump wastes beside water bodies like ponds. Some dump directly in the drains.

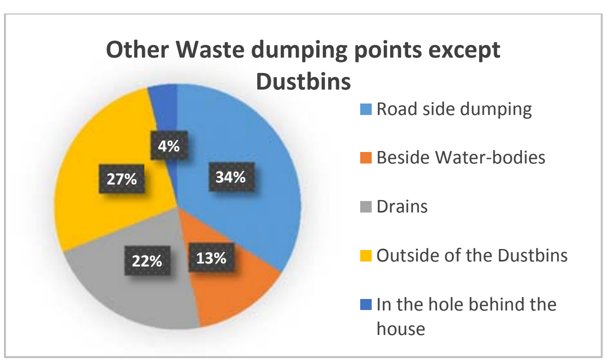


Figure 6: Other waste dumping points where people dump except dustbins

As the dustbins are not cleaned regularly those are creating odor problem in many places. Besides, People dump wastes outside of the dustbins which sometimes unable to replace and spread huge bad smell. A few People of this area avoid those dustbins as they think those are uncomfortable to their health and may cause health problem. So that, they dump in road side, beside water bodies or drains.

Faced problems due to improper Solid Waste Management:

The dumpsites and dustbins both are open and spreading odor and germs. There are no treatment facilities.

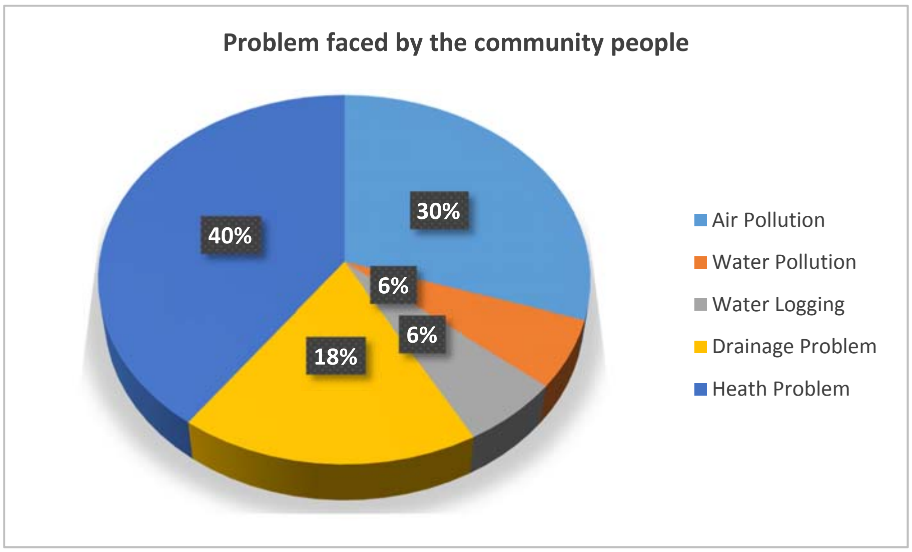


Figure 7: Percentage of the problem faced by the community people according to their opinion

People are facing health problem for this reason. (Figure 5, Figure 6). But no such remarkable initiatives were found to eradicate these problems efficiently. People are being alarmed about this issue but not in the rate that should be existed.

Drainage and Water-logging problem due to improper solid waste management:

People dumps wastes in drains, outside the dustbins, road side or beside the water bodies as they don't have sufficient amount of dustbins or most of the time the nearest dustbins are filled up due to improper management. When people directly dump wastes in the drains the drains, this makes the drains clogged, decrease the water flow and causes water logging. As in the time of rainy season there is huge pressure of rain water run-off, these clogged drains cannot serve as efficiently as they should serve. On the other hand, many areas are suffering from insufficient drains with its design criteria. Often dumped polybags and polythene products block the drain's opening. This also causes water logging in our study area. Those who dump outside the dustbins, beside the water bodies or road side create also drainage problem and water logging problem as the wastes are washed way through rain water during rainy season. Drainage and Water-logging problem also causes Environmental Pollution specially Water pollution in our study area.

(Picture captured by the author)

Figure 8: Blocked drain due to improper Solid Waste Management

Related terrible environmental affects due to improper Solid Waste Management in Khulna City:

Throughout research it became concluded that unsuitable stable waste management systems in Khulna city are resulting following negative affects at the environment:

- ✓ Dispersed solid waste from the illegal open dumps frequently blocks the drains and sewers as shown in figure 6. Ultimately those blockages are growing flooding and unhygienic conditions within the city. During summer-monsoon mosquito increase in a high productivity and generally it breeds in clogged water which is provided by improper solid waste management. From there odor breaks out and it causes Malaria, Dengue and other diseases in Khulna City. Ades mosquito doesn't breed in the staged water but improper solid waste management gives the environment for their breeding.

(Picture captured by the author)

Figure 9: Road-side dumped solid wastes causing poll

- ✓ According to the field investigation, people dump wastes basically beside the water bodies, outside the dustbins and road side in Khulna City. It causes serious harm to the city-scape, Land scape beauty of the roads and precious structures and monuments and urban environment also. The aesthetic damage of a city is not only very harmful for tourist's attraction but also for mental health.

(Picture captured by the author)

Figure 10: Road side dumped Solid wastes

- ✓ Sometimes the dustbins and dump sites are feeding field for various animals and specially rats and Cockroaches. Diseases can spread through Rats, Cats, Dogs, Birds, Cockroaches as they are highly connected to daily human life and they generally live with us in our houses. Human food and water had been contaminated through this process according to the field visit and resident's experience.

- ✓ The open areas are also being uncleansed and dirty with this process. According to the field visit, People dumps wastes in each and every open speces, low or high in amount, even in Jalabad Cantonment Park, Hadis park, Zilla School mathe, Jatisongho park etc. Majority of them 42% did this because of their unconsciousness, 33% of them because of they didn't find any dustbin near and the other for no reason in case of special and land marking open spaces. This proves people's lack of awareness also.
- ✓ According to field survey, several types of harmful wastes like glass, razor blades, hypodermic needles and different healthcare wastes, aerosol cans and potentially explosive packing containers and chemical compounds from industries have been found. Those sharp elements and industrial pollutants may harm to the people who collects waste from the dustbins and also for animals like dogs, cats as those can be staged during feeding. (Cornwell)
- ✓ The vehicles for transporting solid wastes in Khulna City generally are open body pick-up van. This transporting is fully unhygienic. This is also a reason for odor problem in Khulna City.
- ✓ Plastic bottles, medical supplies etc. distinctive segregated solid wastes are used by the poor peoples, slum dwellers that can cause serious health hazard as those are not being properly cleaned. Field investigation says that, sometime children of the nearby slums play with those dumped materials which can make serious health problem to the children.

(Picture captured by the author)

Figure 11: Dumped and stored Solid wastes beside settlement

- ✓ Khulna City Corporation (KCC) is failing to clean market place's solid Wastes. They are filling and raising private lands for dumping wastes. (Water and Sanitation Program, August 2000)
- ✓ During rainy season and in case of urban flooding, leachate from stored solid waste are polluting river, lake, and canal and pond water. (Akio, 2002)
- ✓ People generally dump wastes in dustbins or dump sites in bare hand and those who collect wastes from different points are also unprotected, use bare hands, uncleansed weapons even no musk on their nose. The whole process is highly unhygienic.

(Picture captured by the author)

Figure 12: A middle-aged lady is taking something from dustbin with bare hands

- ✓ Here people give fire to the stored solid wastes illegally as they thought it may reduce pollutants but they don't have enough idea about environmental pollution resulting from this activity. Illegal burning of gathered solid waste in Khulna city is creating severe poor effects on out of doors air exceptional. Furthermore, it's also inflicting contamination and lowering visibility.
- ✓ Open dumping of solid wastes in road side or collecting solid wastes process for big vehicles in Khulna City causing traffic jam, problem for the passersby and road users by narrow downing the roads. (George Tchobanoglous) (N. Ejaz, 2010) (Foday Pinka Sankoh, 2013)
- ✓

Figure 13: Road side dumped and stored solid wastes

(Picture captured by the author)

Figure 13: Road side dumped and stored solid wastes

Conclusion:

Huge amount of population leads to increase amount of solid wastes in Khulna City. Insufficient amount of dustbins, low capacity design of dustbins, poor monitoring and maintenance system, lack of cleanliness of dustbins, lack of public awareness etc. are the main reason behind improper solid waste management in Khulna City. People dump wastes in road side, beside the water bodies, outside of the dustbins, drains etc. which cause several environmental pollution such as Water Pollution, Air Pollution and different health hazards. As well as the improper solid waste management is causing harm to the city aesthetics. To make the city more environment friendly and healthy, the municipalities or City Corporation should take more required steps and launch more programs for raising public awareness. The root cause of all the problems are: Lack of proper maintenance and monitoring (Regular waste collection system), Lack of public awareness and Lack of suitable dustbins and authorised dumpsites. According to public opinion, expert opinion and field investigation if those are provided, people are made aware enough, this city can become more environment friendly and healthy.

Acknowledgement:

First of all we are grateful to almighty Allah who gave us the ability to conduct the study. I would like to express my deepest sincere gratitude to Tusar Kanti Roy, Assistant Professor, D-URP, KUET; Saima Rahman, Assistant Professor, D-URP, KUET for their valuable information and opinion. I would like to thank my friend and brother Misbaul Islam Ritul, Mizbah Ahmed Srestho, Abir Dey for their assistance. I would like to thank all the respondents and concerning authorities for their kind cooperation.

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Social aspects in the pathway towards the closure of a dumpsite: the case of Ngong (Kenya)

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Dumpsites are a common way for waste disposal around the world. Since their impact is not controlled, they represent a threat to the public health and to the environment, being a source of pollutants and greenhouse gases. The dumpsite of Ngong (Kajiado County, Kenya) has been recently targeted as a serious issue affecting the surrounding community. A project for its closure and the establishment of a new facility for waste treatment is on-going. Nonetheless, the framework appears complex from the environmental, economic and social points of view: any intervention will raise challenges for the municipal solid waste management (MSWM) system in place, which involves many stakeholders, including informal workers of the dumpsite. A social assessment has been carried out, revealing some criticalities. A general overview on the MSWM and results of this investigation are presented. The importance of qualitative and sociological research within a technological project will be discussed as well.

***Key words**: social assessment, closure of a dumpsite, waste pickers, low-income countries, municipal solid waste management*

INTRODUCTION

Municipal Solid Waste Management (MSWM) systems are very complicated. An integrated approach to address them requires dealing with both physical and governance components (Wilson et al., 2013). Physical components are related to public health and waste collection, to environmental protection and proper disposal, to reduce, reuse, recycle (the 3Rs). Governance components refer instead to the inclusivity of both users and providers, to the existence of sound institutions and pro-active policies, to the financial sustainability. Consequently, several aspects need to be considered when designing or modifying existing systems (UNHabitat, 2010).

In 2017, UNHabitat promoted a "*Comprehensive feasibility study for the closure of the informal dumpsite and the construction of an integrated sustainable waste management facility in Ngong town*", funded by the Italian Agency for Development Cooperation (AICS), with two goals: the closure of the dumpsite of Ngong (Kenya), which represents a threat for human health and the environment due to its improper management and its location very close to settled areas; and the construction of a new facility that will allow the treatment of waste in a more sustainable way (UNHabitat, 2017). The feasibility study was carried out by a consortium of three organizations, Politecnico di Milano (PoliMI), Technical University of Kenya (TUK) and LDK Consultants Engineers and Planners. Several analyses were required: a baseline diagnostic survey on the current status of MSWM in Ngong; an Environmental and Social Impact Assessment (ESIA) for both the interventions; the support in consultation and awareness campaign; a full project document for the new proposal of an integrated solid waste management facility. The pursuing of technical and financial feasibility was explicit within the Call for expression of interest, while the need for addressing livelihoods from dumpsite was not explicitly mentioned.

Within this framework, a Social Assessment (SA) was carried out as well, considering that all the proposed interventions would have modified not only the final disposal of waste, but the whole MSWM system of Ngong, including the provision and use of solid waste services, the financial arrangements required to ensure the sustainability of the system and the design of transport routes. Such changes are likely to cause social impacts, both positive (e.g. less accidents, better communication, social progress, livelihood options) and negative (e.g. increase in cost of fodder for animals, marginal increase in the time required to travel for people continuing with waste picking, displacement, loss of livelihoods (Houe et al., 2014)).

The purpose of this paper is to present the social impacts which were identified within this case study, together with the methodology used to create a coherent framework in which qualitative and quantitative investigations were done, and a list of relevant aspects was specifically created to take into account all issues and evaluate their relevance. As it will be shown, this list highlighted a variety of social impacts which risk to be neglected in the follow-up of the project, and may represent an important tool for the decision-makers within MSWM systems.

CONTEXT: MSWM SYSTEM IN NGONG AND RELEVANT STAKEHOLDERS

Ngong is a town of about 150,000 inhabitants (KNBS, 2013) which pertains to the County of Kajiado, in Kenya. Its dumpsite is located in the city center, next to the slum of Mathare.

The authority responsible for the MSWM system is the County Government (CG), with its Department of Water, Irrigation, Environment and Natural Resources. The CG has the following tasks: interactions with other stakeholders; planning of the MSWM; street cleaning and collection from street containers; surveillance of the Ngong dumpsite and regulation of the access by trucks.

The functioning of its MSWM system, with relevant stakeholders, is briefly described as follows.

Collection

The collection of waste in Ngong is performed by different actors. The CG is responsible for street cleaning and street collection: street containers (skips of about 6 m^3) are moved to the dumpsite by means of a skip loader and discharged there. Private Service Providers (PSPs) are organized in associations and perform a sort of door-to-door collection at the household level. Other associations involved in waste management and environmental protection exist in Em Bulbul, a township of Ngong.

The coverage of the collection is ensured apparently on the basis of the private land tenure system. In some areas the coverage is ensured by PSPs, while the County Government is charged with collection in other areas (and residents should pay a tariff).

Final disposal

At the present, waste is finally disposed in the dumpsite of Ngong. The dumpsite started operating between 1990 and 1995 on a land owned by the CG. After its establishment, a school and a church were built in its proximity, and the slum of Mathare raised in the area destined to liquid waste treatment (lagoon). The CG is operating the dumpsite in agreement with the National Environment Management Authority (NEMA), without the license and without any Environmental Impact Assessment (EIA). The daily amount of waste entering the dumpsite was estimated between 120 t/d to 160 t/d.

A Community based organization (CBO), the Nuru Youth Group (Nuru), is performing the management of waste and recyclables separation inside the dumpsite since 2004. The role of Nuru is unofficially recognized by the CG and PSPs. According to its Committee (a group of supervisor composed by 9 persons), Nuru has 132 registered members (about half women and half men) and 64 not-registered members.) Members of Nuru may act as selectors (pickers, generally specialized on different materials), traders (3 out of 5 buyers of selected materials are members of Nuru), cleaners (not specialized). Some of them are breeding animals (cows, pigs) within the dumpsite. Non-members select the organic waste or are charged with the cleaning of the unloading area.

With reference to the management of the dumpsite, trucks are charged an entrance fee and directed to a specific unload zone, depending on the type of its charge and its estimated value (County trucks are considered valueless since they collect waste from street containers). Subsequently, the waste load is assigned to a person/buyer, and then moved to a sorting zone to facilitate the handling and the movements inside the dumpsite.

Nuru was provided by NEMA with two shelters (one hosting the office of Nuru, the other dedicated to temporary storage and rest) and a shredding machine, which never started working because the costs of the connection to the electric grid or of a generator were not sustainable considering the temporariness of the dumpsite of Ngong.

Service charges and fees

Information provided by stakeholders on service charges and fees were not always coherent. Service charges are not asked to the population. Anyway, population served by PSPs is paying them a monthly tariff ranging from 300 to 500 Ksh per household.

Location of the new facility

The CG proposed as a location for the new facility an area known as Vet Farm, near Kerarapon, a township of Ngong of about 5,000 inhabitants. The area is a clearing surrounded by the Kibiko forrest. A local association, KErarapon REsident Association (KEREA), is really concerned about the establishment of the new facility. The existence of springs in the area has caused also the involvement of the Water Resources User Association (WRUA) (WRA, 2016).

Service charges and fees

Information provided by stakeholders on service charges and fees were not always coherent. Service charges are not asked to the population. Anyway, population served by PSPs is paying them a monthly tariff ranging from 300 to 500 Ksh per household.

METHODOLOGY

The literature related to the assessment of environmental, social and economic impacts of waste management has been searched in order to properly design the Social Assessment (Houe et al., 2014; Obadina, 2016; Gorgos, 2009; GA Environment Ltd, 2015).

The “five entry points of inquiry” (Social diversity and gender; Institutions, rules and behavior institutional analysis; Stakeholders; Participation; Social risks) mentioned by Bernstein (2004) has been chosen as the main reference to measure the social impacts. Subsequently, other two dimensions have been further developed, as they were partially mentioned in the “five entry points of inquiry”:

1. Physical impacts with social consequences, because a construction project will have physical impacts that may affect the population, with social consequences. An example may be the depletion of springs and groundwater, that will affect the population dependent on local water sources.
2. Health issues, with reference to both population living around the dumpsite and waste workers. In fact, resident population around the dumpsite is subjected to a health risk, due to the contamination of soil and water, to the smoke of the burning waste, to the breeding of animal vectors of disease. On the other side, waste workers are more likely to suffer from diseases or accidents if compared with the total work force (Poulsen et al., 1995). A list of most common occurrences has been derived from the literature (Njagi JM et al., 2013; Giusti, 2009; Bokhoree et al., 2014; Domingo and Nadal, 2009; Sankoh et al., 2013; De and Debnath, 2016; Poulsen et al., 1995), with reference to possible diseases (chest pain, stomach problem, diarrhea, eyes infections or conjunctivitis, skin rashes or other skin diseases, hoarseness, cough, nauseas, vomits, joint or muscle pains) or accidents (fractures, sprains, wounds, burns or bites).

Qualitative and quantitative methods for the collection and elaboration of secondary and primary data have been chosen on the basis of similar studies (Sankoh et al., 2013; Patwary et al., 2011).

Secondary data from the study of scientific papers but also reports and web sources, the so-called “grey literature” (Domini et al., 2017; Schöpfel and Farace, 2010), have been used.

Primary data have been collected on the field, using qualitative methods (semi-structured interviews and informal dialogues) and questionnaires.

Semi-structured interviews (including closed and open questions) have been performed with several stakeholders, and informal dialogues have been used as well, for example during the visit to the dumpsite of Ngong or during the inception workshop organized by the County and UN-Habitat. Most of the questions were asked to waste pickers during a meeting of their Committee, in which part of the project team participated; waste pickers were not individually interviewed. In Table 1 the categories of stakeholders, the number of involved stakeholders and the tool used to collect information are listed.

Table 1 Stakeholders interviewed for the Social Assessment

Category	Stakeholders (number of people)	Tool
Institutions	Kajiado County Government (3)	Semi-structured interview
	Local level and politicians (3)	Semi-structured interview, inception workshop.
Private Sector	Private Service Providers (1)	Semi-structured interview.
Waste workers	Nuru Youth Group (8) (informal workers)	Semi-structured interview, inception workshop, visit to the dumpsite.

CBOs	Em Bulbul Oloolua Env. and SWM Project (1) Kerea (1) Kerarapon Youth Group (2)	Semi-structured interview, inception workshop.
Experts in SWM	TUK (2)	Inception workshop.

Questionnaires have been prepared in cooperation between PoliMI and TUK and administered by the TUK team between April and June 2018. They were addressed to three groups affected by the project: the resident population living within 500 meters from the dumpsite of Ngong or within 50 meters from the river flowing downstream the dumpsite (RPN), the resident population living in Kerarapon, in proximity of the location for the new facility (RPK), the Workers at the dumpsite (WD).

The social impacts on the resident population have been assessed with reference to both stages of the project, the closure of the dumpsite and the siting and opening of the new waste management facility.

The so-called "waste pickers" are vulnerable to many changes in the waste management system, which might prevent them the access to recyclables, such as the establishment of waste-to-energy plants or the implementation of security measures (e.g. enclosures) and rules which forbid and punish the collection of waste. Workers employed in picking, sorting, cleaning and commerce of waste at the dumpsite will be affected by its closure because they risk to lose their source of income, and they can be subjected to forced displacement as well. The questionnaires have been administered to 122 persons, as summarized in Table 2.

Table 2 - Target groups of the questionnaires

Target group	**Methodology**	**Number of questionnaire**
RPN – Resident population Ngong	Questionnaire	36 with interviewer
RPK – Resident population Kerarapon	Questionnaire	42 with interviewer
WD – Workers at the dumpsite	Questionnaire	22 with interviewer
CQ – Combined Questionnaire	Questionnaire	22 with interviewer

In addition to the three different questionnaires (RPN, RPK, WD), a fourth questionnaire combining questions from the others (CQ) was prepared and administered to a random sample of population frequenting the town of Ngong. The dimension of the sample for Resident population (RPN, RPK, CQ) is not enough for the analysis to be statistically significant. With reference to the Worker at the dumpsite (WD), the percentage is about 10% of total population. Nonetheless, results can be used in order to understand whether issues raised by key stakeholders are acknowledged or mentioned as well within the population.

RESULTS

Qualitative investigation

The interaction with the stakeholders allowed the recognition of many social issues. The main questions of the semi-structured interviews were the following: *(1.a) Have you ever heard about the relocation of the illegal dumpsite of Ngong? (1.b) Do you support the idea? Why? (1.c) What do you think it should be taken into account within the project? (1.d) In your opinion, which are major issues concerning waste management in Ngong?*

The answers to these questions were referring to both the current situation and the changes potentially caused by the implementation of the project, whether in Ngong or in Kerarapon. All the issues are summarized in Table 3. Each issue is classified and a short description provided, together with an evaluation on its influence of the project. Stakeholders which mentioned a particular issue are also listed. Finally, each issue is signed with an ID to be clearly identified in the following discussion.

Table 3 - Issues raised by the stakeholders, synthesis table

Issue	Description	Interaction with the project / Expected impact	Raised by:	ID
Physical impacts with social consequences				
Environmental impacts	Current situation in Ngong: Smoke (waste burning) affects houses in the valley Oloolua River has been damaged Improper location of the dumpsite	Positive - The closure of the dumpsite of Ngong will reduce the impact on the environment.	Institutions, CBOs, PSPs	Env_N1
	Current situation in Kerarapon: Lack of a proper disposal area around Kerarapon Several illegal collection points	Positive – The new facility will receive waste from Kerarapon	Institutions, CBOs, PSPs	Env_K1
	Project impact in Kerarapon: Risk of water contamination or depletion (Gateway springs - outlet of Ngong hills; another spring - outlet of Mombasa) Pollution, dust, noise, birds	Unknown	CBOs, PSPs	Env_K1
Social diversity and gender				

Society	Differences between Ngong and Mathare (low income areas) and Kerarapon (high income area).	Unknown	CBOs	Soc_A1
Poverty	Temporariness of the situation affects long term strategies (e.g. operation of the shredder)	Unknown	Waste workers	Pov_N1
	Employment and livelihood of waste workers: Funds obtained from the work in the dumpsite have enabled them to take care of their families, educate their children. Losing the job is a main concern with reference to current workers elderly people, which risk to be excluded considering different roles of waste workers (selecting or sale of recyclables) In the new facility, Nuru should be involved in selection and sale of recyclables Menace to both waste workers and PSPs coming from the high magnitude of the project (external influence)	Negative	All CBOs, Institutions, Waste workers, PSPs	Pov_N1
	Employment: young people local communities in Ngong and Kerarapon	Unknown	Institutions, all CBOs, PSPs	Pov_A1
	Reallocation of families living in the dumpsite	Negative	Institutions, CBOs	Pov_N2
Waste generation	With plastic ban, garbage has decreased drastically!	Neutral -	Institutions, PSPs	WG_A1
Waste management (disposal, storage, reduction at source, recycling)	Different perception of waste in different ethnic groups (luo, somali, kikuyo)	Unknown	CBO	WM_A1
	People don't cooperate on environmental issues Challenges related to the management of households waste	Negative - The project can be affected in a negative way by the lack of cooperation of users.	PSPs	WM_A2
	"Garbage mafia" is apparently absent in Ngong	Positive	Waste workers	WM_N1
	Hospital waste reaching the dumpsite	Positive	PSPs	WM_N2
Institutions & stakeholders				
Resources and roles	Scarce resources allocated for MSWM	Neutral – it is necessary to tackle the economic sustainability of the project.	Institutions	Inst_A1
	The project should generate revenues to the County government		Institutions	Inst_A1
	Licenses for waste dealers and waste collectors are supposed to be released by the National Environment Management Authority (NEMA) and not by the County Government.	Unknown	Institutions	Inst_A2
Training and capacity building	Waste pickers Young people and local community	Neutral	All CBOs, Experts, PSPs, Institutions	Inst_A3
	Institutions: requested capacity building funds are needed	Neutral	Institutions	Inst_A4
Awareness	Lack of awareness: people don't know how to handle waste (factories, hospitals, agriculture, households…) improper language is used creating alarm (e.g. waste-to-energy and not landfill) "the problem is where the waste comes from"	Neutral	Experts, CBOs, Institutions	Inst_A5
Participation				
Participation	Lack of the involvement of population and stakeholders High request for public participation	Negative	Institutions, CBOs, PSPs	Part_A1
	Lack of conservation plan for the area	Neutral	CBOs	Part_A2
Social risks				
Institutional risks	Lack of communication: lack of information on the new location lack of understanding due to lack of information no visible results for investment in awareness Lack of trust in institutions: doubts on adequate capacity of management required transparent accountancy of the subject that will manage the new IWTF interest of the Government limited to waste issue Involvement of institution: requested involvement of local institutions (Environmental Committee, local chief and subchief) role of the County Government to be clarified	Negative -	CBOs, waste workers, institutions, PSPs	SR_A1
Not In My Backyard	Property value diminution Security (scavengers, thieves) Lawyer to stop the project	Negative	CBOs	SR_K1
Forced resettlements and asset/land acquisition	Location has already been chose, no alternatives exist. No opinion on alternative proposals. [KC]	Negative	Institutions	SR_K2
	Existence of alternatives (e.g. quarry) supported by the community	Positive	CBOs	
	Conflict on land property with the Keekonyokie / Masai	Negative	CBOs, PSPs	
Health issues				
Resident population	Current situation in Ngong: Safety issue related to kids moving inside the dumpsite Health hazards, respiratory diseases Proximity of the dumpsite to living places Public hygiene is threatened	Positive – the closure of the dumpsite and changes in waste management will improve the situation.	Institutions, CBOs	HI_N1
	Impact of the project in Kerarapon	Neutral	CBOs	HI_K1
Workers	Health issues affecting workers at the dumpsite	Neutral	Expert	HI_N2
Note: The ID is composed as follows: identifier of the relevant aspect with reference to the general dimension (Env – environment; Soc – society; Pov – poverty; WM – waste management; Inst – institution; Part – participation; SR – social risks; HI – health issues); area of impact (N – Ngong; K – Kerarapon; A – all) and sequential number.				

Questionnaires

Questionnaires were not directly administered, as the team TUK was working on the field and shared undetailed results. Those results have been analyzed in two different ways: some questions were aimed at exploring the perception of people about the current situation of waste management and the impacts of the project; some others at understanding the real behavior of people, for example with reference to their way of disposing waste.

In the first case, people were asked to select relevant issues from a list (Yes/No). The issues analyzed were the following: *(a) negative impacts of the dumpsite; (b) benefit of the dumpsite; (c) benefit of the relocation of the dumpsite; (d) institutional waste management issues.* An analysis done by TUK, which was asking to RPK their *(e) views on waste management in Kerarapon*, was taken into account. Mean aggregated data are presented in TUK (2017).

Data were collected in different ways, and not all target groups were asked the same question. Despite such difficulties, these information were connected to issues raised by stakeholders through the ID. A column "Impact" was added in order to provide a qualitative evaluation of the perceived impact with respect to given answers. The qualitative evaluation ("Impact") was based on the average percentage of respondents mentioning the issue: Very low (0-19%); Low (20-39%); Medium (40-59%); High (60-79%); Very high (80-100%): the answer "All the stated benefits / all the above", when given, was distributed between the different issues. The percentages were not referred to the whole sample because the purpose was to identify relevant issues, not depending on the dimension of the affected group.

In the second case, some aspects were analyzed through the statistical analysis of data in order to understand the difference between perception and real impacts. For example, people's sensitivity about health risks related to improper waste management may be low, but the incidence of waste related diseases is high. Considering the small dimension of the sample and the little time available for the preparation of questionnaires, only few aspects can be analyzed in this way. These aspects are presented as follows:

- People using local water sources will be affected by the depletion of water sources. Further studies are necessary (*Env_K1, Unknown impact with High relevance*).
- Affordability and willingness to pay: 48% of the whole sample is paying a fee, as well as 42% of people coming from a low-income area. The new project is likely to lead to higher costs, which may be co-financed through fees (*Inst_A1, Neutral, with High relevance*), but the value of these fees should be set up in a proper way not to exclude vulnerable people from a proper waste collection (*Pov_A3, Negative, with Medium relevance*).
- Most of the people dispose waste in an improper way: open dumping (45% of CQ, 36% of RPK); roadside disposal (5% of CQ, 10% of RPK); backyard disposal (9% of CQ, 26% of RPK). The project may have a positive influence (*WM_A3, Positive, with Medium relevance*).
- The lack of communication was revealed by the question on awareness about the relocation plans of the dumpsite of Ngong (target: RPK) or the development of a new modern integrated waste management facility (IWMF) (target: RPK, WD). About 67% of interviewed people, on average, was not aware about one or both aspects of the project, so the relevance of lack of communication is considered High (*SR_A1, Negative, with High relevance*). NIMBY or local opposition to the project was investigated by asking RPK if they supported the new IWMF and to RPN and WD if they supported the relocation plans of the dumpsite. Relevance of local opposition, if calculated on the basis of percentage of contrary respondents, should be estimated in both cases as "Low" (18 - 28%). Anyway, few people can do a relevant opposition to projects, so this issue should be considered as Medium (*SR_N1, Negative with a Medium; SR_K1, Negative with a Medium*). Bigger efforts in dealing with opposition is suggested, understanding its main reasons.
- Health issues have been investigated only within the target group identified by CQ (22 interviews). The result is not statistically significant. An epidemiological analysis should be carried out. Anyway, it has to be highlighted that diseases likely related to the dumpsite are the most mentioned: diarrhea (41%), cough (36%), malaria (27%), cholera and typhoid (23%), stomach pain, skin rushes, respiratory diseases (9%). A case of miscarriage (5%) was identified as well.

DISCUSSION AND CONCLUSIONS

Social impacts of a new waste management project, including the closure of an existing dumpsite, have been assessed by means of interviews and questionnaires. Collected data have been analyzed in order to highlight relevant aspects and to obtain a list of aspects which can be used to better understand positive and negative impacts of the project.

Table 4 shows the final synthesis. Each expected impact has been evaluated (positive, negative, neutral or unknown), showing also its magnitude as perceived by the population (very high, high, medium, low, very low) and the intervention required within the project in order to tackle each impact properly.

Table 4 - Table of synthesis: ID of the considered aspect, Description of the aspect

ID	Definition	Impact on the project	Perception	Recommendation for the project
Env_N1	Environmental situation around the dumpsite of Ngong	Positive – Long term decreasing of air and water pollution in the surroundings.	High	Monitoring – The real impact on this issue should be properly assessed.
Env_K1	Environmental situation in Kerarapon neighborhood	Unknown – The opening of the new facility will partially solve the problem of improper disposal of waste around Kerarapon. Anyway, the depletion of water sources has been mentioned as a risk due to both construction works and mis-management of the new facility.	High	Required – Proper management should be guaranteed in order to minimize possible negative environmental impacts. The depletion of water sources would affect severely the local population.
Pov_N1	Employment and livelihood of waste workers	Negative – High risk for vulnerable population and elderly people.	High	Required – A Livelihood Restoration Plan (LRP) for dumpsite workers should be prepared to protect their livelihoods.
Pov_A1	Employment of the local community	Positive – The project is supposed to create employment opportunities.	High	Monitoring – The real impact on this issue should be properly assessed.
Pov_N2	Displacement of waste workers	Negative – Houses built inside the dumpsite of Ngong will be removed.	Low	Required – A Resettlement Plan for people living in the dumpsite is necessary.
Pov_A2	Reduction of child labor	Positive – The closure of the dumpsite is supposed to reduce child labour	High	Monitoring to assess the real impact on this issue. Required - Strategies for guaranteeing schooling for children should be part of the LRP.
Pov_A3	Willingness and affordability to pay	Neutral – The project may provoke an increasing of management costs.	Medium	Required – Affordability of fees should be assesseed.
WG_A1	Generation of waste	Neutral – The project should be able to deal with variations in waste generation.	High	This aspect should be considered in the new strategy for SWM.
WM_A2	Lack of cooperation of user	Negative – Lack of cooperation can affect negatively the project.	Medium	This aspect should be considered in the new strategy for SWM.
WM_A3	Existence of infrastructures suitable for a proper waste management	Positive – The new project may lead to an improvement in SWM infrastructures.	Medium	This aspect should be considered in the new strategy for SWM.
WM_A4	Rapid urbanization	Negative – Rapid urbanization is supposed to affect negatively SWM	Medium	This aspect should be considered in the new strategy for SWM.
WM_N2	Improper management of hazardous and special waste	Positive – The project could lead to a better management of hazardous and special waste	High	This aspect should be considered in the new strategy for SWM.
Inst_A1	Economic sustainability and availability of resources	Neutral – The project may provoke an increasing of management costs.	High	Required – Affordability of the system should be properly assessed.
Inst_A2	Ineffective laws	Negative – Ineffective laws may be affect in a negative way the project.	Medium	This aspect should be considered in the new strategy for SWM.
Inst_A3	Capacity building for people and workers	Neutral – The project may create an opportunity for the formation and training of people and workers.	High	Required – Capacity building within people and workers at the dumpsite is required.
Inst_A4	Capacity building for institution	Negative – Lack of knowledge within institutions would affect negatively the project.	Very high	Required – Capacity building within institutions is highly required to guarantee a proper management of the system.
Inst_A5	Lack of awareness	Negative	Very high	Required – Awareness campaign.
Part_A1	Lack of the involvement of population	Negative – It may enhance local opposition.	High	Required – Promotion of community involvement and participation.
Part_A2	Lack of the planning	Negative – It may affect the effectiveness of the project.	High	Required – Proper urban and environment planning
SR_A1	Lack of trust in institution and lack of communication	Negative – It may generate a local opposition within the population.	High	Required – A proper communication strategies is required to raise the level of trust in institutions
SR_A2	Changes in external markets	Negative – They may affect the economic sustainability of the system	Very low	Monitoring -
SR_N1	Local opposition in Ngong	Negative – Local opposition of people depending on the dumpsite may rise.	Medium	Required – Promotion of the participation within waste workers
SR_K1	Local opposition in Kerarapon	Negative – The opening of the new facility may rise local opposition.	Medium	Required – Promotion of participation within the resident population in Kerarapon
SR_K2	Conflict on land property	Negative – Local opposition as the decision due to lack of involvement of the population.	Medium	Required – Promotion of participation within the resident population in Kerarapon.
SR_K3	Loss of grazing ground for cattle	Negative - The new site will rise in an area currently used as a grazing ground for cattle.	Low	Required - An alternative should be provided, in order not to rise conflicts.
SR_N2	Displacement of grazing ground	Negative - Temporary loss of land available for grazing pigs and cattle.	Low	Required - Requalification of the area will admit a safer carrying out of those activities. The access to the area should be guaranteed in order to ensure the livelihood based on this

				activities.
HI_N1	Exposure of RPN to health risk	Positive – The closure of the dumpsite will lead to improved health conditions in Ngong.	Very High	Monitoring – The real impact on this issue should be properly assessed.
HI_A1	Health hazard due to improper SWM	Positive – The project could lead to a better SWM as a consequence.	Medium	This aspect should be considered in the new strategy for SWM.
HI_K1	Exposure of RPK to health risk	Negative – The construction of the new facility could have a negative impact on health of the resident population in Kerarapon.	Medium	Required – Proper management should be guaranteed in order to minimize negative health impacts.
HI_N2	Exposure of dumpsite workers to health risk	Neutral – The new project may affect positively health conditions of waste workers.	Very low	This aspect should be considered in the new strategy for SWM.

Identified themes are grouped and discussed as follows, mentioning each aspect:.

Environmental, health and security issues (Env_N1, Env_K1, HI_N1, HI_K1), which are supposed to be positive for the area surrounding the dumpsite of Ngong. On the other side, these impacts may affect in a negative way the area of Kerarapon, where the new facility is going to be established. All interventions within the project have been designed to be environmentally sound and healthy. Anyway, their impacts strongly depends on the capacity of the institutions to manage properly the whole system and the proposed plants.

Labor and vulnerability of workers at the dumpsite (Pov_N1, Pov_A1, Pov_N2, Pov_A2, Inst_A3). The management of waste in Ngong involves more than thirty Private Service Providers, while about 200 people depend on the selection and purchase of recyclables in the dumpsite. This equilibrium is based mainly on self-organization and private market and not, or just a little, on public funds. Any change in SWM, even the introduction of waste separation at source without a thoughtful set of rules, may affect the livelihood of people currently involved in waste management. Finally, even if a small portion of the population seems to be negatively affected in this sense, the sensibility towards this issue is widely spread between all actors. Following issues should be further explored: current conditions of informal workers (including health and living conditions); the existence of integration strategies for their involvement in the system and needs for changes in the municipal legislation; possible initiatives for development/strengthening their organization and capacity building programs; the existence of child labor and possible actions to stimulate the education of children.

Trust in institution, community participation and local opposition. A big challenge resulting from the social analysis is the relationship between institutions and local communities:

- The lack of trust in institutions is widely spread between stakeholders, and many communication gaps are evident from questionnaires (SR_A1). The reason for the lack of trust is not clear (e.g. it may be raise from political reasons or it is mainly connected with the previous County Government) but it should be targeted as it may affect the functioning of the whole SWM system. Moreover, it should be taken into account that the society of Ngong is apparently characterized by strong relationships between stakeholders, so increased trust may generate a positive chain effect.
- Capacity building within institutions (officers and technical staff of the CG) is considered very important for the improvement of the SWM system by several stakeholders (Inst_A4). Apparently, there is a good attitude towards trainings.
- Public participation has been required by several stakeholders and within questionnaires (Part_A1, Part_A2). Promoting public participation may raise the trust in institutions. Population and local chiefs in the area of the new plant, and key stakeholders of the SWM system in general, should be involved. The conditions for implementing a multi-stakeholders platform including as well waste workers is highly recommended.
- Several conflicts may raise within the project (SR_N1, SR_K1, SR_K2, SR_K3, SR_N2). The siting of the new facility in the area known as Vet Farm is the most evident conflict, with several reasons mentioned by stakeholders: the possible depletion of water springs in the area; the potential contamination of Kibiko forest; NIMBY syndrome as property values for Kerarapon land are likely to be affected; conflicts on land property and land use, as the area may be subjected as well to phenomena of land grabbing; other interests on Vet Farm, as the area is considered interesting for urban expansion. A trustful relationship between institutions and local communities is a prerequisite for dealing successfully with this issue. In fact, reasons for local oppositions are overlapped, and there are many concurrent interests.

Awareness. Interviews demonstrate a frequent misunderstanding between the concepts of participation and awareness. Concerns about pollution are rather symptomatic of awareness and not of “lack of awareness”. A correct description of the new concept of waste management and of the new facility should have been done following the trail of public participation, including the actors already targeted within the Inception Workshop done at the beginning of the project, and the population as well. Awareness on correct waste management should be raised as well (Inst_A5).

New strategies for SWM. The SA highlighted many aspects which are likely to influence the effectiveness of the SWM system in Ngong (WG_A1, WM_A2, WM_A3, WM_N2, HI_A1): waste reduction, recycling, composting, promotion of 3R's principles are recognized as important by interviewed people. With reference to the management of the new facility, it should be discussed with Nuru and PSPs.

An integrated approach is suggested to deal with social impacts raised by the project. In fact, some issues cannot be treated as they were separated from others, while others can be approached simultaneously.

The SA was affected by some difficulties in the organization, mainly in the design of the questionnaire and its administration. For example, some questions were changed or removed during the administration of questionnaires, without a proper explanation. Other stakeholders should have been involved in the SA. These difficulties were probably a consequences of the short time available for the whole study. Another criticality was related to the project team, which was composed mainly by technicians and engineers, not involving experts in anthropology, sociology, economics, etc. as suggested by Bernstein (2004). Despite these obstacles, the information provided by this study shows the complexity underlying this type of project, and can be used by decision-makers to target successfully important issues.

ACKNOWLEDGEMENT

The authors want to acknowledge the contribution of their colleagues at the Technical University of Kenya, especially Dr. Jane Oteki, the County Government of Kajiado for its involvement and UN-Habitat Urban Basic Services Branch of Nairobi for the financial support.

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Entering Rocinha: a study on solid waste management in a slum of Rio de Janeiro (Brazil)

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Solid waste management (SWM) is recognized worldwide as an important issue to deal with in pursuing livability. The favela (slum) of Rocinha represents a good synthesis of all challenges which can be encountered in this field: high population density , lack of space and narrow streets, residents struggling with low incomes. In Rocinha, services coverage is lacking and unsatisfying in many sectors, including SWM. In this study, we investigate the reason for this inadequacy. Waste streams have been analyzed as a first step. The second step was the description of the SWM system and of its criticalities. All accessible information has been used and Geographical Information Systems (GIS) played an important role in the data processing. In the final discussion, we suggest a small-scale and decentralized waste management network, collaborating with the centralized collection system. This study is a piece of the project Polimipararocinha of Politecnico di Milano (Italy) which pursues the overall urban re-qualification of Rocinha.

Key words:

INTRODUCTION

Managing waste in low income countries has to deal with different challenges, as described by UNHABITAT (2010a). From an economic point of view, the costs of waste management can account for 20-40% of the total costs sustained by the municipalities, and the coverage of these costs through fees may be difficult, especially in poor areas. Inequities in service provision can be a consequence of this assumption, but also of discriminations.

Even if Brazil is not formally considered a low income country, but rather a quickly developing one (BRICS), inequality affects the distribution of wealth, and “favelas” are one of the most evident signal of it. At the same time, this huge country has many experiences in the inclusion of the informal sector, especially regarding waste management (the case of waste-pickers or “catadores do lixo”, organized in cooperatives) (Dias, 2011).

The settlement studied in this paper, Rocinha, is recognized as a neighborhood of Rio de Janeiro (RJ), with some public services as well (health, education, waste management, etc.) (EMOP, 2012). Urban plans and public policies were developed for Rocinha. Nonetheless, they have not always been adopted, or they have been adopted in a partial and inefficient way (Silva, 2015), and services coverage appears as lacking and unsatisfying. Rocinha is characterized as well by many social conflicts, including the phenomenon of the “criminalization of poverty”, “not-common” actors such as narcotrafickers, and a generalized scarce trust in the institutions (Ceppi, 2017), whose lack of coordination may represent an obstacle to the implementation of interventions (Rekow, 2016), apparently more than poor regulation. In this situation, distinguish between sanitation (infrastructural and managerial choices) and hygiene (behavioral change and good practices) is necessary, not to charge individuals of the whole responsibility for improper waste management.

This study is one of the results of a project named Polimipararocinha, funded within the Polisocial program of Politecnico di Milano. A team composed by researchers and technicians, with expertise in different areas (urban studies, architecture, energy efficiency, waste management, ecosystem service analysis), worked together following a methodology called Integrated Modification Methodology (IMM) in order to define a comprehensive framework of interventions within Rocinha, aimed at transforming the “favela” into a more sustainable environment, pursuing as well an improvement in the quality of life for its inhabitants. Waste management has been considered an important aspect due to its recognized impacts on public health and the environment (Wilson et al., 2015).

CONTEXT

Rocinha is a neighborhood of RJ, located in the southern part of the municipality. It is namely a “favela” or “comunidade”, since it was considered as an informal settlement (slum) until 1993, when it was officially recognized by the Municipality of RJ. In 2012, a police pacification unit (UPP - Unidades de Polícia Pacificadora) was established, as a strategy to maintain the control of the territory against drug trafficking. At the present, several public services are located within Rocinha, such as health centres (Centro de Saúde) and the water and sanitation state company (CEDAE - Companhia Estadual de Águas e Esgotos). It rises between two granitic mountains and has a morphology characterized by steep slopes, narrow alleys and lack of spaces.

Located between two of the richest neighborhoods of RJ, Rocinha is one of the poorest, with a Human Development Index (HDI) of 0.735 (IPP, 2017) and an economy mostly based on the informal sector (EMOP, 2010b). It has a high population density, which is difficult to estimate due to the existence of different estimates. Considering an area of 144 ha, the density for the year 2010 was about 500 hab/ha (IPP, 2017). It rises between two granitic mountains and has a morphology characterized by steep slopes, narrow alleys and lack of spaces.

Such characteristics pose serious challenges to the establishment of a proper solid waste management (SWM) system. The location of containers is difficult in all areas, and only few streets are accessible with vehicles. The capacity of containers themselves is apparently not sufficient for collecting all the waste, as well as the frequency of collection. Moving away from the main road, waste is left on sidewalks and empty terrains or thrown inside drains and sewers. A big collection effort is then required for citizens living in disconnected areas, and the habits of dumping waste in empty spaces can originate also from a cultural inheritance (Carvalho, 2016).

The consequences of improper management of waste are well-known: water contamination; hygienic problems due to the feeding of diseases vectors such as rodents and insects; flooding caused by the obstruction of drainage networks; crumple of amasses of waste on surrounding buildings. All these issues exist in Rocinha, in some cases enhanced by its urban characteristics (EMOP, 2012).

Functioning of the SWM system

A description of the SWM system for the whole Municipality of RJ is needed to understand the situation, as Rocinha is just a small part of it (PMGIRS, 2016; EMOP, 2012; UFRJ, 2015). Authorities responsible for environment, sanitation and waste management are on three different administrative levels (federal, state, municipality) (EMOP, 2012), and also the legal framework goes across these levels. At the municipal level, the reference is probably the law on Integrated Solid Waste Management. Other laws concern the separate collection, the downstream market for waste (with measures on the mandatory use of recycled waste in the works of the municipal public administration), the informal sector. Laws related to other issues (sustainable development and climate change, water and sanitation, urban planning) should be considered as well.

Since 2011, a new logistic system for waste management has been developed for RJ, taking into account three steps (collection, temporary storage and final disposal). Comlurb is the public company responsible for the collection of the waste, which is subsequently transferred to Waste Transfer Stations (Estações de Transferência de Resíduos – ETRs). ETRs receive MSW from RJ, but also from other cities. Out of seven ETRs, ETRs Caju is the one receiving waste from the Area of planning AP2, which includes Rocinha. From ETRs, the waste is delivered to the Waste Treatment Center CTR-Rio at Seropédica, opened in 2011.

In 2014 Comlurb managed for the city of RJ the collection of 8370 t/d of waste on average, which correspond to 91% of an overall 9227 t/d received by its Transfer Stations (ETRs). This waste stream was sent to CTR-Rio Seropédica (93.2%); separated collection accounted for 0.5% (PMGIRS, 2017).

The collection system in Rocinha has been described by several authors (Toledo, 2009; Azevedo, 2010; EMOP, 2012). Comlurb is operating inside the favela and is responsible for waste collection, cleaning of public spaces and maintenance of green spaces and public furnitures. At the same time, street cleaning and waste collection can be performed by a specific figure, the “gari comunitario”, a street-sweeper identified by residents’ associations, when streets and alleys are too narrow to allow the passage of vehicles. Tractors and small compactor trucks are used within Rocinha, together with several types of containers (compactors of about 15 m^3, skips of 1-2 m^3, dumpsters of 1.5 m^3) and concrete slabs for street collection. About one hundred people are supposed to be employed in waste collection within Rocinha.

POLIMIPARAROCINHA PROJECT

The theoretical background of the project is the Integrated Modification Methodology (IMM), which is an innovative design methodology developed at Politecnico di Milano and aligned to the UN Sustainable Development Goals (SDGs) 2030. One of the 17 goals identified within this framework, SDG 11, is entirely about cities and human settlements and making them inclusive, resilient and sustainable. According to the IMM approach, cities are regarded as Complex Adaptive System and the focus is on simulating their operative mechanisms, involving both the internal subsystems and the external systems that the cities are part of. The result is a methodological interpretation of the SDG Number 11, suggesting locally-based actions. IMM methodology is based on a multi-stage process, composed of four integrated phases, respectively: Investigation, Formulation, Modification, Retrofitting and Optimization. IMM intends to assist designers and decision-makers, providing them a fully-integrated design process to transform an existing urban context into a more sustainable one. Moving from the SDG 11 as the main catalyser of our action, IMM systematically correlates all the other SDGs in a holistic way.

The Polimipararocinha project has begun with a deep systemic investigation of Rocinha's morphology in which the malfunctioning subsystems and the capacities of the existing context have been studied. This stage unveiled the potential intrinsic relations able to activate the adjustment scenarios in different dimensions. In Polimipararocinha a system mapping is the ground for the analysis and scenario developments. Here, morphology is taken as the substructure that shapes the mobility and functional distribution, and consequently influences the economy, social relations, and energy consumption patterns. Apart from the morphology, Polimipararocinha encompasses various dimensions, each of them framing a broad work theme: ecosystem services, waste management, food production, energy, and information technology. However, morphology is the common hub through which each theme is related to the rest and the aftermath of all intervention is measured with reference to it. The proposed systemic transformation intends to offer limited custom-made modifications and leave the rest to the adaptation and evolving mechanisms.

Energy

Based on the described multidisciplinary and integrated design methodology, the project foresees several focus studies on different topics for the sustainable regeneration of Rocinha. The energy project aims to fulfill basic electrical needs of the low-income households of the favela by exploiting solar energy through photovoltaic panels installed on the rooftop of the buildings, where the incident solar radiation is abundant. Solar energy exploitation can, in this way, reduce electricity thefts and increase grid reliability inside the favela.

Ecosystem services

According to IMM and its multidisciplinary approach, an Ecosystem Services (ES) approach was applied to estimate environmental conditions considering that urban liveability is influenced by natural resources (e.g. soil, air and water). The ES assessment allows identifying areas compromised and environmental degraded that are more subjected to possible disaster events as landslides or flooding. The ES-based approach is pivotal for setting nature-based solutions (NBS) contrasting risks and improving urban ES as well as local quality of life. NBS are actions addressing ecological, social and economic challenges making use of natural processes and ES for functional purposes. Specifically, NBS mitigate flood, drought, erosion and landslide.

Mobility

The current mobility system of Rocinha present critical issues. Many recent studies about favelas mobility highlighted the need to improve the general accessibility of these communities through interventions focused on supporting the no motorized systems, in particular implementing bicycle systems. In consideration of that and on the aims of "Rio Conecta" plan, PolimiparaRocinha highlighted the needs for Rocinha to improve the accessibility level and the potential coming from the bike mode. The lacks of an integrated mobility system able to support the existing subway station makes the underground able just to covers only limited areas alongside the main street of Rocinha. An affordable and integrated bike sharing system has been identified as a priority after the analysis of the street structure, the potential of the system and the mobility index value. The electric bikes are charged by the locally produced energy. The system will be linked to an Urban Management System (UMS) which will collect mobility data for further transportation strategies.

Water and wastewater

The collection of wastewater and rainwaters is necessary for the protection of public health and the correct management of the territory. A "pilot" area has been identified, to allow the replication of the proposed procedures. Sewerage has been sized considering a water supply of 150 l / (ab day) and that 80% of the water supplied is collected into the sewerage. The resulting overall discharges are very low, which could lead to settling and therefore septic problems. In any case, the diameter of the ducts of the network was set equal to 150 mm, to avoid problems of occlusion. The possibility to convey a small percentage of rainwater is considered, in order to “clean” the pipes, when necessary. The designed pipelines are easy to lay and inspect, and, during construction, must be protected against possible damage, both mechanical and due to climatic actions. Before the water is released into the environment, a treatment must be carried out.

Although it is not properly hydraulic, it is essential to underline the need for direct community involvement, to guarantee the correct use of the network (for example: no solid waste must be discharged into the pipes) and a better land management. The community involvement will consent also to achieve a greater awareness and interest in the work and the training on the skills that can be used to learn the correct construction and management of the sewage networks, which can generate an economic activity, even if small.

Food

The problem of healthy food and food education is in Rocinha a main problem for most of the children and their parents, which have no access to fresh food and do not receive any information about how to eat healthy. The project elected food a crucial tool for introducing a synergic strategy toward a new circular metabolism of the favela’s internal processes. Rocinha is characterized by an impressive volume density and almost total absence of voids, with the steepness of the territory make not possible to pursue any kind of traditional cultivation. For this reason Polimipararocinha considered to some innovative and sustainable strategies of urban agriculture, integrated with existing buildings, like green roofs, vertical farming and aquaponic. These vegetable gardens raised by the local communities provide fresh fruits and vegetables, while aquaponic greenhouses participate to the local food strategy production and simultaneously aim to foster local economies. The food topic is considered strongly connected with the Water (gardens will increase the drainage of impermeable surfaces otherwise generating critical runoff) and the Waste sector (re-use of organic waste).

MATERIALS AND METHODS

In order to suggest possible improvements in the solid waste management for Rocinha, a picture of the situation with reference to the amount and the composition of waste flows was needed. Consequently, an effort was done in gathering all available data, and analyze them to define a baseline.

Data analysis

All data available from public sources were collected, in order to evaluate the amount of waste generated in Rocinha, and its composition. Existing data are mostly based on information provided by the Comlurb, but other sources were available as well. When possible, complete data series were used for the analysis (IPP, 2017; IBGE, 2017; SNIS, 2017). At the same time, aggregated data were used to correct or validate the estimate (PMGIRS, 2015; EMOP, 2012; UFRJ, 2015). The analysis was performed with the open-source software R-Stat and related packages (R Core Team, 2015; Wickham, 2007; 2009; 2011).

With reference to waste composition, only that of households waste was available. For the whole Municipality of RJ, data started to be collected in 1981 (Lima and Sorliuga, 2000; GPA, 2012), while data for Rocinha are available for a single year (GPA, 2012). Numerical data for both RJ and Rocinha are listed in Table 1. Data show a coherent picture, which has been taken as the basis for the assessment.

Finally, it was necessary to evaluate the number of inhabitants of Rocinha. Evaluating the population of an informal settlement is not an easy task, due to the lack of reliable information. Official data range from about 70,000 (IBGE, 2010) to about 100,000 (EMOP, 2010) inhabitants. The electricity provider Light S.A. estimates 165,000 inhabitants, while citizens associations suggest a range between 180,000 and 220,000 people. Calculation presented in this paper are based on an estimate of 211,000 inhabitants, based on Polimipararocinha best guess, but further statistical and demographic analysis are required.

Table 1 Characterization of Households waste in Rio de Janeiro (RJ) and Rocinha for the year 2012, weight percentage [GPA, 2012]

Fraction	Rio de Janeiro (%)	Rocinha (%)
Paper / Cardboard	15.99	11
Plastic	19.14	21.82
Glass	3.28	0.5
Organic matter	53.28	60.67
Metal	1.57	1.69
Inert waste	1.81	1.11
Leaves	1.35	0.52
Wood	0.34	0
Rubber & tyres	0.22	0.44
Tissues	1.76	1.11
Leather	0.21	0
Bones	0.01	0
Coconut	0.82	0
Paraffin	0.05	0
E-waste	0.2	1.04
Total	100	100
Specific weight (kg/m³)	133.02	111.17
Moisture content (%)	36.57	39.46

GIS analysis

The analysis has been carried out using both open-source softwares QGIS and related plugins (QGIS, 2017) and GRASS GIS (GRASS, 2017). The base map, containing every single buildings with an estimate of the number of floors, has been prepared by the Universidade Federal do Rio de Janeiro (UFRJ), which is keeping it updated. Other geographical information are available online on the website of the Municipality of RJ (IPP, 2017). Other maps for the location of waste containers in Rocinha were used (Azevedo, 2010; EMOP, 2012).

RESULTS

Solid waste flows for Rio de Janeiro and Rocinha

A database was prepared, considering the following entries: year; numeric value; unit of measure; location (boundaries of the area); phase (production, collection or disposal); source (whether the waste is coming by households, street sweeping, etc.); actor which performed the collection; final destination of the waste; reference for data; material (organic fraction, metal, plastic, etc.); type of data (whether estimated, measured, derived from a survey). Not all information were available for all data.

The analysis led to the identification of several waste streams (depending on the source of the waste), collected by the Comlurb or by private actors, with several final destinations. In the collection phase, we can divide the total waste into different streams:

- Public waste, which comes from street cleaning and sweeping;
- PublicGreen, green public waste from pruning and cutting;
- FreeRemoval, bulky waste removed for free by a specific service provided by Comlurb;
- Households waste, also referred to as “domestic” waste;
- RCC, Construction and Demolition waste;
- RSS, Health-care waste;
- Separate collection.

The role of waste pickers (“catadores”) was not considered in these calculation, as data available do not take them into account.

Since many information were available with reference to RJ, while few information were available for Rocinha, results from the analysis of solid waste flows were used to adjust the data available for Rocinha.

In fact, only Public and Households waste collected by Comlurb data series were available for Rocinha. Moreover, public waste (Public2) was an aggregated data comprehensive of Public, Public Green and FreeRemoval waste, as previously described.

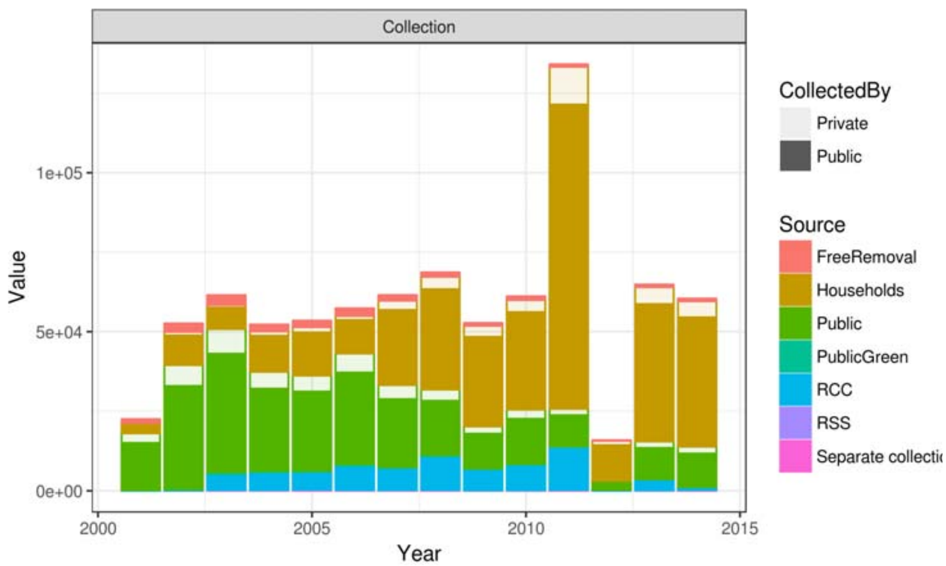
As a first step, both Public2 and Households waste have been increased considering the role of the Private sector, which accounts for 11% of the total amount of collected Public, PublicGreen and FreeRemoval waste, and for 16% of the total amount of collected Households waste in RJ.

Then, Public2 has been split into Public, PublicGreen and FreeRemoval waste, and percentages related to other waste streams (RCC, RSS, Separate collection) have been estimated. These results, which represent the collection phase, are described in Figure 1.

Figure 1 represents only the percentage of waste collected by public or private actors, but the percentage of waste which is not properly collected should be taken into account to estimate the overall waste generation. With reference to RJ, about 59% of Households waste is estimated to be properly collected, while 41% is not collected and improperly disposed (burned, buried, dumped, etc.) (UFRJ, 2015). The amount of collected waste in Rocinha was consequently increased calculating the amount of improperly collected Households waste for Rocinha (18,870 t/y), in order to calculate the amount of total produced waste (60,411 t/y in 2014). The final result, which is a daily production of solid waste of about 166 t, is in line with the estimate of 152 t/d by EMOP (2012).

Considering a population of 211,000 inhabitants, the daily per capita generation of total solid waste is estimated in 0.78 kg/d/in., while the daily per capita production of Households waste is estimated in 0.59 kg/d/in.

Figure 1 Rocinha: solid waste streams in the collection phase from 2001 to 2014



Distribution of solid waste within Rocinha

As a first estimate, Voronoi regions were calculated for each point, whether formal ("Collection point") or informal ("Dumping point"). The Voronoi region for each point represents the set of points in the plane for which that point is the closest one among the others (Fortune, 1987). This choice represents an approximation which does not take into account the presence or absence of streets or alleys, nor the differences in altitude that characterize Rocinha. Nonetheless, a detailed map of streets and alleys is not yet available, and the behaviour of citizens is scarcely predictable.

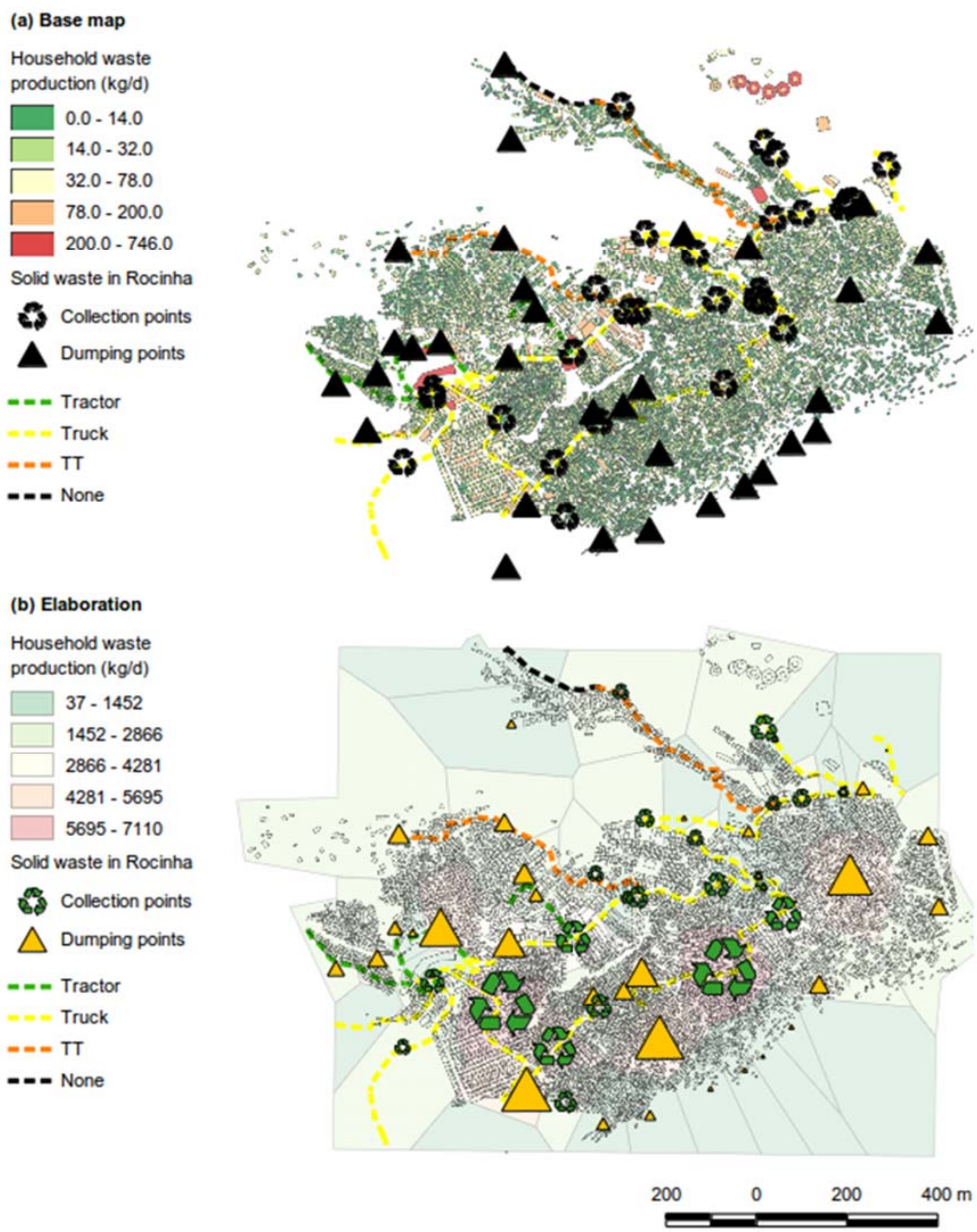
The calculation of Voronoi regions allowed an estimation of waste reaching each point through the sum of the amount of waste calculated for each building included in the Voronoi region. In the Figure 2, (b) Elaboration, Collection points and Dumping points are represented with different dimensions depending on the amount of waste reaching each point, ranging from less than 100 to more than 7000 kg each day. This map can be considered a first tool for the identification of critical points, allowing a first estimate of the number of equipment (such as containers) needed.

A new proposal

A new system for waste management within Rocinha has been proposed. Previous studies, which identified three main actors (companies, local communities, public authorities) and detailed actions (Azevedo, 2010) or solutions such as underground containers to tackle the problem of space (EMOP, 2012), were considered. Anyway, it is worth mentioning that none of these proposals has been implemented yet due to conflicts between the state and the municipal management (Silva, 2014).

The proposed strategy is to build a collection system parallel to the existing one managed by

Figure 2 Household waste production in Rocinha: (a) Base map - daily production for each building, location of Collection and Dumping points, collection routes; (b) Elaboration.



Comlurb, in order to divert valuable materials from the general waste collection. Only a small part of the waste will be treated inside Rocinha, and this percentage will vary depending on land availability: in fact, recycling waste on site requires space for storage and treatment processes, which represents a big constrain for Rocinha.

Promoting separate collection at the household level is required to obtain high quality secondary raw materials and to provide a safer working environment for collection workers. The organic fraction, which is abundant within Rocinha, will be targeted, as well as recyclable waste (plastic, paper, metals, e-waste, etc.) which have a high (potential) economic value.

The new collection system will be based on nodes. Each node represents the focal point of the whole collection system for a certain area. In each node, a group of workers, autonomously or in cooperatives, will be responsible for waste management. A network will connect all the nodes. The network will allow some economies of scale, which include the shared use of equipment (such as: press, shredder, etc.) and an improved access to the market of secondary raw materials. The cooperative of waste pickers Rocinha Recicla (established within the project “De Olho No Lixo”) is operating within Rocinha since 2016 and will represent a fundamental node of the network.

For each node, several strategies will be evaluated with reference to different stages: separate collection, primary storage, local treatments and awareness. Those strategies are explained as follows:

- Separate collection is based on the location of street containers for the organic fraction and recyclables. Innovative solutions should be found in order to address the lack of space within Rocinha. Alternative solutions (door-to-door collection, location in schools or other facilities) may be explored.
- “Eco-Centers” are designed for the primary storage of recyclables. The storage period depends on space availability (less space, shorter period), but also from the size of vehicles accessing the Eco-Center (smaller vehicles, shorter period OR higher number of trips).
- A multi-purpose structure with a hexagonal shape, defined as “the Kiosk”, will serve as: information point to explain the functioning of the SWM system and raise awareness; distribution of items to enhance the separate collection, the recycling and the re-use of materials (paper bags for organic collection, “take-back” glass bottles, locally produced compost) and Personal Protective Equipment (PPEs) for waste workers; collection of paper, metals and plastic.
- Local treatments for the organic fraction will consider both composting and anaerobic digestion, depending on the local situation (e.g. land availability, distance from buildings, request of compost in surrounding areas…). With reference to composting, it may be eventually divided into sub-modules and managed on a community basis. The anaerobic digester will be designed according to a local project implemented in RJ (Mattos and Farias, 2011), considering safety issues and the evaluation of the potential market for the biogas.

The study presented in this paper provides technical support for the establishment of a node. In fact, moving from the identification of an area, it will make possible to calculate the amount of waste produced within that area, and the quantities of organic and valuable fractions such as paper, plastic and metals. Then, it will be possible to calculate the space required for street collection, storage and local treatments, allowing the identification of proper places.

The analysis performed on the six zones identified within the “Polimipararocinha” project is presented as an example of the procedure. Since an important goal of the project is to diminish the amount of waste improperly disposed, which has been quantified in about 41% of generated Household waste, this has been chosen as the amount to be diverted through separate collection. Consequently, the efficiency of separate collection should reach about 45% of organic fraction and about 73% of recyclables (plastic, metals and paper/cardboard).

Design choices are summarized hereafter:

- Separate collection. The dimension of containers has been calculated considering specific bulk weights for each fraction (organic: 0.3 t/m³; paper: 0.13 t/m³; plastic: 0.072 t/m³; metals: 0.12 t/m³) and a maximum weight of 80 kg for the full container. Daily collection.
- “Eco-centers” have a maximum height of 2 m. Maximum storage period has been fixed in 7 days as a first choice.
- The “Ecoponto Kiosk” has a side of 2.5 m and a total area of about 16 m², and can accommodate a volume up to 1.83 m³ of plastic, 1.1 m³ of paper and 0.3 m³ of metal. The “Ecoponto Kiosk” is located in areas without already existing structures.
- Composting slabs will have a maximum height of 1.5 m, with a width of 2 m at the bottom and 1.5 m at the top; the smaller module should have a depth of about 2 m; a reduction of about 30% of volume is considered. The anaerobic digester has a circular shape with 2 m radius

and requires a circular buffer zone with 10 m radius. The retention time is assumed to be 30 days.

The final result is resumed in Table 2. For each zone, the area required for the implementation of each strategy is presented, together with the impact on empty spaces existing in that area. The number of containers required for each zone has been calculated as well.

Table 2 Design of the new system for waste management in the seven zones of the project

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 6**
Number of inhabitants	4058	4166	4774	4404	4227	2234
Amount of diverted waste						
Weight (t/d)	1.26	1.30	1.49	1.37	1.32	0.70
Volume (m^3/d)	9.24	9.49	10.87	10.03	9.63	5.09
Total area required (m^2):	98	486	115	108	88	62
Primary storage (m^2)	4	7	7	7	7	3
Ecoponto Kiosk (m^2)	16	No	16	16	No	16
Secondary storage (m^2)	25	26	30	28	26	14
Composting (m^2)	53	-	62	57	55	29
Anaerobic digester (m^2)	-	452	-	-	-	-
Impact on empty spaces	5%	36%	6%	6%	7%	14%
Equipment required:						
Metals – Bins 0.12 m^3	0	2	1	0	2	0
Paper – Bins 0.24 m^3	2	6	4	4	6	0
Organic – Bins 0.24 m^3	10	12	12	12	12	6
Plastic – Cages 2 m^3	2	4	4	4	4	2

CONCLUSION

The analysis carried out allows a first estimation of the distribution of solid waste within Rocinha, which may represent a support to decision making in solid waste management.

The new collection system has been proposed taking into account its possible impact on the existing situation. In fact, waste collected in Rocinha does not reach any sorting plant, so its diversion will not affect negatively the cooperatives involved in waste separation in other nodes of the waste collection system of RJ (ETRs or Seropedica). On the other hand,the recovery and recycling of valuable materials may become a source of income for individuals and the community itself, and the diversion of waste from the existing system would lead to decreased costs for collection.

A successful implementation of this proposal should consider different aspects, which are shortly presented as follows.

Identify and contact existing actors (public authorities, academy, civil society organizations and non-governmental organizations, companies, waste pickers from the informal sector) is really important, as a high level of engagement of the community is required for the functioning of a waste management system. In particular, Comlurb should be involved and asked for a different management of the collection, in order to cover more areas, or for an institutional or economical support of other projects.

Moreover, the integration of the proposal within institutional programs should be evaluated, considering that many initiatives have been taken in the past (e.g. Plano de Desenvolvimento Sustentável; Programa Alternativo de Coleta Seletiva; Lixo zero). The most important and recent initiative is “De Olho no Lixo” (2016), which will represent a focal point for our project.

Finally, the role of the lively civil society of Rocinha, which generated in the last years many activities related to waste management, should be enhanced, and the environmental awareness tackled.

ACKNOWLEDGEMENTS

The authors wants to thanks: the NGO “Il sorriso dei miei bimbi” for the precious insights from the heart of Rocinha; the team of the Federal University of Rio de Janeiro (UFRJ), and in particular Gabriella Rossi, Gisele Silva Barbosa and Roberto Machado Correa; Marco Contardi and Pietro Ceppi from the Foundation Getulio Vargas (FGV); Maria Izabel de Carvalho for sharing her social-based perspective on waste management issues in Rocinha, her hometown; professor Stefano

Mambretti and professor Gianfranco Becciu; Silvia Ronchi, Hadi Mohammad Zadeh and Anita Tatti, the operative team of Polimipararocinha project, for their efforts.

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STUDY ON PAPER AND METAL WASTE RECYCLING IN KHULNA CITY

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ABSTRACT

All over the world, the rate of solid waste generation is increasing day by day. In Bangladesh, the rate is also alarming. The solid waste generation is directly related with living standard, the economy of the society and people attitude. Though it is not possible to stop solid waste generation, it is possible to minimize the solid waste generation. Paper and Metal (PAM) wastes are parts of solid waste. This study has been performed over Khulna City which is the third largest city in Bangladesh. Total waste generation is calculated at 520 tons/day where paper waste forms almost 9.5% of this total waste. A questionnaire survey is performed over existing reuse of PAM materials to find out the present condition of reuse of PAM waste, determining the recycling rate of PAM on primary data in Khulna City and newly recommended technique for reducing recycling time and cost and increasing the rate of recycling. The questionnaire survey is carried out on shops of reusable PAM waste materials at some selected area of Khulna. Primary data were collected from PAM waste collectors, recyclable dealers, industry. Secondary data as statistical were collected from the quantity of PAM waste generated by previous research, book etc. Metal recycling shops are located at Sheikhpara area and paper recycling shops are located near Khulna Railway market area enormously around 200 metal and 50 paper recycling shops entirely in Khulna. About 600 people directly involved in this sector. Paper waste generation is increasing day by day and Metal waste generation is not increasing due to increased use of Plastic.

Keywords: *Paper Metal, Recycling, Questionnaire survey, Waste generation*

1. INTRODUCTION

Wastes are all the materials arising from human and animal activities that are discarded as useless or unwanted. Once substance or object has become waste, it will remain waste until it has been fully recovered and no longer poses a potential threat to the environment or to human health.

Generally, when the wastes are in solid form it is termed as solid waste. Also, it can be said that solid waste is that are solid or semi-solid, non-soluble material garbage and sewage sludge. Waste may be of different types. It may be shortly classified as decomposable and non- decomposable waste or may be classified on the source of generation i.e. food wastes, household wastes, livestock wastes, commercial wastes, industrial wastes, hospital wastes, hazardous waste, demolition waste etc. Hazardous wastes are the wastes which exert potential hazard to human health or living organisms. Now a day, wastes are also generated from used computer parts, automobile parts, pieces of furniture are also taken into consideration.

Wastes also are arisen from construction, remodeling, and repairing of individual residences, commercial building and other structures which are called construction wastes. Agricultural wastes are generated from agricultural activities such as the planting and harvesting of raw, field, tree and vine crops. To restrict agricultural waste, coir pith is recommended for flourishing ZnCl2 activated carbon and it is applied for discharging toxic anions, heavy metals, organic compounds from water (Namasivayam & Sangeetha, 2005).

Now a day, waste is a global dilemma. Generation of waste has been started from the very commencement of mankind and it is augmented with the advancement of mankind. Though some wastes are decomposed and stabilized, most of them are not decomposed and they become harmful for the environment. With the progression of time, the quantity of waste is expanding at an alarming rate. Hence it has become the predicament for Mankind. To stabilize these phenomena, the process of Reuse has been practiced.

In Asia, People are migrating to cities from rural areas. That's why cities are being transformed into more urban and financial expansion has also been befallen. That's why solid waste generation domination is increasing and having diversity rather than western countries (Tapan, 2009). In details, the urban areas of Asia propagate about 760000 tons of Municipal Solid Waste per day or nearly 2.7 million m3 per day which will be 5.2 million m3 per day in 2025. Despite it is bourgeois, the actual rate will be more than double (Riyad, 2014). In India, 90% wastes are dumped in open spaces, therefore, the waste management is an obstacle for this country and average waste generation rate is 0.3- 0.6 kg/capita day though varies by citizen sizes (Dyson, 2005). In Malaysia, waste generation rate is 0.5-0.8 kg/person/day (Latifa & Samah, 2009). The average household solid waste generation rate of Turkey is 0.6 kg/year per capita. Almost people of Turkey in the project regions is ready and intending to take part in individual collection programmes. (Metin, et al., 2003)

To subdue this pernicious problem, recycling and reuse are needed all over the world. Recycling means the reprocessing of wastes to retrieve an original raw material and producing the same or different products from it. Such as recovering steel contents from tin cans and producing steel pots. Reuse means the subsequent use of a material in the same form after the original purpose of this material has been fulfilled. The materials which are called recyclable include many kinds of glasses, papers, and cardboard, metals, plastic, tires, textiles, and electronics. In our Country, the textile sludge is being dumped without any enactment of legislation. Thus, our environment is facing a great problem. Textile sludge has different parameters as Moisture -30.095%, Colour-Brown, Smell- Acute, conductivity- 0.75 m/cm etc. (Turna, et al., 2015). The composting or other reuse of biodegradable waste such as food or garden waste is also regarded as recycling. At Dhaka in 2001, the average percentage of the wet weight of bio-degradable waste was 70%. (Zurbrügg, 2002).

Bangladesh is generally faced with the fast decay of environmental and sanitation conditions due to the common system of transportation, collection, and damping of Solid Waste. In Khulna, KCC is not able to motivate people to use dustbin usually yet (Ahsan & Islam, 2009). In a fast-growing city, System dynamics model should be used to predict solid waste generation for future if have less historical data (Dyson & Chang, 2005).

The prediction of PAM waste generation plays an important role in PAM waste management. However, obtaining the anticipated conjecture accuracy by regarding the generation trends facing many fast-growing regions is quite challenging. Moreover, to population growth and migration, underlying economic development, employment variation, house size, and the impact of waste recycling would impact the PAM waste generation interactively. In Khulna City, Per capita, Metal waste generation rate is 6kg/day. Average total per capita waste generation rate of KCC area is estimated at 0.35 kg/cap/day. Total waste generation is determined at 520 tons/day where paper waste forms almost 9.5%of this total waste (Riyad, 2014). This study exposes that there are around 695 ferrywalas involved in the chain of recycling network of Khulna. More than 277 small recyclable dealers (SRDs) in Khulna accept all types of waste from tokais and ferrywalas and sell the recovered materials to medium recyclable dealers (MRDs). There are approximately 140 medium recyclable dealers in Khulna. In the KCC area, there are about 33 large recyclable dealers (LRDs).

2. The Per capita paper and board consumption in Bangladesh is about 3.5~4 kg and more than 300 kg in developed countries. The world average is around 50 kg while the Asia average is nearly 30 kg. If we grow up to Asia level, our consumption will be extended up to 10 times of current expenditure

3. METHODOLOGY

Khulna is the third populous city of Bangladesh, with a large population, has been a place of commercial importance for more than 150 years, stands on the banks of the Rupsha and the Bhairab rivers. It is in the south-western part of the country with its location on the axis of Jessore-Mongla port, the second largest seaport of the country. Geographically, Khulna lies between 22047´16´´to 22052´ north latitude and 89031´36´´ to 89034´35´´ east longitudes. The city is 4 meters above the mean sea level (MSL). At present, Khulna city holds a population of about 0.92 million with an area of 45.65 square kilometers and 31 Wards. Khulna city generates an immeasurable amount of PAM waste daily. So, it is important to manage this huge amount of PAM waste. The present condition of the PAM waste management should be investigated to find out which steps are more becoming for managing this huge volume of solid waste. A complete investigation of the reuse of PAM waste was conducted in Khulna city to find out the present situation of PAM waste management. To review the present condition of the reuse of PAM waste in Khulna city, the following steps were performed in Khulna city.

- Selection of Study area.
- Preliminary survey on selected area.
- Selection of different shop from preliminary survey
- Detail survey on selected shop.

3.1 Selection of Study area

Different areas were selected on basis of availability of Retailer and wholesaler shops. Retailer shops are those whose owner collect PAM waste from primary waste collectors like as Tokais, Feriwala etc. They can purchase PAM waste from collectors individually or by miscellaneous. Generally, the retailer shops are tiny and very dusty. The wholesaler shops are relatively large size than retailer shops. These areas were selected by discussing with different primary waste collectors and local people. Only the shops which deal with reuse are included in this study. The shops for recycling materials (PRMs and MRMS) were developed in the vicinity of three types of transportation modes such as the city railway station, city river port and a local truck stand. The selected study sites for Paper Waste Recycling shops (PRMs) and Metal Waste Recycling shops(MWRS) in Khulna city were: Khalishpur 45, Daulatpur 21, Sonadanga 85, Sheikpara Railway station, Ferighat.

3.2 Survey on selected area

To conduct a preliminary survey of the selected areas required to discuss with the local people and the waste collectors of the selected area. It was more significant and definite to find out the expected reuse shops for a detailed survey. The local shopkeepers also encouraged to find out the required reuse shops. The survey then performed over the people associated with the recycling process such as waste collectors, workers, and owners of recycling retailers, wholesalers and recycling factories. The waste reuse shops built of in clustered form. These shops located by roaming through the side roads of the city. A secondary survey was executed over the retailers and wholesaler shops to find out the daily selling and buying weight rate in 2010. It was easy to find out the clusters of waste reuse shops, but it was difficult to find out the actual number of shops as some isolated shops may not count. Many shops owners completely disagreed to share about buying and selling information by themselves. For this reason, the questionnaire survey was carried out for a long time about 8 months.

4. RESULTS AND DISCUSSIONS

A questionnaire survey on the existing recycling process was performed over the people connected with the recycling process such as waste collectors, owners, and workers of shops and recycling factories. The survey is carried out by three different categories: Primary PAM waste collectors, PAM wastes recycling shops, and PAM waste recycling factories.

PAM wastes excerpted from households, shops etc. are attained enormously by local collectors called ‘Ferriwala’ in Khulna city. There are 580 ferriwalas available in Khulna City who transport PAM from Khulna City. People also dump PAM wastes into dustbins, metal waste containers. The ferriwalas (Figure 4.1) collect and then convey PAM wastes using personal carrying item, Covered trucks, Normal trucks, Container Carrier Trucks, Tractors, Rickshaw van to Retailer shops. There are three types of recyclable dealers. 40 Large Recyclable dealers have employed around 10 labours. The number of medium recyclable dealers is 150 who have assigned approximately 5 labours. Lastly, 270 Small Recyclable dealers who have engaged around 2 people on average.

Maximum paper recyclable shops near Railway Market grouped into a large market. For paper retailer shops, they buy miscellaneous papers like chronic papers, newspapers, cartoons etc. from ferriwalas. Eventually, Grocers purchase reused paper from retail shops to make packets and posters, shown in Figure 4.1

Figure 4.1: Activities observed on Ferri wala and paper Retailer shop in Khulna area.

When the retailer shops have an adequate amount of paper waste, they sell to wholesaler shops. The papers are sorted into different categories in wholesale shops. There are 10 paper recyclable shops noticed who only deals with cartons and handle 100-400 kg cartoon daily. But most of them are at haphazard conditions as they have a little time to sell them. The papers, not possible to recycle are dumped underground. They sell their paper wastes to Khulna Newsprint Mill (KNM) or transfer to Dhaka by the truck which is seen in Figure 4.2.

Figure 4.2: Paper wholesaler shop’s activity for transporting paper wastes to Paper mill.

Paper mills lie as Khulna Newsprint Mill always recycle damaged products. They purchase waste papers depending on the fiber strength, fiber yield following by type of product produced. The Paper mills have a scarcity of desired recycle fiber, foreign pulps, chemicals, new technology etc. (Quader,2011). Khulna Newsprint Mills (KNM)’s initial production capacity was 50000 tons.

There are around 200 metal recycling shops in Khulna city. The Metal Retailer shops purchase used irons from ferriwala. Even they collect the construction iron rubbish if they are summoned by the owners. They fix a partial amount of Metal wastes which are traded to local buyers which are seen in Figure 4.3. They systematized them by category like as Tin, Rickshaw puller, Reinforcement etc. in their shop. When they got a large amount of scrap Metal materials, they sell them to Wholesaler shops. The wholesaler shops distinguished various items of irons and arranged to their shops by categories noticed in figure 4.4.

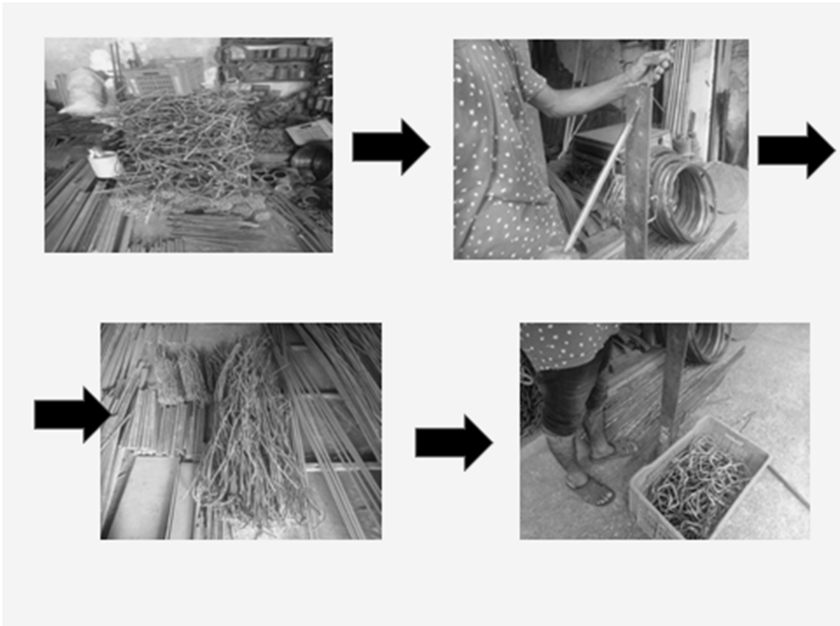

Figure 4.3: Activity of Metal retailer shops in Khulna area

Figure 4.4: Distinctive view of Metal wastes by Wholesaler Metal Waste Collector in Khulna

There is no Iron Mill in Khulna. That's why the Wholesaler shop sends their scrap iron by trucks to Dhaka Iron mills as there is no Iron Mill in Khulna.

This study expresses that the recycling process of Khulna city is quite flourishing. The shops for PAM reusable material use to sell and buy the valuable parts of the PAM waste materials for their further use. The people of Khulna City should be motivated more to help the recyclers by using dustbins, containers.

4.1 Tables

Two types of data as primary and secondary obtained for executing the research. Primary data collected from PAM waste collectors, recyclable dealers and industries. Secondary data as statistical collected from the quantity of PAM waste generation through previous research, book.

There are about 28 paper shops which are shown in Table 4.1. However, some paper recycling shops located in another places in Khulna city. Sheikpara is a place where most of the metal dealers run their business. There are about 200 metal dealers and the area is seen crowded most of the working time.

Table 4.1: Number of Shops separated by Area and Character of Solid Waste as Metal, Paper, and Mixed Shops.

Location Names	Number of Paper Dealers	Number of Metal Dealers	Number of Mixed Dealers
Khalishpur 45	0	0	22
Daulatpur 21	2	4	3
Sheikpara	0	200	2
Railway station	28	0	0
Ferighat	2	0	3

From Table 4.2 can be seen that the most of paper collected by Feriwallas rather than Tokais and Vangari. Ferriwallas assembled 1000 kg per day. Sometimes retailers send their own transport as Vangari or Truck to collect recyclable materials based on large order.

Table 4.2: Daily Quantity of Recyclables Paper Collected in Khulna area.

Collectors	Quantity of Paper Collected per day (kg)	Percentage of Recyclable Materials
Tokais	500	21
Feriwallas	1000	70
Vangari	1200	20

This study evolved the data from 10 shops in varied position of Khulna city. A split but near about price rate is found during this research. The price rate of buying and selling varies based on different factors such as market demand and supply. Here, the 9th number of shop was found comparatively large, and they sell extensive amount of old cardboard which is noticed in Table 4.3.

Table 4.3: Weekly Sell weight and Price Rate of Papers waste Retailers in Khulna area.

No of Shops	Buying/Selling Weight (weekly) (ton)	Buying Price Rate TK/kg	Selling Price TK/kg	Materials
01	0.5	10	11	Old book page
02	1	9.5	10.5	Old book, page
03	1.5	8.5		Old cardboard, book etc
04	0.8	8	9	Old Cardboard, book
05	2	8.5	8.5	Old Cardboard, book
06	3	9	10	Old Cardboard
07	1.6	8.5	9.5	Book, page
08	0.7	9.5	10	Book, page
09	2.5	9	10.5	Old Cardboard
10	2	10	11	Cardboard, book, page

The third number of wholesaler shop who sales 72-ton paper weekly and they sell by highest rate as 10.5 as they were very larger group (Table 4.4).

Table 4.4: Weekly Sell weight and Price Rate of Paper waste Wholesalers in Khulna area

No of Shops	Buying/Selling Weight weekly (ton)	Buying Price Rate TK/kg	Selling Price Rate TK/kg	Element
01	40	9	11	All Paper types
02	45	9	10	All Paper types
03	72	9	10.5	All Paper types
04	65	8.5	10	All Paper types
05	70	10	11	All Paper types

The number of different sizes of paper packets per kg was given in Table 4.5. The number of packets per kg varies widely according to their size. The price of the packet was not assigned according to the sizes but to the weights. The price of different sized paper packets was approximately tk 70 per kg.

Table 4.5: Different sizes of Packets made of Waste Papers (Price: 70 TK per kg of any size packet.

Sizes of Packets	Number of Packets per kg
Very Small	800
Small 1	500
Small 2	300
Medium 1	250
Medium 2	200

Table 4.6 gives us information about the foremost seller of metal waste sell about 5 tons weekly including plate and Cast iron. The number 1 shop sell less amount of metal waste than all as its size is low.

Table 4.6: Weekly sell weight and Price Rate of metal wastes by Retailers in Khulna area.

No of Shop	Sell Weight Daily (kg)	Sell Weight Weekly (Ton)	Worker Number	Price Rate
01	100-200	3	3	Rickshaw Axle: 15Tk/kg Tin: 8 Tk/kg Reinforcement: 11Tk/kg Cast iron: 27Tk/kg
02	150	2	3	Rickshaw Axle: 15Tk/kg Tin: 8 Tk/kg Reinforcement: 11Tk/kg Cast iron: 27Tk/kg
03	100-250	2	0	
04	500	4	2	Average 35-45 Tk/kg Sell most of Reinforcement
05	500-700	5	2	Angle: 60 Tk/kg Plate: 70 Tk/kg
06	600-1000	1.3-1.5	0	Average 32-200 Tk/kg Ship Metal Material: 75-85Tk/kg Reinforcement: 35 Tk/kg Angle: 60 Tk/kg
07	200-300	3.5	2	
08	600-700	4	3	Average: 18-35 Tk/kg
09	300-400	3	1	Tin: 8 Tk/kg Reinforcement Material:11 Tk/kg
10	700-800	5	3	Plate: 70 Tk/kg Cast Iron: 27 Tk/kg

Table 4.7: Average weekly sell weight of metal wastes weekly by Wholesalers of Metals in Khulna.

No of Shops	Sell Weight Weekly	Worker Number
01	35	5
02	45	7
03	40	5

From Table 4.8 and Table 4.9 can be seen that the amount of paper waste is increasing, and amount of metal waste is decreasing day by day. The paper waste weekly weight has been turned from 0.8 to 2 in 2017 than 2010. In the other hand, metal waste weekly weight has been decreased from 7 to 5 observed on shop no 5.

Table 4.8: Comparison of average Buying/Selling weekly weight rate of Paper wastes weekly between 2010 and 2017 in Khulna area

Shop No.	Buying/Selling weight weekly (ton) in 2010	Buying/Selling weight weekly (ton) in 2017
01	0.4	0.5
02	0.7	1
03	0.7	1.5
04	0.7	0.8
05	0.8	2

Table 4.9: Comparison of average Buying/Selling weekly weight rate of Metal wastes between 2010 and 2017.

Shop No.	Buying/Selling weight weekly (ton) in 2010	Buying/Selling weight weekly (ton) in 2017
01	4	3
02	3	2
03	2.5	2
04	6	4

05	7	5

5. THE PROPOSED TECHNIQUE

An enormous time and money loss occur, during the sorting and collection of different types of wastes by the retailers This is a tiresome process for the consumers (who produces wastes) to carry and sell their wastes to the retailers. It is carried to them mainly by street urchins and a very few numbers of consumers. It can be increased by placing a lot of dustbins in different areas of the city. But not the usual way of our country. The model we are talking about is placing the three-dustbin band with different visual gestures. We must put three instead of one at different important points of the city beside homes. The outlook for the dustbin would be different. It can be differed by inserting different solid colors, which can be seen in many western countries. But we want to visualize what to dump in which dustbin. The body of the dustbins is colored in such a way that the looked like the pile of a specific type of waste. A nameplate is provided to ensure the specific type of waste. Here we are proposing to make three; one for paper, one for metal and one for others. The graphical representation is given in figure 5.1. However, proper adjustment between the higher and lower chain in the materials flow path, as well as personal hygiene training for the workers, would further improve the achievements of the established reuse scheme.

Figure 5.1: Diffrenet Waste Containers for different waste type.

Waste management by this process is a matter of practise by the consumers. With time, if they got evaluated to place the perfect waste in perfect container, the total waste management system would be much easier and time saving. This is the primary process. Then the collected wastes should be sorted a little and carried to the related recycler.

6. CONCLUSIONS

Through a study of PAM waste propagated from the city household, shops etc. in Khulna, we attained following conclusions.

- Weight of paper wastes are augmented to 2017 than 2010. That’s why upgradation of eco-friendly technology and resorting innovative and coherent management strategies should be developed for minimization of this increased solid wastes to prevent our environment.

- Diminution of paper use at Home and office is another solution to be grasped. Ordering newspapers is not only extravagance but also produce a lot of room devouring waste while everything is on the internet in the digital era.
- Metals wastes recycling are reduced to 2017 than 2010 for the increased use of plastic products rather than metal. It may be increased by generate new items for example reusable packaging like tin containers from recycled metals.
- The papers and metals which are not possible to recycle to be incinerated and dumped into underground.
- Eventually the Paper-Waste-Other Dustbin technique can be solution for sorting huge amount of wasted wastes and it will also help to recycle these.

ACKNOWLEDGEMENTS

The project was carried out under the supervision of my supervisor of Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh. The author wishes to express his profound gratitude and indebtedness to him for his valuable guidance, advice, help constructive criticisms during the investigation and preparation of the project. The author would also like to thank to all the teachers of Department of Civil Engineering, KUET. The author gratefully remembers the friends Argha, Mostakim, Ujjal all well-wishers, who helped me a lot in different important phases of the work.

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WATER SUPPLY HISTORY OF KHULNA CITY

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ABSTRACT

Khulna is the third-largest city in Bangladesh. The present water supply of Khulna is mainly drawn from groundwater sources by both deep and shallow tube wells. The average annual rainfall during 2004 to 2016 is 1948 mL. In future as demand will increase, conjunctive use of groundwater and surface water will be required. The study area comprises the region under the Khulna City Corporation (KCC), which is about 45 km^2. The study is performed by questionnaire survey from local people, visiting KCC, Khulna Water and Sewerage Authority (KWASA), previous and present water supply distribution points and collecting relevant data from Public Library newspaper. Additional survey works had also been conducted to justify the current water supply system in Khulna city. The total population of KCC is almost 1.5 million but only forty five percent of these populations get the service of KWASA. Almost 75 million liters of ground water is pumped up daily and supplied through its pipelines against an aggregated daily demand of 250 million liters by KWASA. Khulna people have been suffering from water crisis due to salinity in the dry season and insufficient rainfall for decades. Due to the increasing demand of water, road side tap system had been introduced. Though Khulna is the most rapidly developing city in the south and has a glorious historical background, no water history of the city is found yet. This paper deals with the assessment of the preceding and existing condition of water supply in Khulna City including water history from 14th century during the era of Khan Jahan Ali to ongoing KWASA project.

Keywords: *KWASA , fresh water, salinity, water supply, water history*

1. INTRODUCTION

The scarcity of water for drinking and domestic purposes is becoming more prominent in the third world countries. In Bangladesh, like many other developing countries, there is a high demand for safe water. Now, Khulna city faces the same problem. Khulna is the third largest city of Bangladesh which is situated in the southwest region of Bangladesh and lies in the delta of the Ganges. The scarcity of water has been increased gradually owing to increasing resettlement from the surrounding districts, for rapid urbanization and industrialization but lack of parallel growth in necessary water supply infrastructure. KWASA is the third WASA in the country, following the Dhaka WASA and the Chittagong WASA. Before the formation of KWASA, the water supply of Khulna City was under the responsibility of Khulna City Corporation (KCC). The current estimated production capacity of KWASA is only 75 million liters per day (MLD) through 54 production tube wells against the theoretical projected demand of 250 Million liters per day (MLD) (KWASA, 2016). Nevertheless, quality of water is also an issue due to widespread arsenic contamination and salinity of the groundwater. Several studies have been conducted in the past to find out dependable water source and to assess the quality of available groundwater resources for the Khulna water supply system. The maximum temperature is 33°C during March to May in Khulna. Saline intrusion in surface and groundwater is a big problem here. In Khulna, there is a high demand for improved water supply and drainage facilities. The Ancient name of Khulna was Jalalabad.

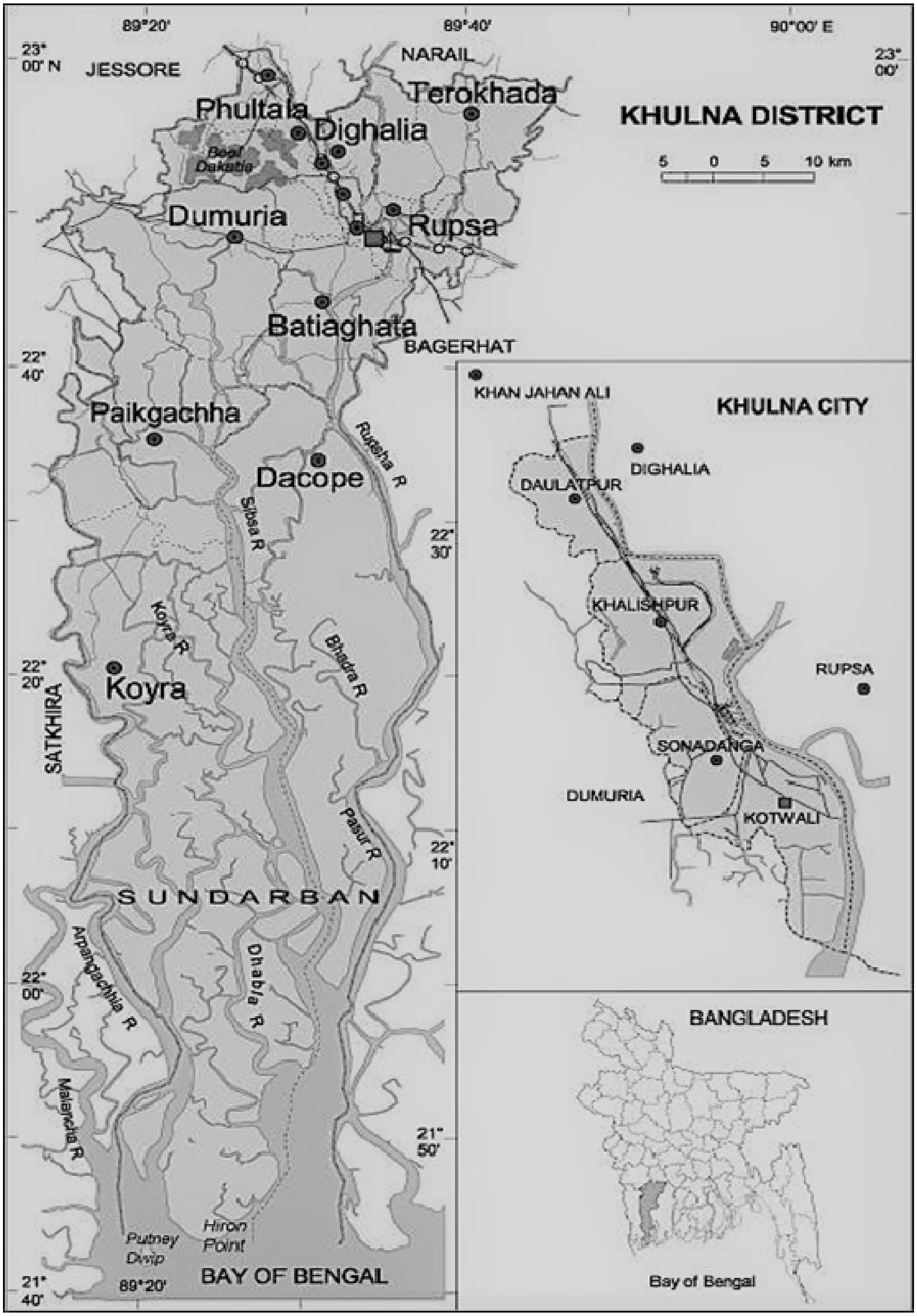

Figure 1.1: Area of Khulna city

Figure 1.2: Water supply in Khulna

Shamsuddin Firoz Shah was the first Muslim ruler who appeared in the city in the 14th century. During his government, the Muslim settlement in the city was increased. He established many mosques during his time. Khan Jahan Ali, a Muslim saint came here during

15 the century and existed here until his death. On that time saint Khan Jahan Ali excavated some Dighis to fulfill the demand of water for People. After his death, this area occupied under Vikramaditya. He established an independent Kingdom. Vikramaditya was succeeded by the support of his son who availed prevalence over the Baro-Bhuyans, holding strong possession of southern Bengal. Eventually, in 1611 AD, he was defeated by Man Singh, a Hindu general of the Mughal emperor Akbar. Khulna persisted under the rule of autonomous nawabs (rulers) of Bengal till 1793, when the British East India Company abolished Nizamat (local rule) and obtained the control of the city. In 1842, the city converted a part of Khulna subdivision of Jessore District. In 1882, it became the headquarters of Khulna District, comprising of Khulna and Bagerhat subdivisions of Jessore district, Satkhira subdivision of 24 Parganas district and the Sundarbans. Khulna was declared as a Pouroshava / Municipal council in 1884 and promoted to a Municipal corporation in 1984 on the platinum jubilee of Khulna Pouroshava. In 1990 Khulna has been listed as a City Corporation.

2. METHODOLOGY

2.1 Collection of Study Reports

The studies and literature accumulated from the reputed sources including KCC, Old KWASA, New KWASA, Newspaper and Magazines from Khulna Divisional Public Library. The survey took 6 months. We got a chance to meet with an Assistant Engineer-2(Civil) of Khulna City Corporation. We gathered many pieces of information from him. By attending two high administrative personnel of Khulna City Corporation including an Architect and Chief Health Officer, a distinct amount of information was received. Numerous facts collected from Khulna Wasa. Therefore we revisited two Sub Asst. Engineer, one executive Engineer. They responded with detailed information concerning water supply history of Khulna city. The ancient structure and the historical pond used for water supply purposes in the last century was also visited (Figure 1.2). This study also comprises a questionnaire survey from provincial people of Khulna City (Table 1). About 350 aged people were surveyed. We got an enormous amount of facts from them.

Table 1.1: The Questionnaire survey form

Ques No.	Questions
01	When and how did the city of Khulna get its name?
02	What was the water supply system in ancient Khulna?
03	Which was the system followed by people for collecting drinking water in ancient time and pertinent difficulties with it?
04	When the wells were excavated first in Khulna city?

05	When tube wells were installed in Khulna city?
06	Who took the primitive action for installing Tube wells?
07	When Khulna Wasa was constructed and why?
08	How much area was covered by Khulna Wasa at the commencement?
09	Is KWASA be able accomplish the extensive demand of enormous people?
10	What is the present condition of water supply system?
11	Are the local people satisfied with the facilities provided by KWASA?

2.2 Study Area

Khulna is the third-largest city in Bangladesh. It has an old river port governed by the Port of Mongla, the second largest seaport in the country located on the Rupsha River (Figure 1.1). Additionally, Khulna is also one of the two principal naval command zones of Bangladesh Navy. As a deltaic plain, the land is flat and poorly drained. The city is about 2.5m above the MSL (Mean sea level) and the land is influenced by the rapid growth of population and economic activities. The city also has many industries and factories.

3. RESULT AND DISCUSSION

3.1 Historical Overview

1884, Khulna was represented as a Pouroshava / Municipal council. After 100 years later, Khulna was declared as the Municipal Corporation and converted to Khulna City Corporation in 1990. The water supply system of Khulna was controlled by the City Corporation. However, It was unable to fulfill the public demand for a proper distribution of water due to a lack of manpower. That’s why Khulna WASA (Water Supply & Sewerage Authority) was established in 2008 to generate a proper distribution of water. The prominent ruler of the middle era, Khan Jahan Ali’s memorable Khulna area is about 46 square Kilometres. At present, the total population of the Khulna city is 1500000. Here many doctrines are found for conventional for nominating Khulna. One of them is “Chad Sawdagor was dwelling in Ujan city nearby the Ajay river. A temple was consecrated by Chad Sawdagor that named Khullonessori. Khulna was named by this temple.” Again it is apprehended that when people pass Voirob River they hear a sound as ‘Khulona’. Then may be the name of this city converted to Khulna. In 1836 Khulna Thana was established at Mirzapur field which is situated at the bank of Forest and administrative programs of Khulna were started. In 1842 Khulna subdivision was established at Kismat thana which was located between Talimpur and Srirampur. At the same time Khulna City, Bagerhat, Narail became the part of this subdivision. At 25th April 1882, the administrative programs were started fully. Then Khulna area was only about 12000 square kilometres where the Sundarbans area was 7000 square kilometres. The total population was 43500 then. In 12 December 1884, Khulna municipality was established under Bengal municipal. Though the municipality established in 1884, there was no water supply system. People used water in daily works from their digging well. But the deficiency of pure drinking water was available there. Then a very few reserve tanks were excavated from where people met their demand by collecting water. Remarkable significant reserve tanks of that time were Klay tank, Brickfield tank, tarer pukur. On 26th May 1896 a proposal was presented in a meeting of Pourashava to reduce the water demand problem of the municipality by supplying treated water. According to that proposal, initiatives for safe water purpose were developed in 1906 in Khulna city to supply treated water. However, this system served only a limited part of the whole city. At that time there were six reserve tanks viz main reserve tank, post office, civil court, Tut para, Dakhbangla, and Bajar. Now all of them are almost destroyed. In 1921 the modern water supply system was introduced in Khulna city. The treatment plant's capacity to treat 1.25 Million Litre of water per day. A revolutionary development was performed on water distribution work in 1929. At Hadis Park (previous brick field tank) an overhead tank was built which capacity was 0.078ML. Another overhead tank was constructed near Sher-e-Bangla road having a capacity of 0.02 ML (LGED 2005a & 2005b). This two-tank made a significant improvement in the water supply of Khulna city. Due to the tumid demand for water, roadside tap system was introduced for people and pipelines were installed in different residential areas of Khulna city. According to the municipal administration ordinance, People Health & Engineering Department received the responsibility to search new source of drinking water in 1960. By installing deep tube well, they figured a new water supply connection to different areas. In 1979 with the assistance of the Netherland government, the underground water of Khulna city was investigated. According to this investigation, twelve production tube wells were installed which were capable of supplying 0.15ML water daily. From 1989 different types of development works were performed in Khulna with the assistance of Bangladesh government. The capacity of water supply was raised up to 25 ML in 1994 through implementing different development activities. After implementing further development program by the Department of Public Health Engineering (DPHE) of GOB fund in 1997, the capacity augmented up to 32.5ML. At 1990, the responsibility of water supply was given to Khulna City Corporation from the Department of Public Health Engineering (DPHE). Due to the lack of development activity, most of the production tube wells became choked up and caused the depletion of the present water supply to 23.6 ML. Some existing tube wells became abandoned by this time. To mitigate the water crisis of Khulna city, Municipal Support Project (MSP), LGED carried out a feasibility study by Mott MacDonald (1994) under the financial assistance of the World Bank. This study was completed in 1997. After the study, ten production tube wells of capacity 16 MLD had been installed by the MSP project in 2002 (MacDonald, 1997).

3.2 Water Supply Condition of Recent Time

Water demand was rising quickly by the increment of population density. A project was started at 2004-05 to supply twenty production tube wells water by installing 20 km transmission and rising line as a remedy. But this project could not continue due to various problems. Khulna City Corporation led a water supply system with constrained resources and manpower. As a result, people suffered a lot for pure drinking water for almost twenty years. To resolve this problem, Khulna WASA was established in 2008 and commenced their journey with 32 production tube wells and 19 mini tube wells inherited from Khulna City Corporation. At present Khulna WASA covering 45.60 sq. km as their service area and serving 0.7 million people out of 1.5 million people. At present, a number of Hand tube wells, production tube wells (14”x 6”) and mini tube wells (6”x3”) are 10,000 Nos, 33 Nos, and 52 Nos respectively. KWASA supplying 59 MLD water through the pipeline and 60 MLD by 10000 hand tube wells constructed in the whole KWASA area. About 20,200 houses get water supplied by KWASA. It also supplies drinking water by vehicles in different areas to meet water demand. Annual rainfall plays a vital role in the supply of water to the people in

Khulna as salinity effects a problem in Khulna. The seasonal rainfall in Khulna is insignificantly lower compared to the national average.

The Figure 3.1 represents how much of a rain fell in millimeters in three different years throughout 12 months. In total, the lowest number of precipitation was observed from December to February.

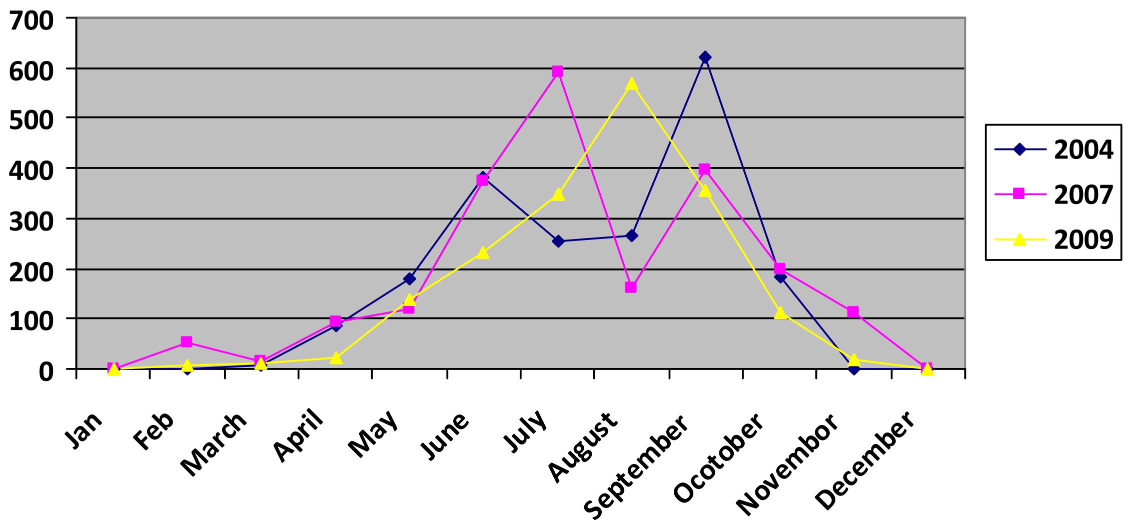

Figure 3.1: Year wise variation of Rainfall in Khulna City

Source: Feasibility Study for Khulna Water Supply Improvement Project in the People's Republic Of Bangladesh, 2011

Then the number fluctuated and by 2004, the rainfall had risen to just under 180 mm. A gentle increase in rainfall was detected up to June in three years. Most of the rainy days were from June to September. However, the greatest real increase was in 2004 where the rainfall in September had increased by approximately 266 to 621 mm.
3006 families were reviewed; just 913 (30%) families have associations with channeled water. Concerning 913 families, 64 family units (07%) have a place with amazingly poor, 376 (41%) poor and 52% (473) is above poor. This finding reveals extraordinary poor and poor family units have low access to channeled water.

In the Questionnaire survey, people of different areas, different ages and different economic (Extreme poor - income is less than Tk 2,700; poor – income is less than TK 5,300 and above poor – income over TK5,300) conditions 3006 people were surveyed. Here, 351 family units were extreme poor, 1343 family units were poor and 1312 family units were above poor. From figure 3.2 can be seen that 36% of above poor people households are connected to KWASA pipeline whether 82% of extreme poor people households are not connected.

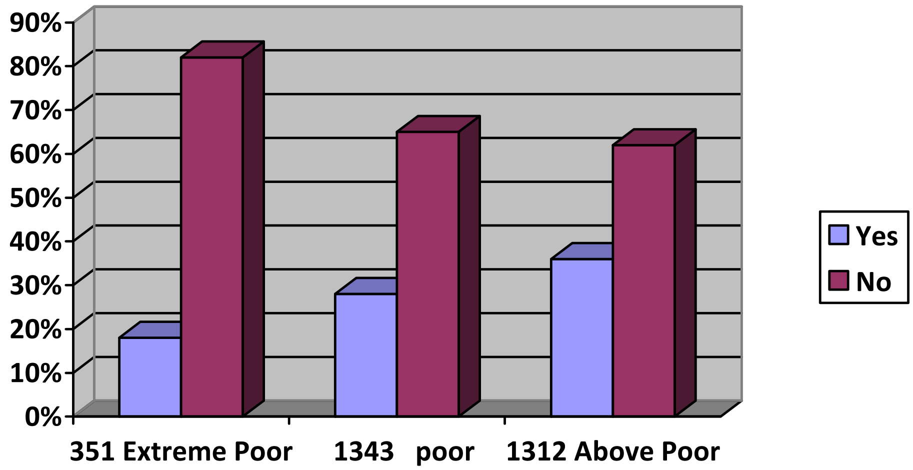

Figure 3.2: Connected to KWASA Piped Water

With regards to the accessibility of water, respondents whine that KWA outrageous poor and (77%) of poor family units. The FGD results likewise attested that there is a steady low pressure of water in this way supply isn't adequate. Generally speaking, sees on KWASA funnelled water is considered as poor. (Figure 3.3)

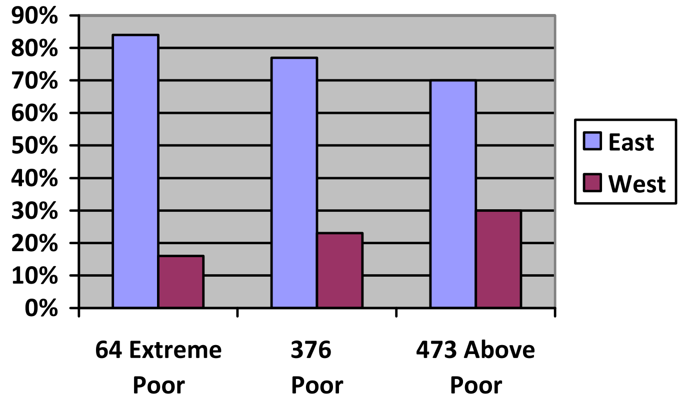

Figure 3.3: Availability of Piped Water

From figure 3.3 we can see that all people including Extreme poor, poor and above poor drink water without boiled or filtered. Public hand pump tube well is for the most part used by the lion's share (62%) remarkable poor family units, 63% of the poor families and 55% above poor. Both remarkable poor and poor family units in like manner use private tube wells. In general, 94% of family units insisted the nature of water is fit for drinking and is plentiful consistently. There is no compelling reason to bubble water for drinking as indicated by 96% all things considered.

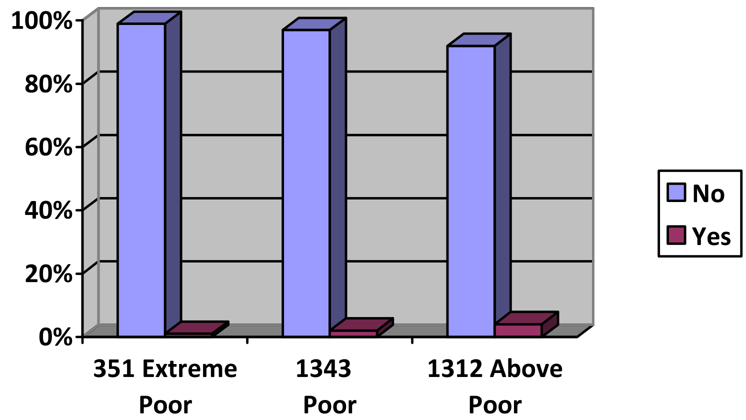

Figure 3.4: Is Water Boiled or Filtered?

From Figure 3.4 it can be seen that the utilization of open hand tube wells is prevalent among 70% of them to a great degree poor, 64% poor and 57% above no poor family units. Outrageous poor family units have a higher utilization of around 10.8 cubic meters for every month, while 8.41 cubic meters for each month for poor people and 5.27 cubic meters for each month for the above poor. This is normal as the normal family unit among them to a great degree poor is higher contrasted with poor families. In like manner, there is no restriction in extracting water from open tube wells. Cost of water shifts relying upon utilization. Generally, the normal cost of water from the hand pump tube well is about Tk 8.16 for every cubic meter.

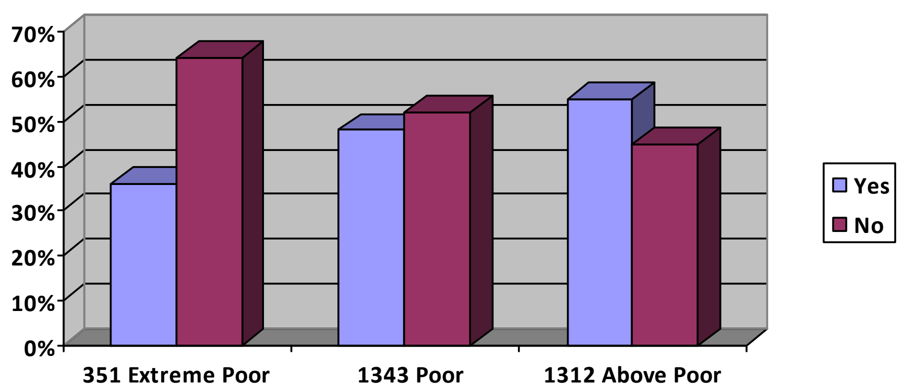

Figure 3.5: Households using private hand Tube Well

Water clients of private hand tube well include half of the studied 3006 family units, Of the 1500 water clients, not very many 127 (9%) contain outrageous poor, 648 (43%) poor families. The larger part 725 (48%) are above poor. The greater part 96% of the respondents from all classifications certified that there is adequate water in private hand tube wells that satisfy their demand. Water from private hand tube wells is regarded as poor by the larger part of water clients. Perspectives on water quality are generally good and fair although some claims that there are private tube wells that have been introduced for more than 10 years back, consequently, water quality isn't so safe, with suspected iron substance and saline taste.

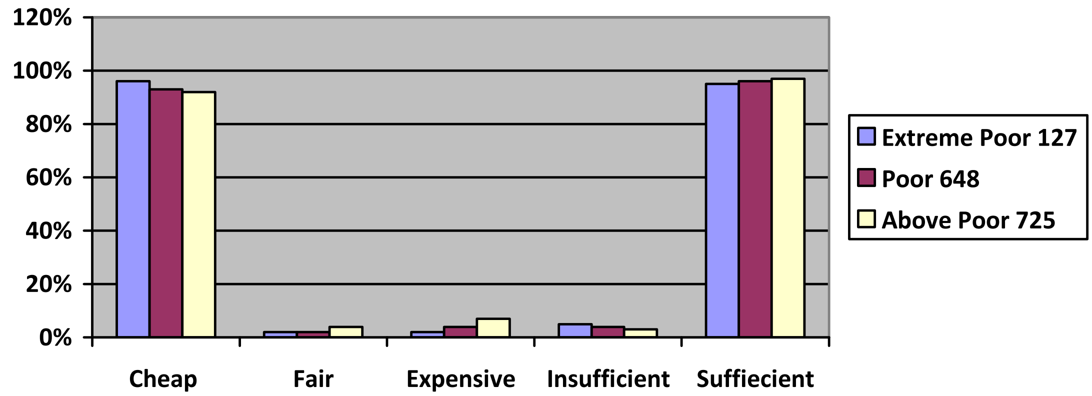

Figure 3.6: Perception on Cost and Availability of Private Tube Well

Table 3.1: Abstraction of Groundwater in Khulna Area

Category	Annual increasing Rate	Commercial & Industrial private Tubewell Hand Tubewells	Small private motorised Tubewell	Hand Tubewells (Private House)	Commercial & Industrial private Tubewell	Small private motorised Tubewell	Hand Tubewells (Private House)
Abstraction (m^3/D)							

1994	2.90%	33067	15270	9473	2748
1995		34026	15713	9748	2828
1996		35013	16169	10030	2910
1997		36028	16637	10321	2994
1998		37073	17120	10621	3081
1999		38148	17616	10929	3170
2000		39254	18127	11246	3262
2001		40118	18526	11493	3334
2002		41000	18934	11746	3407
2003		41902	19350	12004	3482

2004	2.20%	42824	19776	12268	3559
2005		43766	20211	12538	3637
2006		44729	20656	12814	3717
2007		45713	21110	13096	3799
2008		46719	21574	13384	3883
2009		47747	22049	13678	3968
2010		48797	22534	13980	4055
Total for 2010		Shallow Tube wells	71331	Deep Tube wells	18035

Source: IWM, BANGLADESH: Khulna Water Supply Project, 2011

KWASA water supply system services serve approximately 25% of the population. These include water users using piped water (18%) public tap (1%), and non-revenue water (6%). On the other hand, hand pump tube wells supply water to approximately 30.1%, private tube wells for approximately 44% and pond/river to about 2%. Based on the Consumer Survey result, there is only a very small proportion of the population using water vendors as their main source of water. The Consumers Survey showed that water supply sources of surveyed households (3006) include piped connection (KWASA) 19.4%, hand pump tube well (KWASA) (39.4), street hydrants/public taps (KWASA), private tube wells, (31.9%) water vendors (0.7%) pond canals and rivers, (1.4%) In Table 3.2 and Table 3.3 it is clearly shown.

Table 3.2: Sources of Domestic Water of Khulna Respondents - Overall

Source	Piped water	Public tube well	Private tube wel	Stand Pipe	Water vendor	River, pond	Other sources
% Respondents	19.4%	39.4%	31.9%	0.2%	0.7%	6.9%	1.4%

Source: Md. Wahiduzzaman, Water Consumer Survey in Khulna City – TA 7223 BAN: Establishing the Khulna Water Supply and Sewerage Authority, August 2009.

The Consumers survey also showed that drinking water is sourced by the majority from public hand tube well (59.1%) and private tube well (38.45). Only 0.2% use the KWASA piped water for drinking.

Table 3.3: Major Source(s) of Drinking Water by Sample Households

Source	KWASA Piped water	Public hand pump tube wel	Private tube well	Water vendor	Other sources
% Respondents	19.4%	39.4%	31.9%	0.2%	6.9%

Source: Md. Wahiduzzaman, Water Consumer Survey in Khulna City – TA 7223 BAN: Establishing the Khulna Water Supply and Sewerage Authority, August 2009

Majority (93%) of the extreme poor and 85% of poor households, including 55% of the non-poor fetch water by themselves. By doing so, instead of paying for water carrier, households utilizing public tube well have a guaranteed savings of about Tk120/month which can be used for other needs. In order to convince households to connect to piped water would require intensive social preparation and marketing. Households have very low assessment on the current KWASA services and this would defer people's willingness to connect to services. However, if people are assured of the quality and continuous supply of safe water, they would be willing to invest.

Table 3.4: Household consumption and Cost of water (m^3)

Source of Water	No. Of	Volume / Month m3	Cost /Month Taka	Unit Cost Taka/m^3
Piped	1033	19.5	71	3.65
Public Tube well	2165	6.9	125	18.12
Private Tube well	1708	18.8	138	7.35

From questionnaire survey, (Table 1.1) it is found that normal people are facing scarcity of drinking water. Though in many areas people are pleased with provided facility but it is very limited. KWASA informs their limitations but they ensured us there will be a big project by JICA about 2.5 thousand cores BDT. It will reduce the problem greatly and KWASA will be in the first position in Bangladesh for capable of supplying greater percentage water in proportion to demand compare to other two WASA.

Table 3.5: Key information from various resources

Corporation	Key Information
Khulna City Corporation	It led the water supply system with limited resources and was continuously facing problems. That's why Khulna WASA was developed to assemble the water supply system.
Khulna Wasa	From 1980 to 2008, 32 Nos of large diameter and 22 Nos of small diameter tube wells have been operated by Khulna Wasa. Now it has taken various steps to improve water supply system.
Endemic People	People previously collected water from well. But these sources were polluted due to lack of maintenance. For this reason, reserve tanks were installed.

4. CONCLUSIONS

In Bangladesh, numerous people do not have enough knowledge about the quantity of potable water. Despite water is plentiful, only 1% of total water resources are being used for drinking purpose. From total withdrawn of water resources, 86% is for agriculture, 12% for domestic water supply and 2% for industry. It is predicted that Bangladesh's population will increase from 129 million people in 2012 to 181 million by 2025 and 224 million by 2050, accompanied by an increased demand for water. People are now moving to city from rural areas and it has turned to 60% which were 13% in 1900. For that, scarcity of water in urban areas is increasing. Furthermore, many sources of water supply are greatly influenced by the presence of arsenic in groundwater which is estimated to affect 27% of all wells. The price of water is increasing day by day. We should check the pipeline leakage and be careful about the safety of water sources. Consequently, Water Supply History can give the further investigation of water supply. Borehole should be installed; canal and river should be extracted. Improved technique for water supply method will be developed to ensure the availability of pure drinking water to all parts of the society. To develop a sustainable water supply system, new sources of water are to be developed.

ACKNOWLEDGEMENTS

The project was carried out under supervision of my supervisor of Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh. The author wishes to express his profound gratitude and indebtedness to him for his valuable guidance, advice, constructive criticisms during the investigation and preparation of the project. The author would also like to thank to all the teachers of Department of Civil Engineering, KUET. The author gratefully remembers Ujjal who helped a lot in different important phases of the project.

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Applying Nudge Theory Strategies in Solid Waste Management

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ABSTRACT

The current policies on Solid Waste Management (SWM) have little or no avenues to bring desirable changes for effective SWM since they demand multi-criteria evaluations and a high level of cognition. Applying means of behavioral sciences such as nudge instruments have found to alter human behavior in a desired direction. This study aimed to explore the application of nudge theory and associated instruments in reforming the policy domain of SWM sector. Emphasis was given on the producer-waste interphase where majority of the leverage points relevant to the decision making and behavior change existed. Based on observation and case studies in Nepal along with the review of nudge theory applications in other countries, it was found that applying nudge theory strategies can substantially contribute to reform SWM sector and provide an effective solution of SWM. The findings are expected to be beneficial to planners, policy makers and practitioners in SWM sector.

Key words*: behavior change, leverage point, Nepal, nudge, solid waste management*

INTRODUCTION

Solid Waste Management and Contemporary Issues

Managing the municipal solid waste (MSW) is becoming more challenging with growing urbanization in developing part of the world. The situation is no different for Nepal where the urban dweller had risen by 16 fold in the last five decades (Sharma, 2014). Kathmandu, one of the fastest growing metropolitan cities in South Asia (Bakrania, 2015) is not only the capital city but also a commercial hub of the country. Changes in demographics and lifestyle in the last few decades have converted its agrarian society into modern metropolis. Kathmandu Metropolitan City (KMC) alone produces 660 g/capita/day of solid waste (Dangi et al., 2010). More than 65% of the generated waste is organic (UNEP, 2001; Shakya and Khatiwada, 2017). Until few decades ago, the city had rural setting and almost all of its wastes used to be organic which were traditionally decomposed in the pits inside the houses to produce compost or sold to farmers. Urbanization brought changes such as decline in agricultural practices and increase in the usage of non-biodegradables like plastic, metal and glasses. With the increasing trend of inorganic waste, people started discarding waste in the streets and along the river banks. The concept of organized solid waste management in the country began only in 1980 that established a compost plant at Teku and Gokarna Landfill Site but the whole system failed after the project ended (Udash, 2004). This led to open dumping of waste which is widely practiced even today.

According to the Organization for Economic Co-operation and Development (OECD), solid waste management (SWM) refers to the supervised handling of waste material from generation at the source through the recovery process to disposal. Local Self Governance Act, 1999 of Nepal establishes a decentralized governance structure for SWM while the Solid Waste Management Act, 2011 has mandated local bodies to take the necessary steps to promote reduce, reuse, and recycle (3R), including segregation of MSW at source. In the new federal Nepal, there are 293 municipalities but most of them do not have adequate infrastructures, human resources and financial resources for SWM. This has also impeded the implementation of the Act. ADB (2013) found out limited segregation and low level of 3R practices in Nepal which led to generation of large volume of mixed wastes that ultimately make their way to landfill. At the present time, residents of Kathmandu valley depend on the only functioning landfill site called Sisdol Landfill in Nuwakot district, which is also in a dilapidated condition. The MSW management is thus becoming complicated as the country is not able to match waste management services with the growth of urban centres.

Municipalities in Nepal are increasingly acknowledging the role of private sector in SWM service delivery. However, there are difficulties for them to integrate the sector owing to lack of technical capacities as well as lack of Integrated SWM Policy in the country. Private sector has been outperforming municipalities in some of the activities such as door-to door collection and recycling. Private companies and non-governmental organizations (NGOs) collect and transfer 30% of MSW, informal scavenging handles 10% of solid waste management (SWM), and the formal recycling is still non-existent in Kathmandu (Dangi et al., 2017). The local bodies have a vital role in leveraging the private sector in SWM, especially the Small and Medium sized Enterprises (SMEs) and entrepreneurs by facilitating the access to microfinance for SWM activities. But the effort of municipalities and private entrepreneurs alone will not be sufficient for effective SWM. Public participation and cooperation is crucial in this regard for which change in perception and behavior is a must. If public see SWM as their responsibility too and change their attitude accordingly, SWM can be sustained.

Leverage Points in Solid Waste Management Chain

Leverage points are places within a complex system where a small shift in one thing can produce big changes in everything (Meadows, 1999). Leverage points in SWM chain for managing waste in cost-effective and efficient ways and without causing adverse impact to the environment lie on the producer-waste interfaces. Irrational behavior of the producer costs more (Shakya and Khatiwada, 2017). Every individual makes several decisions each day regarding the waste generation and disposal. The diversity of waste types, differences in volumes and other salient features and the temporal and spatial variation of the location of a waste producer would reinforce the attributes leading to one's choice and decision. Majority of the leverage points relevant to the decision making and behavior change exist on the producer-waste interfaces which need to be targeted for obtaining efficient SWM i.e. reduced volume and increased segregation, reuse and/or recycling of solid waste.

Some of the leverage points on the producer-waste interfaces that can be targeted for obtaining efficient SWM are:

- Labeling by a factory on its products about good SWM practice. Example: Labeling toothpaste tube and/or packet cover as "Buying toothpaste tube only will generate less waste than that with a packet cover".
- Changing physical environment by a supermarket for enhancing good SWM behavior of customers. Example: Placing of the products with and without cover (toothpaste in a tube only and/or with a packet cover) separately in the shelves, placing of separate bins for bio-degradable and non bio-degradable wastes.
- Becoming aware by customers on good SWM practices. Example: Using glass plate instead of plastic/paper plate, drinking soft drinks like coke, fanta and sprite in glass bottle instead of can and plastic bottle, using reusable razor blades by men instead of disposable ones, using own reusable bags for shopping instead of buying a new one.

Nudge Theory

The governing policies on waste management assume that individuals use their cognitive resources in making rational choices and decisions based on the given situation, information on 'dos' and 'don'ts', economic incentives and moral obligations. Often such choices and decisions would need multi-criteria evaluations and a high cognitive level. In case of solid-waste, either in a work-place or residence, people would prefer to avoid complexity and apply no or little mental efforts in making a choice of disposal. More importance is given to the task at hand rather than proper or guided disposal methods. In such instances, individuals are dictated by rule of thumb, mental short-cuts, biases or irrational choices (Lehner et al., 2016).

Studies have shown that applying means based on behavioral sciences such as nudge instruments can influence the human behavior and the decision making process (Kallbekken and Sælen, 2013; Rivers et al., 2017). Irrespective of the interfaces and activities, the majority of human decisions are made intuitively and voluntarily. Nudge theory states that behavior of individuals can be altered in a predictable way without forbidding any options or significantly changing their economic incentives (Thaler and Sunstein, 2008). Humans have two systems of thinking: System 1 which is fast (automatic, intuitive) and System 2 which is slow (deliberate, conscious). The majority of governing policies in waste management targets System 2 for bringing desirable changes in human behavior, thus is ineffective. In contrast, nudge tools target System 1, therefore can bring desirable changes in human behavior (Lehner et al., 2016).

OBJECTIVES AND METHODOLOGY

Since nudging as a concept has been recently advanced in the developed countries, there is little investment and research in creating a nudge on the system in developing countries including Nepal so that individuals are encouraged to change their behaviors. There is a tremendous scope in developing countries to find avenues of nudges in the aspects of no using, reducing, producing, reusing, recycling and reclaiming as regard to the solid waste. Therefore, this study aimed to explore the application of nudge theory and associated instruments in reforming the policy domain of SWM sector. Emphasis has been given on the producer-waste interphase where majority of the leverage points relevant to the decision making and behavior change exist.

The paper was written utilizing the secondary information from various published articles and relevant documents. The information was also collected from different forms of nudging instruments practically used by the government and public authorities in SWM. The observation of notices in hoarding boards in the places where solid wastes are dumped in the city provided some materials to ponder over. This is how the idea was generated for the development of this paper.

RESULTS AND DISCUSSION

The nudging mechanisms are related to the attitude and behavior of the individuals making decisions. Table 1 describes four types of mechanisms applicable to SWM which were also applied in other sectors (Lehner et. al., 2016). Simplification and framing of information refers to providing the notice and instructions in an easily understandable way so that individuals are encouraged to follow them in voluntary way. Obligatory or coercive policy instruments provide information which may not encourage the individuals to act rationally or fail to influence their judgment, choice or behavior. On the other hand, simplified and well-framed information would fit to the processing capability and decision making processes of individuals. Thus, their cognitive efforts are automatically guided to correct the biases and errors in human behavior (Thaler and Sunstein, 2008).

Changes to physical environment refers to designing the context where the individual would interact with the objects while making a decision. Decisions related to solid waste generation and disposal are guided by the life-span of a product while it is in the economy, user-product interface and the salient features of the product which would turn to be a waste with the judgment of the user. Use of different types of bins and accessibility of the bins also come under the domain of this mechanism. For example, placement of the products with and without cover (toothpaste in a tube only and/or with a packet cover) in the shelves would certainly matter.

People are greatly influenced by defaults or standard choices because they often take path of least resistance, prefer not to act unless they have to and procrastinate the decision (Lehner et. al., 2016). They even fall victim of locked in or inertia as the preferred option is to follow intuition and appealing way of doing it. (Kahneman, 2011). An example of benefits obtained by alteration on default policy as applied to SWM was given by Egebark and Ekstrom (2013). They mentioned that paper consumption was reduced by 15% by switching the default to double sided printing.

The social norms and individual's belief system are the strong force that influences human behavior. The individual actions on waste disposal and management are also guided by these attributes. For example, the pilgrims would not like to mix the flowers offered during the worshiping with other wastes. Khatiwada and Gautam (2006) have explained the fact that this would often create a situation of conflict if the belief system and emotional aspects of the beneficiaries is not paid due attention during the design of an intervention.

Table 1 Nudge mechanisms for solid waste management

Nudge mechanism	Application in SWM	Evidence of effectiveness
1. Simplification and framing of information	Provide information in persuasive way	Banner displayed in a social event[a]
2. Changes to physical environment	Design of the user-waste interface	Clearly labeled separate bins for disposal
3. Changes to default option	Segregation as opposed to disposal without segregation	Single sides vs. double sided printing
4. Use of social norms and belief system	Provide information so that the users are motivated not to litter on the designated places	Replacement of prohibition notice by pictures of god and goddess

[a] Similar to the one described in this paper

In Nepal, current practices of providing information and instruction to the public have been found to be using coercive policy instruments such as laws, bans, jail sentences or economic instruments such as taxes or subsidies. Randomly selected examples of such notices are given below.

1. Do not litter on the ground. Let us identify ourselves as civilized citizen. (moral obligation, voluntary)
2. Let us clean it, let us not litter it. Disposal of waste is strictly prohibited. If found violating the rule, action will be taken as per the law and could be fined upto the maximum limit.
3. It is prohibited to urinate and defecate in this area. If found violating this rule, the offenders will be fined upto NPR 500 and will be asked to sit up. (following rule, obligatory)
4. Those who urinate here are dogs.
5. Individual who throw wastes on the street is son/daughter of a dog. He / she would end up in the Hell. (hard words)
6. Littering is strictly prohibited. You are under the surveillance of CC Camera.
7. Public notice. This is not a place to throw waste.

If we analyze the above notices one by one, we get a spectrum of instrument used to change the behavior of the public with regards to solid waste. There is use of hard words (No. 4 and 5), legal tool (No. 3), and persuasive words (No. 1). These in turn either obligate the public to watch out their behavior or voluntarily agree on what has been said or requested.

A typical example of a schematic diagram of a notice put by Kathmandu Metropolitan City is provided in Figure 1. The notice reads as “Do not to litter on the public places. Reflect an identity of a civilized citizen”. Such notices also include name and logo of the notice issuing authority. However, as shown above, when compared the statements contained in the notice seem to be different in terms of content, message to be delivered, language and structure of the texts written in the notice.

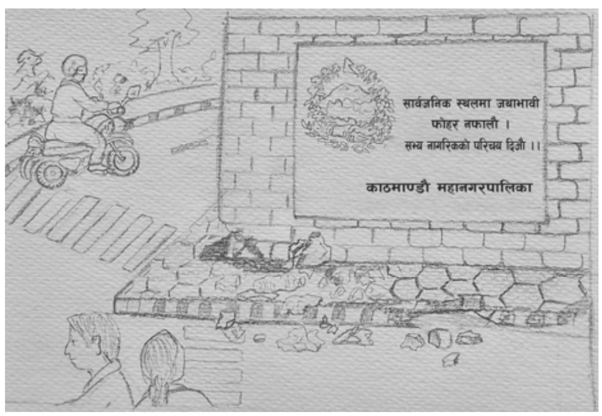

Figure 1 A schematic diagram of a notice as a coercive policy instrument put by Kathmandu Metropolitan City

Figure 2 depicts a scenario similar to Figure 1 in terms of the message to be conveyed. However, instead of the text and the information of the notice issuing authority, the display simply contains pictures of god and goddesses. This has been considered as a good example of the nudge instrument. It was found that the locations where these pictures have been displayed were found very clean compared to the locations where coercive policy instruments (1 to 7) described above and Figure 1.

Figure 2 Pictures of gods reflecting the illustration of Nudge instruments

This illustration is described mainly by mechanism 4 of the Table 1. Majority of people in Nepal follow Hinduism and Buddhism. Use of pictures of god and goddess captures the religious belief and value system of people. This example is also related to mechanism 2 and 3. When people see the pictures of god in a place, it automatically makes them think that the area should be kept clean and by default they take that area as not designated to throw the garbage. Hence, they will refrain themselves from carrying out any activities that will be regarded as a disrespect to the god.

Another example of Nudge was found in a wedding reception ceremony. A banner containing the following information was displayed near the dining area right in front of the table where the foods were displayed. It was buffet type arrangement. People while collecting the different food items would directly see the banner which reads as "Kindly appreciate our efforts and convey the message to others. In case, you have any complains or suggestions, kindly let us know. Please note, if you waste the food, both of us will not be appreciated". As shown in Table 1, this illustration is related to appeal to the customers to avoid wasting the food is explained by the first instrument. The information is simplified and catchy, yet very powerful. It not only motivated the customers but also inspired the researches to consider it as nudge instrument.

These examples illustrate that application of behavioral economics such as nudging can help policy makers in SWM in order to systematically integrate behavioral insights into policy design and implementation. This would certainly help to reform the SWM sector and provide a sustainable and more effective solution.

CONCLUSION

With urban development, SWM is becoming more complicated day by day. The efforts to manage the waste by municipalities and private sector are apparently not sufficient. The public must cooperate with government and other private companies involve in SWM activities for which the change in their behavior and attitude is crucial. Conventionally, the governments use direct methods such as command and control regulation to shape people's behavior which has not been very successful. In order to achieve the goal of behavior change, appropriate nudge tools need to be applied along with coercive instruments. It is evident through some examples that this approach is effective. There are possibilities of reforming the policy domain of SWM sector through wide application of nudge tools with a particular focus on producer-waste interphase.

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ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

Proceedings of the WasteSafe 2019 – 6th International Conference on Solid Waste Management in South Asian Countries
23-24 February 2019, Khulna, Bangladesh

Leachate Management at Sisdol Landfill Site in Nepal: Current Status and Proposed Technology

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***Key words**: leachate characterization, rock filter, Sisdol Landfill Site, solid waste management, treatment technologies*

Leachate, a tainted liquid emanating from the bottom of the solid waste disposal facilities such as landfills, is a serious pollutant (if not treated and safely disposed) affecting surface and ground waters, soil, human health, hygiene and aquatic life due to presence of soluble organic and inorganic compounds as well as suspended particles. Leachate composition is influenced by composition of waste in the landfill, age of the landfill, depth of waste in the landfill and local climate. Therefore, understanding of landfill leachate characteristics is crucial for managing the leachate in the most efficient manner possible.

Sisdol landfill Site (SLS), which is located on the northern bank of Kolpu River in Okharpauwa of Nuwakot district, receives over 800 tons of municipal solid waste (MSW) per day from 18 municipalities of Kathmandu Valley, Nepal. The installed facilities for leachate management at the SLS including leachate collection system (pipe network and re-circulation system including retention pond, aerator and pump), gas vents and clay liner system are in poor condition at present with the generated raw leachate being discharged directly into the nearby Kolpu River which is used for irrigation, bathing, cattle feeding, human consumption and washing purposes. This demands an urgent need for leachate treatment at the SLS. In this context, the present study investigated the physico-chemical characterization of the landfill leachate and proposed appropriate leachate treatment technology options for the SLS.

Two leachate samples were collected; one from discharge outlet (L_1) and the other from filter bed pond (L_2) on 13 February 2018 and analyzed for 21 parameters as shown in Table 1. The samples were collected, preserved and analyzed according to the Standard Methods for the Examination of Water and Wastewater. In addition, two leachate samples from the same locations L_1 and L_2 were collected on 21 March 2018 in two 10 L jerry cans respectively and taken to lab for conducting jar test. Jar test was done in order to identify optimum dosage of coagulants (alum and ferric chloride) required to reduce turbidity of leachate.

As shown in Table 1, high values of pH were obtained in this study which is a characteristic of mature landfills. Similarly, extremely high value of EC as obtained in this study can be attributed to high levels of cations and anions. Concentration of TDS was much higher than that of TSS in both samples. High TDS may lead to the death of aquatic organisms by limiting the growth suggesting need for leachate treatment. Similarly, the obtained TSS values are greater than the acceptable Malaysian standard level (100 mg/L) for sewage and industrial effluents. Concentrations of NH_3-N dominated total nitrogen content (> 90%) in both samples compared to lower values of organic Nitrogen. This might be the reason for bad odor of leachate in the study site. Very high concentration of TN dominated by NH_3-N and relatively low concentration of TP as compared to TN suggests that Nitrogen removal is crucial but conventional biological treatment methods might be unproductive, and therefore some nutrients can be supplemented manually to balance the nutrient contents. Obtained values of BOD and COD were 3700 mg/L and 7560 mg/L respectively for L_1 and 3600 mg/L and 7392 mg/L respectively for L_2. BOD is used as an indicator of the organic matter subject to biological oxidation, and thus is helpful when assessing the feasibility of biological treatment of organic matter. The determination of BOD involves measuring dissolved oxygen used up by microorganisms in the

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ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

biochemical oxidation of organic matter while COD measures the toxicity of inorganic substances and in general COD is greater than BOD. High values of BOD and COD as obtained in this study suggests need for biological treatment methods for the leachate. BOD/COD ratio of 0.49 (~0.5) for both leachate samples as obtained in this study implies that about 50% of the leachate content is biodegradable. Similarly, high values of Organic Dry Matter obtained in this study can be attributed to high organic composition (61.86%) of solid waste at the SLS and also a reason for high BOD values. The obtained values of TDS, NH_3-N, BOD and COD in this study fell in the ranges which belong to the acid-formation phase of leachate. Out of the seven heavy metals analyzed, iron was of serious concern. In contrast, concentrations for other heavy metals were insignificant where chromium and lead were not detected. Concentrations of the parameters as shown in Table 1 at L_1 were not significantly different than those at L_2 (paired *t*-test, $p>0.05$) suggesting non-functionality of the existing leachate treatment system. Therefore, it's an urgent need to install/upgrade leachate treatment system in the SLS.

Table 1 Leachate characteristics at Sisdol Landfill Site

Characteristics	*Unit*	L_1	L_2
Temperature	°C	21	18
pH	-	8.55	8.52
Electrical Conductivity (EC)	µS/cm	33,900	33,900
Total Solids (TS)	mg/L	17,988	18,130
Total Dissolved Solids (TDS)	mg/L	12,280	13,490
Total Suspended Solids (TSS)	mg/L	994	1105
Total Phosphorus (TP)	mg/L	9.7	8.8
Total Nitrogen (TN)	mg/L	3,536	3,226
Ammonia-Nitrogen (NH_3-N)	mg/L	3,268	3,022
Organic Nitrogen	mg/L	218.4	151.2
Organic Dry matter	mg/L	6,498	8,980
Oil and Grease	mg/L	5.1	4.7
Biological Oxygen Demand (BOD)	mg/L	3,700	3,600
Chemical Oxygen Demand (COD)	mg/L	7,560	7,392
BOD/COD	mg/L	0.49	0.49
Iron	mg/L	13.31	11.33
Manganese	mg/L	0.19	0.18
Copper	mg/L	0.2	0.18
Zinc	mg/L	0.72	0.72
Cadmium	mg/L	0.01	0.01
Hexavalent Chromium	mg/L	ND (<0.1)	ND (<0.1)
Lead	mg/L	ND (<0.01)	ND (<0.01)

ND means not detected

Jar test results showed that the highest turbidity removal in L_1 sample was obtained at 5 g/L dosage of alum (46.1% turbidity removal) and 3 g/L dosage of ferric chloride (44.9% turbidity removal). Similarly, the highest turbidity removal in L_2 sample was obtained at 5 g/L dosage of alum (39.0% turbidity removal) and 3 g/L dosage of ferric chloride (54.0% turbidity removal). The results indicate coagulants such as alum and ferric chloride are not enough to remove turbidity of the leachate in the SLS. Therefore, it is suggested to perform the jar tests with non-ionic, anionic and cationic polymers flocculants such as poly- aluminum chloride (PAC) for better efficiency of the coagulation-flocculation process.

The quality analyses of the Sisdol landfill leachate showed that the major concern was NH_3-N, BOD, COD and TS. Similarly, removal of iron is required while other heavy metals do not require much attention. The obtained leachate quality data, review of the available treatment technologies and consultation with experts, suggest that integration of physical, chemical and biological treatment systems is required to achieve optimum removal of contaminants. Option of chemical treatment can be used as polishing option. Various treatment options such as rock filter (physical), settling tank (physical), upgrading existing constructed wetlands (biological) and activated charcoal methods (chemical) have been identified and proposed for treating the Sisdol landfill leachate. In addition, it is suggested to test leachate treatment technologies such as struvite precipitation, leachate recirculation system and coagulation/flocculation using PAC. Regular monitoring of leachate, Kolpu River and nearby groundwater resources is recommended in order to aid in minimizing adverse health impact to humans, cattle and aquatic lives in the study area. This study was carried out in the dry season only. It is suggested to carry out similar study in the wet season in order to facilitate leachate management. The government authorities are recommended to take findings of this study at the SLS as one of the examples for applying to other municipalities.

SITUATIONAL ANALYSIS OF STRATEGIC SOLID WASTE OF MELAMCHI MUNICIPALITY IN NEPAL

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ABSTRACT

Uncontrolled urbanization has become the cause for emerging municipalities in Nepal. Solid waste management is one of the most prioritized responsibilities of those emerging municipalities. Because of limited financial resources and lack of well-trained human resources to address adequate solutions, solid waste management has largely remained a socially complex and technically ever challenging task for municipal authorities. Due to lack of proper and sufficient resources the municipalities have been managing the solid waste in ad-hoc and temporary basis without any periodic and strategic plan due to which they are facing crucial problems. In this context, this study aimed to assess the present status of the solid waste In Melamchi municipality for further preparation of strategic solid waste management plan.

***Keywords**: Strategic Solid Waste Management, Municipality, Solid Waste*

INTRODUCTION

Solid waste management is one of the most prioritized responsibilities of the municipalities. Yet, it largely remains a socially complex and technically ever-challenging task for municipal authorities. It is basically because of their limited financial resources and lack of well-trained human resources to provide appropriate solutions to these issues. In municipalities like Melamchi, earthquake rehabilitation has been a task of the highest priority. Municipalities have realized the need of incorporating an effective waste management strategy to their plan of action as urbanization is rapid in these municipalities. There has been an increase in settlement in an unplanned manner with poor management that has led to an increase in solid waste generation, without proper arrangements for disposal. SWM services have been given a low priority by the municipalities as the demand of other public service tends to be higher. However, it remains as one of the basic services which need to be developed by the municipality to keep the area under their jurisdiction clean, and to prevent future issues in health of the residents and physical and social environment of the area. These municipalities are in need of an effective waste management strategy that can involve the residents, capacitate them to understand the benefits of proper waste management practice and encourage them to participate and take ownership of the management plan.

The Local Government Self Act (LGSA), 1999 and Solid Waste Management Act (SWMA), 2011 have made the local bodies such as municipalities responsible to maintain a clean and healthy environment by constructing, operating and managing infrastructure for collection, treatment and final disposal of solid waste. It also mandates the municipality to take necessary steps to promote the 3R concept. It authorizes the municipality to formulate rules, by-laws, guidelines and a system with stakeholders from the private sectors, CBOs and NGOs, with approval from the municipal board. The SWMA, 2011 has a provision which says that Solid Waste Management Technical Support Centre (SWMTSC) shall provide support to all local bodies for effective and sustainable SWM and advance research and development in this sector.

OBJECTIVE AND SCOPE

The overall objective of this assignment was to do situational analysis of Melamchi Municipality in joint partnership with the Municipality, which will serve as a practical decision making tool for short term and long term interventions to improve the living standard of the city.
The specific objectives of the project are to:

- Address the Solid Waste Management Problem of the municipalities.
- Address quantity as well as quality of flows.
- Address all sources and flow chains of solid waste produced in the municipalities and all target groups, including squatter settlements.

STUDY AREA

Melamchi Municipality lies in Sindhupalchowk district of Central Development Region, Bagmati Zone. The area of this municipality is 90.04 sq. km. The municipality was established on 2071 B.S. with 15 wards. The total population of the municipality is 35836 and the average household size is 4.1. (CBS, 2011). The municipality has its borders with Mahankal, Dubachaur and Lag Arche VDCs in the north; Sipalkavre, Nawalpur, Badegaun, Sipapokhare VDCs in the east; Thakani and Bhotechaur VDCs of Sindhupalchowk and Shakarpur municipality of Kathmandu District in the west and Panchkhal Municipality of Kavrepalanchowk District in the south. VDCs were added to the municipality after the restructuring of the state. These are Bhotechaur, Haibung, Thakani and Duwachour.

Figure 1 Map of Melamchi (after reconstruction) with its borders.

METHODOLOGY

Desk Review, Rapid Appraisal, Household Survey, Focus Group Discussion (FGD) and Key Informant Interview (KII) were the methods adopted for the evaluation. Secondary data were obtained from desk review method. Other relevant information on solid waste management in Nepal and study areas was obtained from the relevant literature review.

Rapid appraisal was made on all the component of the solid waste management plan, which included the field assessment with the understanding of the social and economic status of the municipality and the demand of the people for the exact understanding and the mapping of the problems of the municipality.

Structured questionnaires and baseline data collection is performed at household level to quantify the waste generated in the municipality with representative sample from each ward. A total of 13 HHs in Melamchi municipality were considered for this study.

The materials used during field survey were:

- Digital weighing machine - for weighting household, commercial and institutional waste.
- The density of the waste was calculated using the relationship between mass and volume and the measure the volume standard 0.45 m3 bag was used.
  Density=$\frac{Mass}{Volume}$
- Collection Bag- for the collection of waste as well as estimating the volume of the waste
- Gloves- for handling the waste and precautions from any contaminations.
- Masks- for the protection from the aerial contamination.

The population growth rate and future population is calculated based on the following formula:

$$P_n = P_O(1+r)^n \qquad (1)$$

Where, r= Population growth rate and n= number of years

Two FGDs in each municipality i.e. one with male and another with female respondents were conducted to ensure adequate response from concerned stakeholders. The discussion were made on the problems, opportunity, challenges, objective of each component of SWM and probable solutions for all problems associated to this issue within the municipality.

Key informant interviews (KIIs) were conducted to collect information from a wide range of people including municipality officials, business man, local NGO representative and members of various user groups.

RESULTS

Demographic Profile

The waste generation as well as its characteristics is a function of the population. The review of available data reveals that there has been a 3.64% population growth rate in the past decades in Melamchi Municipality.

Table 1 Population Trend in Melamchi Municipality

Municipality	Melamchi	
Census Year	2011	2001
Population	5230	3836
Annual Growth Rate	3.14%	

Solid Waste Generation

The population growth rate calculated above was used to calculate the projected population and solid waste generation for the year 2020, 2025 and 2030 A.D. the population census done for Melamchi Municipality itself in the year 2015 was taken as the base year. The waste generation for Melamchi was found to be 0.098 kg/capita/day (waste disposal 6.90 kg/week and average household size 10.05).

However, the average household size mentioned in the study was found to be unreasonable, hence the waste generation calculated by Dugar, was taken (0.167 kg/capita/day). Based on these figures the population and solid waste generation (SWG) projection (kg/day) are calculated as following:

Table 2 Population and Solid Waste Generation projection for Melamchi

Old Ward No.	New ward	Ward Name	2015		2020		2025		2030	
			Pop	SWG	Pop	SWG	Pop	SWG	Pop	SWG
1	6	Talamarang	2385	398.30	2784	464.88	3249	542.60	3792	633.30
2			2385	398.30	2784	464.88	3249	542.60	3792	633.30
3	5	Sindhukot	2175	363.23	2539	423.95	2963	494.82	3458	577.54
4			2575	430.03	3005	501.91	3508	585.82	4094	683.76
5	11	Melamchi	1487	248.33	1736	289.84	2026	338.30	2364	394.85
6			3455	576.99	4033	673.44	4707	786.02	5494	917.43
7			2536	423.51	2960	494.31	3455	576.95	4032	673.40
8	12	Bansbari	3457	577.32	4035	673.83	4709	786.48	5497	917.96
9			3544	591.85	4136	690.79	4828	806.27	5635	941.06
10	13	Fatakshilla	1863	311.12	2174	363.13	2538	423.84	2962	494.69
11			1752	292.58	2045	341.50	2387	398.59	2786	465.22
12	10	Shikharpur	2157	360.22	2518	420.44	2938	490.72	3430	572.76
13			1443	240.98	1684	281.27	1966	328.29	2294	383.17
14	9	Jyamire	1997	333.50	2331	389.25	2721	454.32	3175	530.28
15			2625	438.38	3064	511.66	3576	597.20	4174	697.03
	1, 2	Botechaur	5378	898.13	6277	1048.27	7326	1223.51	8551	1428.05
	3	Haibung	2811	469.44	3281	547.91	3829	639.51	4470	746.42
	4	Thakani	3892	649.96	4543	758.62	5302	885.44	6188	1033.47
	7, 8	Dubachour	6465	1079.66	7546	1260.15	8807	1470.81	10280	1716.69
Total			54382	9081.79	63473	10600.03	74084	12372.09	86469	14440.38

The average municipal solid waste generation rate was 9.08 metric ton per day while it is estimated to increase to 14.40 metric ton per day by the year 2030.

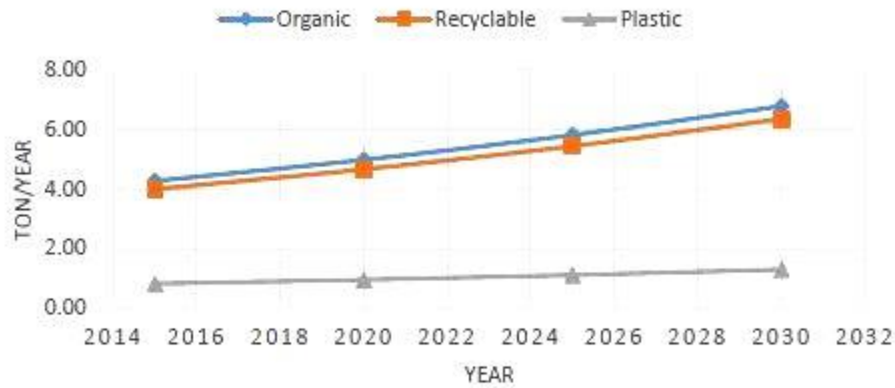

Figure 2 Projection of Waste Characteristic for Melamchi

As shown in figure 2, the organic waste and recyclable materials (paper, glass and textiles) in Melamchi is expected to increase to 6.79 ton/day and 6.35 ton/day in the year 2030 from 4.27 ton/day and 4.0 ton/day respectively.

Waste Characteristics

It was found that there was a high organic waste content in the waste produced in Melamchi Municipality, as majority of the people there are involved in agriculture. The comparative chart showing the composition of waste in the municipality is shown in figure 3.

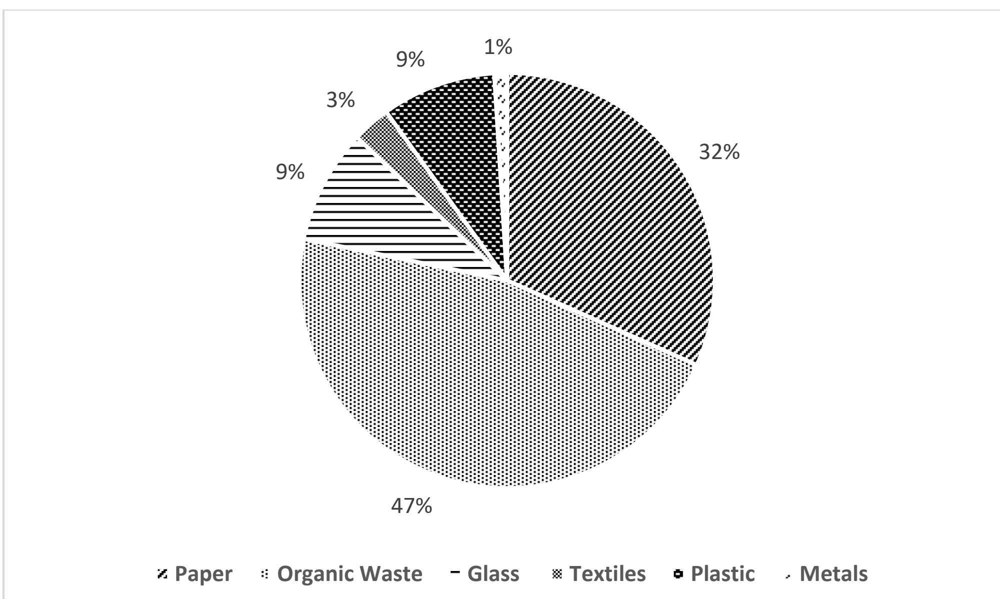

Figure 3 Waste Composition of Melamchi

As shown in the figure 3, organic waste makes up about 47% of the total waste produced in the Municipality and the least produced waste is metal waste.

Waste Management Practice

The waste management practice that is prevalent is open disposal to the environment or burning/burying within in household. According to the survey conducted in 107 households, composting practice is conducted by 57 households. The details of waste management practice followed by the number of houses in Melamchi are given in figure 4.

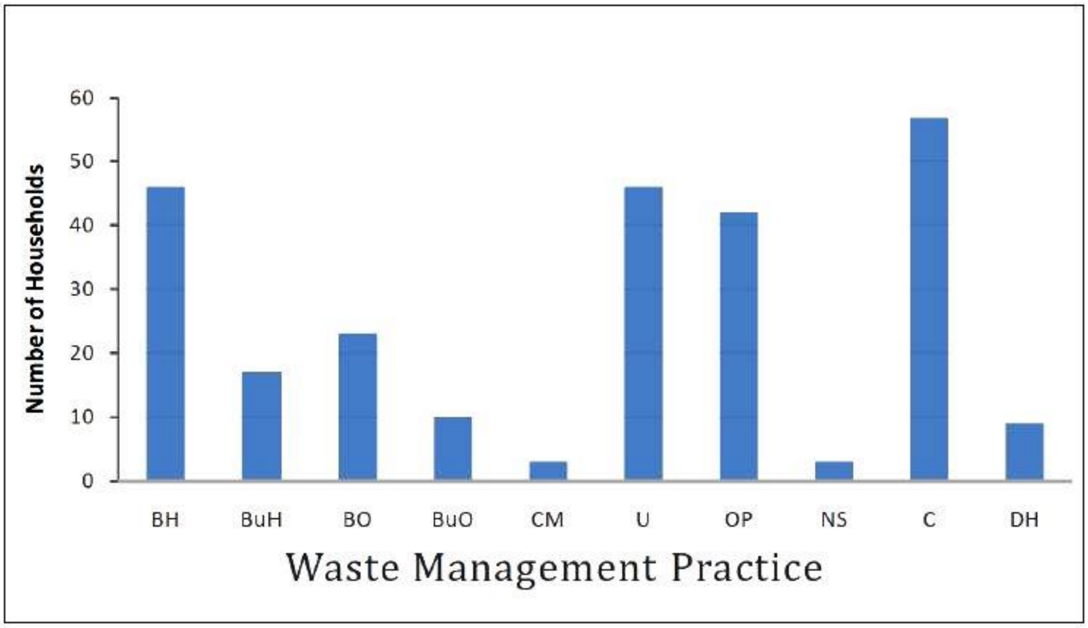

Figure 4 Waste management practice in households of Melamchi

(Here, BH- household burning, Bah- household burying, BO- Burning outside, BuO- burying outside, CM- collected by municipality, U- unorganized disposal, O- other practices, NS- Not sure of disposal practice, C- composting, DH- Disposed within household)

As shown in figure 4, the waste management practice that is prevalent is open disposal to the environment or burning/burying within in household. Out of 107 households, 57 households practice composting, 46 household practice unorganized disposal, 42 households practice open disposal, 46 households practice burning within the households.

Segregation of Waste

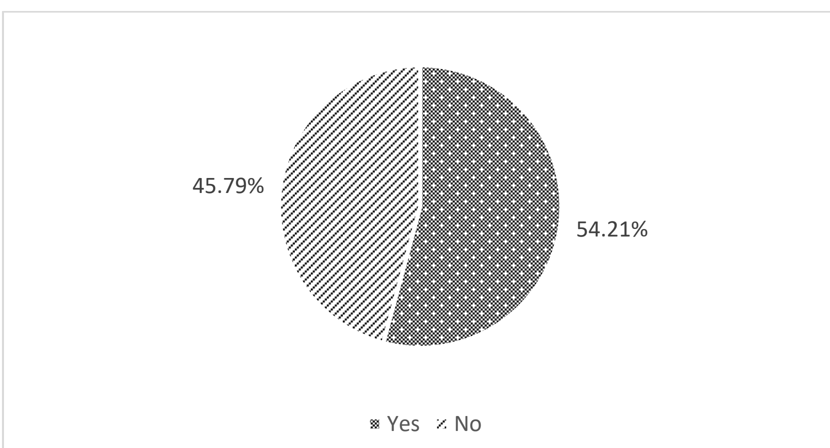

Figure 5 Segregation of Waste in Melamchi

From figure 5, it can be seen that 45.7% of the respondents didn’t segregate the waste. As for the reasons for not separating the 25.8% respondents said that they don’t have any knowledge of separation while 56.8% said that they don’t need the waste again (no value to them). There have been plans to encourage creating fertilizer from degradable waste, according to locals. However these plans to create fertilizer from degradable waste were never materialized.

Provision of Waste Collection

According to our study no waste collection mechanism existed in Melamchi. The waste collection that existed was highly irregular; according to our FGD participants, in some instances they were unable to throw wastes up to a full week. There were previously plans to collect waste by separating biodegradable and non-degradable waste in two separate bin on alternate days. Furthermore, it was planned that HHs that fill both bins (one for degradable and other for non-degradable) pay full fee for waste collection while those HHs that don't have degradable waste pay only 50%. It was believed that this will encourage people to take care of their degradable waste by themselves whether by producing compost or feeding to livestock. Also, there were plans to collect glass wastes separately and resell them. All the plans, unfortunately, could not be implemented due to social conflicts and lack of resources.

Provision of Waste Disposal

Previously there was a plan to dig up 2 holes near Indrawati River. It was supposed to be used as a temporary disposal site (except for medical and glass waste) and cover it. But the plan was shelved after digging up a hole due to the opposition from local people. Currently, the municipality is in search of a new landfill site. One option recommended by stakeholders is located at Khanikhet. This site has been explored further in the upcoming sections. Also, nearly 1 million rupees has been allocated to create the landfill site.

Figure 6 Haphazard Disposal of Melamchi Bazar Area

CONCLUSION AND RECOMMENDATION

This study was carried out to assess the present status of the solid waste in Melamchi municipality for further preparation of strategic solid waste management plan. This was executed by carrying out qualitative and quantitative method of data collection technique. The main findings of the study are described in the following points:

1. The average municipal solid waste generation rate was 9.08 metric ton per day while it is estimated to increase to 14.40 metric ton per day by the year 2030.
2. The Organic waste makes up about 47% of the total waste produced in the Municipality and the least produced waste is metal waste.
3. The waste management practice that is prevalent is open disposal to the environment or burning/burying within in household. Out of 107 households, 57 households practice composting, 46 household practice unorganized disposal, 42 households practice open disposal, 46 households practice burning within the households.
4. 45.7% of the respondents didn't segregate the waste. As for the reasons for not separating the 25.8% respondents said that they don't have any of separation while 56.8% said that they don't need the waste again (no value to them).

Following are some of the recommendations that should be adopted for the good practices of solid waste management:

1. Weekly waste collection in the municipality.
2. Assigning collection areas
3. Categorizing types of waste collected
4. Formation of monitoring team and management committee
5. Training for segregation of waste and collection of waste to the local community

ACKNOWLEDGEMENTS

The author would like to thank Dr. Murali Ranjitkar for the continuous guidance and assistance to conduct the assessment. Also the study team is also very grateful to the staffs of the municipality for their kind assistance to perform the study.

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AN ASSESSMENT OF WASTE PAPER PRODUCTION OF THE WORK PLACE IN NEPAL

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ABSTRACT

Paper is the third largest component of total solid waste generation in Nepal. Even use of computer in the workplace has not been able to reduce the consumption of paper to the extent it was expected. On the contrary, paper consumption has increased with the growth of computer usage. The main objective of this study was to assess the consumption of paper in a firm and recommend appropriate strategies to diminish its use and techniques to recycle it. To achieve this objective, the waste paper generated from different departments of the organization was assessed and several statistical analyses were performed so as to obtain the final conclusion. When a quick survey was done in a firm, it was estimated that an average of 30,000 sheets of paper which is equivalent to 132 kg used in a year. Also, it was known that the firm had no organized policy to reduce and recycle the paper products. The reason behind the consumption of huge volume of paper in the workstations may be due to the lack of awareness or locked in effects. Also, no any interventions and incentives are taken by the leaders or executives for the users to not use, reduce and recycle.

INTRODUCTION

Solid waste management (SWM), being one of the crucial component of urbanization, is also one of the major environmental issues in cities of many developing countries, including Nepal. Growth in urban population and economy results in increased generation of municipal solid waste (MSW). Bulks of wastes are generated from offices, schools, and colleges, which are categorized as institutional wastes. A recent study indicated that the highest waste fractions were organic matter (65%) followed by plastics (11%). Paper and paper products and others comprised 9% and 7 % of the waste respectively. Glass, metal, rubber and leather, textile components were either at or below 3 %. Similar to other developing countries, the solid waste in the subject municipalities has high organic content. Recyclable materials like paper, glass, metal and plastic content account for not more than 11%. (Shakya et al., 2013)

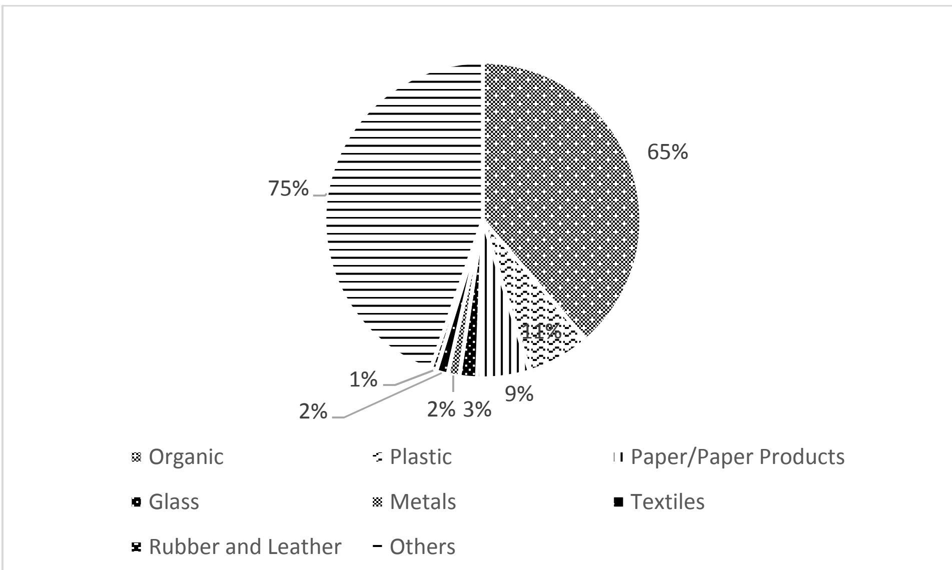

Figure 1 Composition of waste

Offices not only use large quantities of printer and copier paper, but also use other types of white paper (letterhead, bond, and note paper), colored paper, file folders, and many types of envelopes (including envelopes), making them paper-intensive. Office paper waste is an important segment of waste stream. However, firms and companies have relatively high degree of control over the use and disposal of paper wastes, making it a possible choice for source reduction. Furthermore, substantial amounts of money can be saved by reducing office paper waste. Almost every piece of office paper can be used on both sides, and opportunities abound for using paper more intensively in other ways (single-spacing documents, for example) and for eliminating some uses altogether (proofreading documents on the computer screen, for instance). Altogether, reduction of office paper usage has environmental benefits in addition to the direct cost savings.

Among all the wastes, newspapers are the most readily recycled commodity in municipal solid waste. They have the potential to release about 8,000 British Thermal Units (BTUs) per pound if burned in a waste-to-energy facility. Unfortunately, when placed in a landfill, they biodegrade very slowly, producing organic acids that have the potential of carrying toxic constituents to water supplies. By performing a simple chemical analysis, it is evident that the amount and the type of toxics released into the environment from this short-lived product is alarming.

OBJECTIVE

The main objective of this study is to assess the consumption of paper each day in an organization of Nepal and recommend appropriate strategies to diminish its use and techniques to recycle it. The specific objectives of the study are to

- Determine the per capita paper consumption in the workplaces.
- Assess psychological causes for the overuse of the paper among the staffs.
- Recommend a strategy to reduce paper consumption and waste volume reduction.

METHODOLOGY

Study Area

For the assessment of the usage of paper materials, Nepal Development Initiative (NDI) Consulting Private Limited was selected for the study. NDI Consulting is a limited liability company privately owned by shareholders. It has a rich inventory of a number of professional engineers, scientists and researchers and technicians for consulting and research works. About twelve full time staffs are employed in this firm few part time staffs.

Data collection technique

The study was conducted using quantitative and qualitative data collection techniques which comprised of Survey, Key Informant Interview (KII), and observation within the office premises.

A quick survey was done among the employee to gain the information about the daily use of paper by them during the office hours. Likewise, the number of printings made per day was also assessed through the survey with Human Resource Manager of the company.

KII was conducted with five employees of the company. The participants for the KII mainly were Executive Director, Program Officers, Admin and Finance Officer and Human Resource Manager. The reasons behind the overuse of the paper and recommendations to diminish its use were formulated through the interviews.

Likewise, the study team also observed the office premises and working tables of the staff to capture the information about the frequent use of papers by the staffs of the company.

RESULTS AND FINDINGS

Paper Analysis

It was acknowledged that about 30,000 sheets of A4 size paper is exploited each year in Nepal Development Initiative Consulting Private Limited.

In a quick survey conducted among the staffs, it was known that about 4-6 sheets of papers are used by them daily during the officer hours. So, Assuming 5 sheets of paper used by a single employee in each day and 200 sheets of paper used for the report and proposal printings in a month, the sheets of paper exploited each month equals to 2000 by full time staffs. Also, through the past year observation it was known that 500 sheets of A4 size paper is used by part time staffs in a month. Likewise, when calculated for yearly, 30,000 sheets of paper are used by the organization. The detail information about the usage of paper by the firm is shown in table 1.

Table 1 Usage of paper by the firm

Paper used by the full time staffs per month (No. of sheets)	2,000
Paper used by part time staffs per month (No. of sheets)	500
Total paper used by the firm per month (No. of sheets)	2,500
Total paper used by the firm per year (No. of sheets)	30,000
Quantity of paper used per month (kg)	11

Besides the usage of copier paper, it was reported that two sets of newspaper were delivered each day to the office i.e. 730 sets of newspaper each year. Additionally, about 50 B5 size note books containing 60 sheets of pages was used in the year 2017 in NDI by the staffs for daily office use and project implementation. Approximately, 12 pads of sticky notes and 96 toilet paper rolls were reported to be exploited each year in NDI. About 200 letter heads were used up in the year 2017.

Cost Analysis

The cost analysis for the paper was also done for the organization. It was estimated that NRs.42,860 is spent for the paper by NDI Consulting Pvt. Ltd yearly. The calculation involving cost analysis is shown in the table 2.

Table 2 Cost Analysis for the Paper Products

Items	Yearly Cost (NRs.)
A4 size copier paper	27,000
Newspaper	6,200
Notebooks	3,500
Toilet Paper Rolls	4,800
Sticky Notes	360
Letter head	1,000
Total	**42,860**

Psychological effect

The study revealed that the major use of paper over technologies is also due to the psychological effect among the employees. The older generation employees were found more comfortable using pen and paper to take notes instead of using memo in mobile phones. Some staffs are still unaware about the advanced technologies and the ways to use it whereas some find it very length and time consuming. Also, the employees would prefer to use fresh paper than the recycled ones. The organization is also greatly influenced by e standard choices; For example, a single-sided print option is a default which contributes to much higher volumes of paper than if default would have been double-sided copy. A Swedish study showed that 30% of paper consumption is determined by the default and that by switching the default to double sided option paper consumption could be reduced by 15% (Egebark and Ekstrom, 2013 €).

In the KII conducted with the executive director of the organization, Ms Rita Khatiwada, she expressed "*If given a choice to use between paper or use computer, I would definitely chose paper as I find it very much handy and comfortable taking notes on it. The technical problems that arise in computer is something I would like to avoid.*"

Similarly, when asked about the use of recycle papers in the office to the Admin Officer, Ms. Renu Tamang, she revealed that for printing the rough works and unofficial documents, the recycled paper is used. However, for the official works, the organization wishes to use fresh paper. She also expressed that they have been trying their best to diminish the use of paper but still have not been successful in it.

CONCLUSION AND RECOMMENDATION

This study was carried out to assess the waste paper production in the organization of Nepal. This was executed by carrying out qualitative as well as quantitative survey among the staffs of Nepal Development Initiative Consulting Private Limited. The main findings of the study are described in the following points:

1. In an average, about 30,000 sheets of copier paper are exploited each year in medium organizations in Nepal.
2. NRs. 40,000 to 50,000 is spent by the organization in paper products.
3. Psychological effect also played main role in the excess use of paper.

Some of the recommendations for diminishing the use of paper products can be mentioned as follows:

1. Replacing the single sided printer with double
2. Use of electronic mail, internet, intranets, and document scanners instead of paper products.
3. Printing the documents in a draft mode, which will generally lighten the shade, but still one will be able to read clearly.
4. Reducing the margin settings so that the printer uses less paper.
5. Use of air dryers instead of paper towel in the bathroom and common areas.

Thus, individuals, and companies should take pride in minimizing their waste as they will be helping to reduce global environmental damage and making this earth a better place.

ACKNOWLEDGEMENTS

The authors thank to Ms. R. Khatiwada for approving to conduct the assessment in Nepal Development Initiative Consulting Pvt. Ltd. The study team is also very grateful to the staffs of the organization for their kind assistance to perform the study.

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Emerging Issues in Solid Waste Management in South Asia: A Situational Analysis of Nepal

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ABSTRACT

There are many unresolved issues in solid waste management (SWM) starting from source through the recovery process to the final disposal, and are fairly similar in nature in South Asia. New challenges keep on emerging in the region with growing urbanization and consumerism. This paper, based on primary and secondary information, has tried to identify some of them with particular findings from Nepal. The issues are prominent in interventions such as Public Private Partnership (PPP), Small and Medium Enterprises (SMEs), SWM Technologies, Micro-Finance Institutions (MFIs) and Regulatory Instruments. The capacities of municipalities are found to be limited but they can leverage private sector, an important actor of municipal SWM. Access to microfinance has not been effective in SWM activities in particular for SMEs. Government intervention is deemed necessary in facilitating microfinance as well as in compost certification. In a nutshell, the issues found were comparable to the region.

Key words: *Solid Waste Management, Public Private Partnership, Small and Medium Enterprises, Micro-Finance Institutions, Composting*

INTRODUCTION

Solid Waste has become a big environmental discourse in South Asia as the region struggles to manage the growing waste management situation. The production of greater amount of solid waste is attributed to high rate of urbanization (Hassan, 2000; Hoornweg and Bhada-Tata, 2012). Urbanization in South Asia has grown from 17 percent in 1950 to 35 percent in 2015 (Deb, 2017). Scattered waste in the streets, drainage blockage, water and air pollution caused by solid waste and unmanaged landfill sites are commonly observed in South Asian countries. Nepal, currently with 293 municipalities has witnessed a 16 fold increase in urban population in the past five decades (Sharma, 2014). Figure 1 shows the urban areas in new Federal Nepal which had only 58 municipalities until 2014. The average Municipal Solid Waste (MSW) generation in the country is 317 g/capita/day with the situation more worrisome in urban cores. Kathmandu, the leading urban centre of Nepal, is one of the fastest growing metropolitan cities in South Asia (Bakrania, 2015). Kathmandu Metropolitan City (KMC) alone produces 660 g/capita/day (Dangi et al., 2010) which is much higher than the average waste generated in South Asia that stands at 450 g/capita/day (Hoornweg and Bhasa-Tata, 2012). About 800 tons of solid waste is generated daily in Kathmandu Valley alone with 66% of the waste being organic (Shakya and Khatiwada, 2017).

In Nepal, MSW management (MSWM) is under the domain of local government. The municipalities are weak administratively and financially, and lack qualified and motivated human resources leading to poor service delivery. It is reported that approximately 80–95% of the total MSWM budget is consumed by collection and transportation activities whereas the disposal and treatment of waste lack adequate investment which has led to open, uncontrolled and poorly managed landfills across most municipalities. Majority of MSW generated end up in landfill sites as there is very limited segregation done at household level and limited practice of recycle, reuse and recycle (3R) of the waste (ADB, 2013). The resulting volume of waste has put huge pressure on landfill sites and also resulted in generation of higher amount of leachate

(Khatiwada et al., 2018). Apart from these fundamental problems, other issues related to actors of SWM, financing and regulatory instruments, and SWM technologies have evolved over time. But in Nepal, policymakers continue to enact new laws and codes that emphasizes mainly on the technologies used to transport and dispose which are not bringing positive changes in the sector (Dangi et al., 2017). It is in this premise, this article aims to look into those emerging concerns that are not receiving the attention they deserve. It also aims to draw the attention of policymakers to integrate all important actors of SWM and facilitate the interventions needed for sustainable SWM.

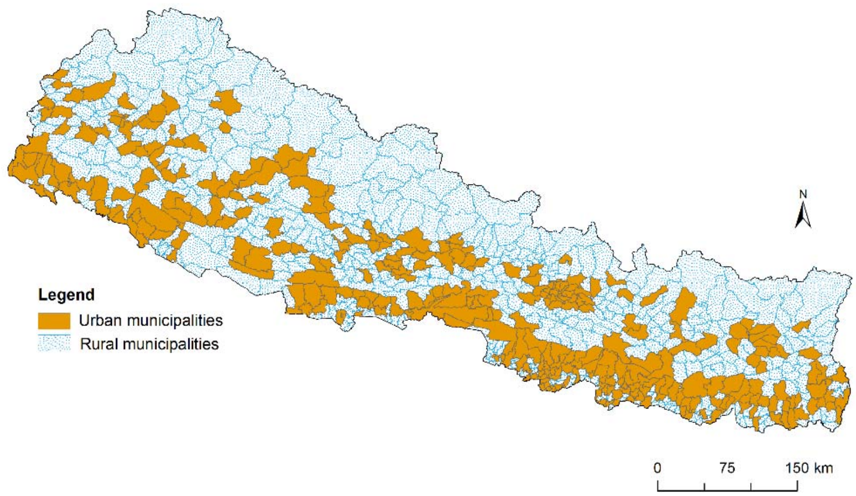

Figure 1: Map of Nepal showing urban municipalities

METHODOLOGY

The paper utilizes secondary information acquired from official reports, journal articles and other published documents. Relevant policies, Acts and regulations were reviewed too. Similarly, information has also been collected through formal and informal interviews with various subject experts. Such information was authenticated by holding group discussions on the subject matter.

EMERGING ISSUES

Nepal does not have an Integrated Solid Waste Management Policy due to which every municipality has to face the challenge of managing the waste that only grows with population and urbanization. In recent times, new issues are rising in the emerging interventions such as Public Private Partnership (PPP), Small and Medium Enterprises (SMEs), SWM Technologies, Micro-Finance Institutions (MFIs) and Regulatory Instruments (RI).

Effectiveness of SWM Regulatory Instruments (Policies, Acts and Regulations) in Nepal

Nepal formulated the Solid Waste Management National Policy in 1996 with an aim to ensure the proper management of solid waste for healthy and safe working and living conditions of the citizens. The first designated law on SWM in Nepal was Solid Waste Management and Resource Mobilization Act, 1987. This law has been replaced by Solid Waste Management Act in 2011. This new Act governs waste collection, transportation, storage, and landfill of the household and industrial waste, and reuse of the waste as secondary raw material. The Act is the regulatory basis of waste segregation at source and has emphasized the introduction of the 3R principles too. According to the Act, SWM is a shared responsibility as it requires waste management plans to be developed, implemented and operated by local governments in association with other agencies. Hence, it intends to lay the ground for involving private sector, community based organizations (CBOs) and non-governmental organizations (NGOs) in SWM through competitive bidding (ADB 2013).To set higher recycling targets and generate jobs in the recycling chain for private sector, the SWM Rules (SWMR), 2013 has arranged for official agreements to be signed between the central government/local governments and the business sector. Besides, several legal instruments govern the management of waste and outline the responsibilities of waste generators, waste management organizations (private companies and local authorities), waste planning authorities and waste regulators.

All countries in the region have enacted waste-related legislation but the compliance remains poor (UNEP, 2017). The enforcement of SWM Act, 2011 in Nepal is being considered less satisfactory as the sector is contingent upon the availability of adequate staff, financial and technical resources, which is lacking in municipalities. Moreover, judicial activism and public participation is lacking while the implementation of imposition of fines and penalties, provided in the Act on defaulting individuals/organizations are not effective. On the other hand, the Solid Waste Management National Policy, 1996 states that the solid waste management should be organized and managed at local level (Shakya and Tuladhar, 2014) but it is not adequately harmonized with the needs and capabilities of the local governments. Similarly, the apex regulatory and central technical support center called Solid Waste Management Technical Support Centre (SWMTSC) lacks administrative and political will. There is no clear short-term and long-term plans with strategies for implementation of technical support program (SWMTSC and MoFALD, 2013). Generally, the local governments or municipalities in developing nations sometimes waste the opportunities provided by donors due to carelessness. A good example would be from Sri Lanka where World Bank fund for SWM project was cancelled twice due to lack of political support (Muneera, 2012).

Lack of coordinated effort and cooperation are the key gaps in the legal and institutional framework for SWM. Such inefficiencies can be attributed to many factors, such as frequent changes in political power that often lead to either change in the name of the institution or in the deployment of human resources that serve the particular institution (at all levels and at each change of government). Such discontinuity, misplacement of capacity and uncertainty have weakened administrative efficiency. Also, institutional roles and responsibilities at different levels of government are not clearly delineated, thereby leaving a gap in ownership and responsibility in Nepal. In other South Asian countries like Sri Lanka, there are overlaps in SWM responsibilities of government agencies leading to arguments due to ill-defined policies related to waste management (Muneera, 2012). At present, municipal governments in Nepal implement SWM activities as individual projects rather than as part of a national program. Most donor-funded programs are also implemented directly by working at the local government level with no clear (national) institutional framework that impedes the proper development of human resources and the program sustainability. Similarly, more than 90 percent of municipalities do not charge for urban cleaning services, and when they do, the collected amount is insufficient to cover even partial costs. The country is in need of strategies to make the legal provisions effective and implementable financially as well. There are already a large number of privately owned organizations that have a significant potential to provide quality service but no institutional forums exist for dialogue between municipal governments and such organizations.

Effective Solid Waste Management (SWM) through PPP

The increasing waste generation with urbanization demands the enhancement of waste management and handling capacity. The local governments are increasingly depending on private sector for waste collection, transportation and disposal because the sector has shown an improved performance in solid waste management and service delivery. They have been involving the private sectors through short-term contracts. Usually, the large municipalities have contractual arrangements with the private sector, NGOs, or CBOs in Nepal (ADB, 2013). Similar is the case in India where the private sector provides limited sections of SWM services in contractual basis (Mohan et al., 2016). There are more than 150 private sector waste operators independently involved in various aspects of waste management in Kathmandu valley only, indicating a wider private sector involvement in waste management. Escalation in the participation of private sector is also evident through long-term partnerships with the local government in recent times. Private sector involvement in SWM attracts capital as well as relieves the enterprise from political interference and introduces competition and efficiency. Hence, advocates of PPP consider it as a tool to improve economic performance. Nevertheless, there are speculations on the possibility of monopoly of private sector and negative impact on employees. Although the popularity of PPPs is rising in the country, the institutional setting, governance and regulatory structures and market linkages (for recyclables/compost) are just at the budding stage creating challenges for successful implementation of PPPs. Mohan et al. (2016) states that the Public-Private-People-Participation models to waste management in India are also at a nascent stage of development that seek strong institutional, governance, policy and market support for successful implementation at large scale.

Both formal enterprises and informal sector are involved in SWM, especially in recycling. But a larger informal sector (mainly rag pickers) are not formally integrated into waste management system. Like in Nepal, there is no legal framework to incorporate heavy informal private industry into the participation mechanism of SWM in Pakistan (Nasreen, 2012). PPP in SWM involving both formal and informal can ensure sustainability in SWM and job opportunities. But local governments do not have good understanding of partnership approach and procurement processes. The lack of practical guidelines for the preparation of contracts and bidding documents, along with technical support for such functions such as performance-based specifications, payment mechanisms, organization of the bidding process, conditions for promoting competition between service suppliers, arrangements for quality and performance control, as well as required education and trainings to familiarize with the existing policy and the legal and regulatory framework has hindered the establishment of local governments' satisfactory working relationships with the private sector.

There are some legal frameworks that facilitate PPP in SWM. For instance, SWM Act 2011 and SWM Rules 2013 detail out PPP processes and areas of interventions. Similarly, PPP Policy, 2015 has embodied three key policies, promotion of PPP principles and values, maximization of private sector expertise and creation of conducive environment for the sector. However, the legal and regulatory instruments for PPP activities pose a risk to private investors since the laws that govern PPP are not always consistent with each other or municipal policies may be revised with little consideration on the impact on private partners. Similarly, the system of fixing tariff for public services are generally unscientific and could impact the profitability for the private investor. Transparency is also an issue in the bidding and project supervision process in PPP projects.

The ultimate responsible agency for SWM is municipality even after involving the private sector. Hence, municipality must be accountable and ensure the quality of service delivery under PPP arrangements. Municipalities should assess the capital market and institutional capacity of the private sector before engaging appropriate service providers in different components of SWM. Table 1 shows the components of SWM activities and the opportunities in them for PPP. Without financial security, competition, transparency, conducive legal environment and good monitoring and evaluation systems, the PPP objectives will not be met. Dangi et al. (2017) have underscored institution as the key component for sustaining SWM activities. For an effective PPP, a strong political support and better bureaucratic procedures are imperative. Also, municipalities need support from the policy making and financing bodies at the highest level of the government. With the support for PPP from these institutions, solid waste related problems can be reduced.

Table 1 SWM components and the opportunities in them for PPP

Main Components	Sub-components	Implementation Status
Primary Waste Collection	Source to Collection Point	Already contributing to many aspects of PPP suitability
	Source to Containers	
	Source to Transfer Station	
	Source to Landfill Site	
Waste Transportation and Management	Containers to Transfer Station	Operational in some municipalities
	Containers to Landfill Site	
	Transfer Station to Landfill Site	
SWM Facilities Management	Transfer Station Management	The need for municipal support has to be taken into account
	Landfill Site Management	Not preferred
	Waste Processing Facility Management	Not practiced

Composting Technologies and Compost Certification

There exists an opportunity to reduce the volume of waste and convert into valuable resources such as fertilizers and bio-fuels. As a large portion of the waste of the region's MSW is organic, composting technologies offer a sustainable solution for managing such bio-waste. Estimates show that the region could produce 8 million tons of compost worth $709 million and additionally carbon financing could provide a revenue of $218 million from reduced greenhouse gases annually (ADB, 2011). Hence, composting is appealing to both the environment and economy. Yet, composting in bigger scale is not that popular in this region, including Nepal. This can be attributed to mixed nature of the waste as a result of poor segregation, and higher operation and maintenance costs as compared to open landfilling (Glawe et al., 2005). Nevertheless there are many simple and eco-friendly technologies which the local governments can introduce to the communities such as vermin or worm composting or traditional windrow method, compost bins and biodynamic composting for sustainable bio-waste management, to facilitate the process of transition to circular economy.

One of the challenges for the community and NGOs is the capital cost to establish a composting centre. The reason why there is still few composting centres in most municipalities, even after years of successful operation, is the lack of financial and technical support by the local government. In fact, local governments have enough resources to extend their financial and technical support for composting as it facilitates their waste reduction efforts and subsequently reduces waste management costs.

Another challenge is securing the market for the compost to make it profitable. The demand for compost fluctuates seasonally forcing the producers to store a large stock of compost. Furthermore, chemical fertilizers are generally sold at a subsidized price making it hard for compost to compete. Quality control and pricing are the key aspects for scaling up compost marketing efforts (ADB, 2011). But Nepal has not, to date, adopted the Compost Quality Standards. Compost production either at a household or at a commercial level does not require to any quality controls under any domestic legislation. There is no official compost certifying body in the country that makes any quality concern/investigation regarding the compost, which is a voluntary undertaking both on the part of the producer and the consumer alike. In other cases in the region, countries have been found to be weak in promoting their national programme for green product certification, such as the eco-mark scheme in India (UNEP, 2017). Such situations decline the confidence of the users regarding the claims and product performance.

There is lack of scientific research on composting technologies and the limited demand and supply capacity in Nepal. So it becomes important for concerned agencies to initiate safer and scientific composting programs which gradually assure the end-use quality. Similarly, the quality of bio-waste used for composting needs to be of the highest quality to avoid the soil from getting contaminated. On the other hand, there are no sufficient efforts from the concerned agencies to secure carbon financing for the projects related to bio-waste management.

Small and Medium Enterprise Mobilization in SWM

Small and medium sized Enterprises (SMEs) are recognized as important actors of MSWM in Nepal as they drive cost efficiency and improve the quality of service delivery. Many formal and informal micro and SMEs are involved in waste recovery and selling of materials to industries that recycle waste exhibiting their interest in service provision. There is considerable demand for recyclables which offers employment opportunities with positive economic and environmental impacts. Although SWM Act, 2011 has a provision of legal aspects of recycling and reuse of waste generated, it has not made any dedicated provisions that directly links SWM in SMEs and SWM through SMEs. Also no formal structures have been created to facilitate the partnership of local governments with community groups and SMEs involved in recycling and re-use of waste. Furthermore, there is no provision of incentives to the SMEs for investing in SWM. Additionally, these entrepreneurs and enterprises face the challenges such as high transport costs for wastes (raw materials), high operational costs, lack of incentives like tax subsidies from government, low profit margins, cumbersome waste sorting exercise, harassment by government agencies and lack of capital to aid business expansion.

Micro financing in Small and Medium Enterprises on SWM

The SWM in general requires good investment which may not be affordable to SMEs without financing. It has also been realized that waste sector will require significant investments in new infrastructure while the municipalities already struggle with budgets for the delivery of basic collection and disposal services.

Although easy access to finance and facilities to the small entrepreneurs will support local private sector institutions' participation in SWM, lack of access to risk capital and support systems is one of the many challenges faced by entrepreneurs in Asia (UNEP, 2017). Among various aspects of SWM, provision of micro finance to the SMEs of the sector has not gained much attention in Nepal. The use of micro finance intermediaries to supply the credit needed to implement 3R related activities has become a promising approach to improving SWM in many municipalities. Such activities may be decentralized to the SMEs where municipal capacities are inadequate and/or where low-cost solutions are essential. An estimate shows that about 10,000 to 15,000 waste pickers and 700 to 800 Kabadis (waste/scrap dealers) are involved as informal waste worker in dealing with waste generated in Kathmandu Valley. They play vital role in waste minimization and recycling and also represent small and medium scale enterprises of SWM. Unfortunately, majority of the waste collectors, particularly waste pickers, have no saving and credit practices in any type of formal/informal institutions (Practical Action, 2014).

Currently, only few entrepreneurs have successfully expanded the SWM business. Growth of the SMEs will depend on access to the services such as access to skill development (both technical/vocational and business skills), as well as market assessments and other types of information. Most SWM activities supported by micro finance are small and is popular with the small private companies. Part of the microcredit goes usually into SWM services such as procurement of equipment, employment of more staff and development of recycling activities.

In most of the municipalities bank loans are not easily accessible by SMEs involved with SWM. Some forms of credit are available through informal money-lenders that charge very high interest rates. Micro finance services are confined to some of the bigger municipalities only due to the lack of awareness and experience. There is a need to expand the services in smaller municipalities too. Case studies have shown that if financial support could be linked with empowerment (productive activities) and people's involvement (social marketing), it decreases the risk of non-reimbursement of loans. The financial access through micro financing in solid waste management needs to be fully explored as it is having lesser discourse in Nepal. Micro finance is the most important and credible source that provides an access of finance to SMEs. An access to finance and credits services in SWM sector can help boost job creation and raise income in the sector.

CONCLUSION

The situation of SWM in Nepal is no different than other South Asian countries as the country is unable to manage the growing waste to keep pace with growing urban areas. Moreover, in recent times, new issues are sprouting as additional challenges which are similar in their nature in the whole region.

Although there are fairly well developed policy and regulatory frameworks related to SWM and protection of environment in Nepal, their enforcement has been hindered by lack of national policy to support the SWM Act, and to address the financial constraints, skills and resources gap, and technology barriers, especially at local government level. The regional context is fairly similar to that of Nepal. It is deemed necessary to provide a strong foundation, through new or amended legislation, for mainstreaming the SWM in the context of sustainable development as well as in the prospect under newly structured federal Nepal.

MSWM is a demanding endeavor and is difficult be handled alone by the local governments which are already impaired with resource constraints. Thus, it is high time that Nepal acknowledged the role of private actors (both formal and informal) in SWM and integrate both in the waste management system. The private sector is a crucial component in managing the waste and hence, it needs legal, institutional, financial and technological back up. PPP practices are growing among the municipalities in Nepal, which are based on the principles of sharing risks and benefits. At the same time, it is important to evaluate the performance standards to be met by privatized enterprises, establish detailed impacts of monitoring plans of PPPs and develop performance indicators. Conducting a cost–benefit analysis is recommended in order to assess the centralized (technology driven) or decentralized (community based) approaches of PPPs and define the most effective option in the context of Nepal. PPP can further be lifted up in the future by better harmonization of working relations between local governments and private companies. In this context, competitive tendering and complete transparency particularly with regards to financial accountability are crucial.

The involvement of SMEs in SWM are not only creating jobs but are also managing recyclable wastes at low cost. But neither any incentive mechanism nor financial support for such players are in place. Even the solid waste related laws do not have special provisions for them. In order to develop SMEs' service potential in SWM as well as business potential, access to finance must be ensured. Municipalities should build partnership with SMEs as it is in the interest of cost efficiency and effective service delivery. They can provide guarantees to enable small banks or cooperatives to provide micro finance to the SWM sector which otherwise would be considered too risky. The institutions such as MFIs which currently do not run programs with SWM, should consider building the capacity of SMEs involved in SWM.

Composting can significantly reduce the amount of organic waste. In the developing world like South Asia, the environmental factors are less prioritized while managing solid waste. Composting is environment friendly and economically beneficial to the communities as well as the government. Hence, composting technologies as suited to the communities should be promoted. Nepal, in particular, needs an authorized body for compost certification in order to ensure the quality product and the market.

With the endorsement of federalism in the country, more power, authority and responsibilities are delineated to the local level. SWM is both a challenge and opportunity for the municipalities as it is one of the performance indicators of municipality. Coordination with the central/provincial government is necessary to materialize the aspirations of relevant legal instruments in the sector. For a sustainable SWM, municipalities can and need to integrate private sector as well as facilitate financial opportunities for entrepreneurs of SWM.

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SOLID WASTE SEPARATION AND MANAGEMENT SYSTEM FOR URBAN AREA OF BANGLADESH

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ABSTRACT:

Solid Waste Management is a prime concern in present days regarding the environmental impact. The increased population leads to the growth of urban areas and slums which, in turn, generating a huge volume of waste. Until recently, environment was not an issue in a developing country like Bangladesh and solid waste management was definitely not the prime concern of environmentalists and the government. It is only in very recent times, when certain NGO's started working and highlighting the pathetic state of municipal waste services provision in the country, that the decision makers realized the importance of this particular aspect of environmental management. A large proportion of the waste is not properly managed and dumped in unplanned sites that are creating severe environmental hazards. According to the Economist Intelligence Dhaka is the worst city to live in and according to pollution index report 2015, Dhaka is the 7th most polluted city and Bangladesh is the 9th polluted country in the world. The objectives of the study are to explore the present status of municipal solid waste generation and its management in Bangladesh, to recommend a schematic SWM Model in order to improve the present waste management system, to reduce the use of solid waste for land fill, Waste Segregation for Bio-gas plant &Refuse Derived Fuel (RDF), Reducing MSW waste for land fill purpose, To contribute in the way to reach the goal of 2021, 2040 and millennium development & Meet up the UNEP target. It is found in the study that suitable landfill area for waste disposal will hardly be available in near future if the current waste disposal practice continues. . In Bangladesh informal sector is contributing from 3% to 15% recycling of inorganic wastes. If waste recycling gets proper government attention and assistance and if operated in environmentally sound manner, the rate can be increased to meet the UNEP target.

Key words:_Solid Waste, population,recycle, management system_

INTRODUCTION

Bangladesh is a densely populated country in the third world. World's eight highest populated country with population of 158.512 million (July 2014) (United Nations, Department of Economic and Social Affairs, Population Division .World population prospect: the 2012 revision) and one of the fastest urbanizing countries, is a land of physical, climatic, geographic, ecological, social, cultural and linguistic diversity. At present there are 522 urban centres in the country including 298municipalities and 11 City corporations. The annual population growth rate of approximately 4 percent in urban areas in Bangladesh is concentrated in a few large cities. Dhaka with 13 million people accounts for about 40 per cent of the total urban population (UN HABITAT, State of the World's cities 2008-2009).It is predicted that by 2020, 2030 and 2050 about 50, 80 and 100 million people will be living in Bangladesh's towns and cities respectively. The increased population leads to the growth of urban areas and slums which, in turn, generating a huge volume of waste. Until recently, environment was not an issue in a developing country like Bangladesh and solid waste management was definitely not the prime concern of environmentalists and the government. It is only in very recent times, when certain NGO's started working and highlighting the pathetic state of municipal waste services provision in the country, that the decision makers realized the importance of this particular aspect of environmental management. A large proportion of the waste is not properly managed and dumped in unplanned sites that are creating severe environmental hazards. According to the Economist Intelligence Dhaka is the worst city to live in and according to pollution index report 2015, Dhaka is the 7th most polluted city and Bangladesh is the 9th polluted country in the world.

Background study

Solid waste generation has facing myriads of problems with the growth of population. of Municipal Solid Wastes (MSW) continues to remain one of the most neglected areas of urban development in Bangladesh. The 6 metro cities and pourashavas in Bangladesh generate about 13,332 tonnes (Sinha , 2006) of such wastes per day. Piles of Garbage and wastes of all kinds littered everywhere have become common sight in our urban life. Magnitude and density of urban population in Bangladeshis increasing rapidly and consequently the Civic bodies are facing considerable difficulties in providing adequate services such as supply of water, electricity, roads, education and public sanitation, including MSW.

METHODOLOGY

As Bangladesh still a low income country its highly hard to implement mechanical / auto system to the all sector of waste management like develop country .We should think solution at our perspective that system can be more economic, easy to applied orhandle , safe and can be turned into much better option of solid management system in the future. It is seen that both developed and developing country, they collect mixed solid from sources with manual process(now a day's western country turned it into mechanical) and take them to the damping site than only develop country process the mixed solid waste mechanically and then separated waste take into the plant to convert energy. But in developing country like Bangladesh they just remove some recyclable material at the manual process and maximum waste used as to fill up low land without ensuring any environmental aspect. That creates most environmental Hazarders. We Bangladesh highly shortage of energy and fuel emphasizing this point we should install such a system for solid waste management that we can easily recover energy.
Maximum study shows that in management system they collect mixed waste from sources that means a huge volume of solid waste have to travel that cost much. If u can implement segregation of solid waste in the point of sources its can reduce the volume of solid waste as well as reduce the cost of management.
A statistical data of solid waste generation of Bangladesh is given below with the increase of population:

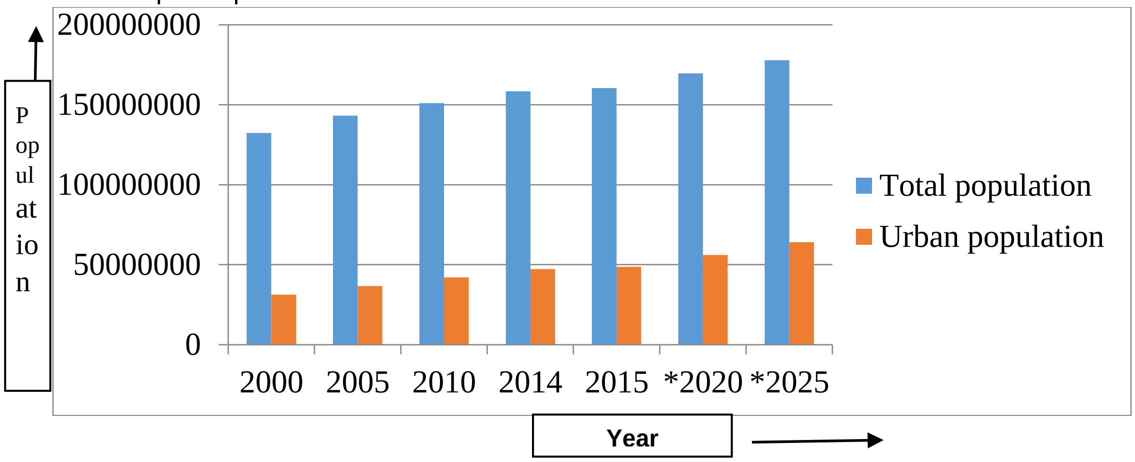
Table 3.1 Bangladesh Population and waste generation scenario

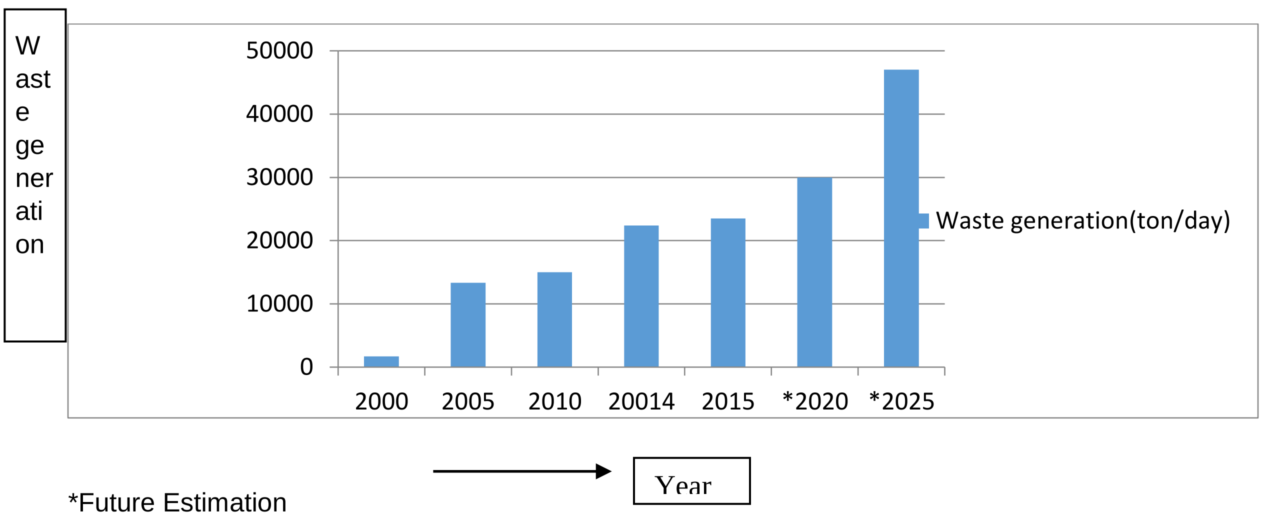
Year	Population	Yearly % Change	Yearly change	% Urban Population	Urban population	Waste generation (ton/day)
2000	132383265	2.01%	2502736	24%	31229212	1700
2005	143,135,180	1.57%	2,150,383	26%	36,694,135	13,332.89
2010	151,125,475	1.09%	1,598,059	28%	42,154,940	15000
2014	158,512,570	1.22%	1,917,608	30%	47,334,620	22400
2015	160,411,249	1.20%	1,857,155	30%	48,724,917	23500
2020*	169,565,959	1.12%	1,830,942	33%	56,100,898	30000*
2025*	177,884,947	0.96%	1,663,798	36%	64,083,052	47000*
2030*	185,063,630	0.79%	1,435,737	39%	72,400,593	-
2040*	195,861,405	0.50%	963,925	46%	89,236,415	-
2050*	201,947,716	0.24%	486,761	52%	105,317,753	-

Source: 1 World Meters, (World Population Prospects, The 2012 Revision), 2 Field 2006

*Future estimation

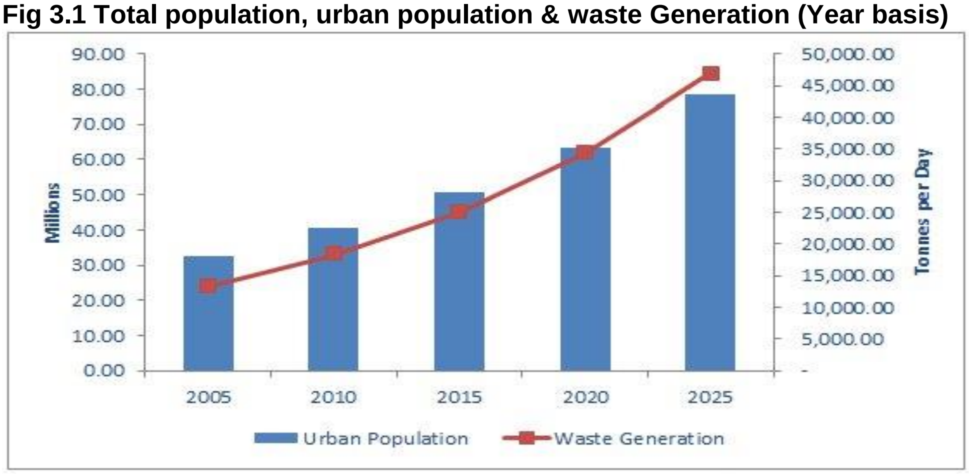
3.1.1Graphical presentation





*Future Estimation

Fig 3.1 Total population, urban population & waste Generation (Year basis)



Source: World Bank, Waste Concern, and Frost & Sullivan Analysis

Fig 3.2 Urban Population and Waste Generation, Bangladesh, 2005-2025

Table 3.2 Total Waste generation in urban areas of Bangladesh (2005)

City/town	WGR (kg/cap/ day)	Estimated population (2005)	Total population (2005)	TWG(ton/day)		Avg TWG (ton/day)
				Dry season	Wet season	
Dhaka	0.56	6116731	6728404	3767.91	5501.14	4634.52
Chittagong	0.48	2383725	2622098	1258.61	1837.57	1548.09
Rajshahi	0.3	425798	468378	140.51	205.15	172.83
Khulna	0.27	879422	967365	261.19	381.34	321.26
Barisal	0.25	397281	437009	109.25	159.51	134.38
Sylhet	0.3	351724	386896	116.07	169.46	142.76
Pourashavas	0.25	13831187	15214306	3803.58	5553.22	4678.40
OtherUrban Centers	0.15	8379647	9217612	1382.64	2018.66	1700.65
Total	0.41 (Avg)	32765516	36042067	10839.75	15826.04	13332.89

Total	0.41 (Avg)	32765516	36042067	10839.75	15826.04	13332.89

*WGR= Waste Generation Rate,** Including 10% increase for floating population,***TWG= Total Waste Generation, which increases 46% in wet season from dry season

Source: 1JICA (2005), 2Chittagong City Corporation, 3Field Survey, 4Sinha (2000), 5Field Survey, 6Sylhet City Corporation,

From the Field Survey it is found that total waste generated in the urban areas of Bangladesh per day is 13,332.89 tons. Based on the total estimated urban population of the year 2005, per capita waste generation rate is computed as 0.41 kg/capita/day.

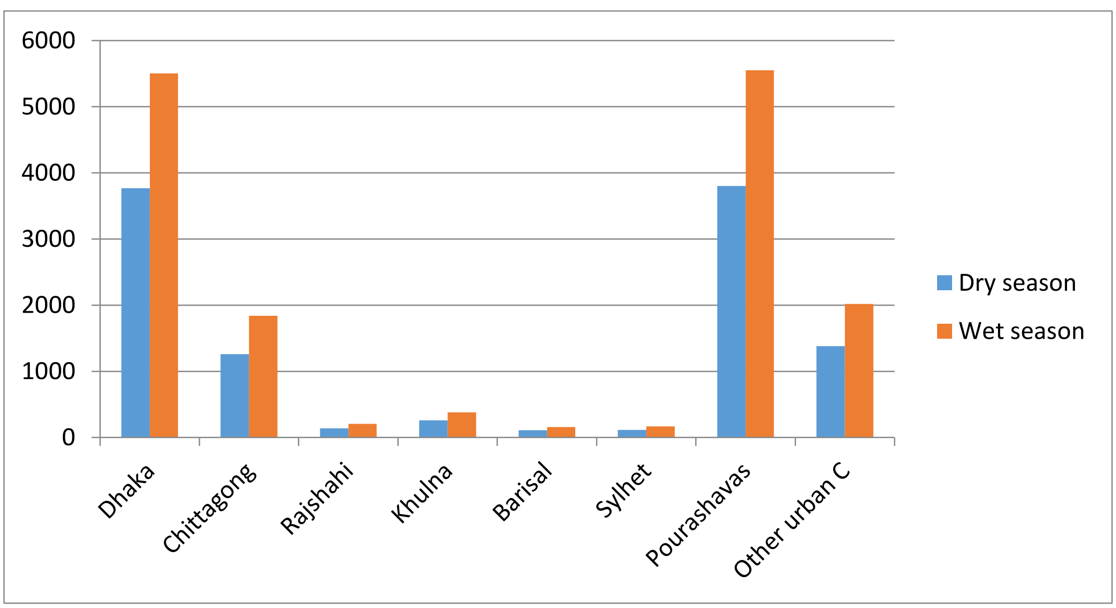
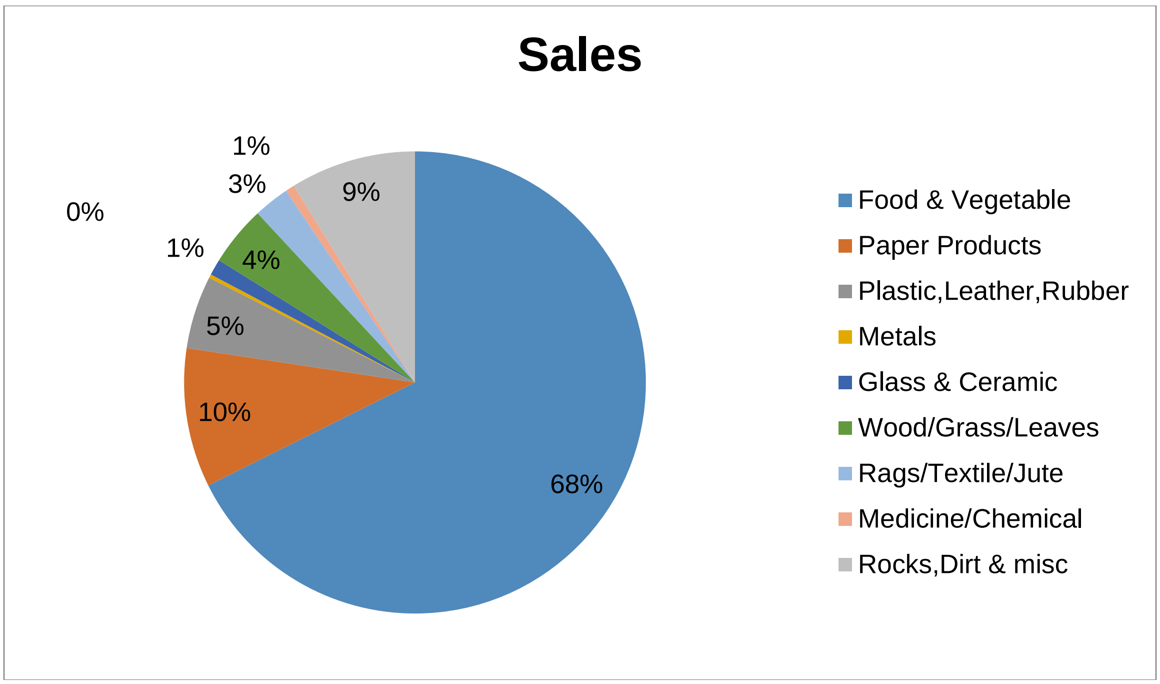


Fig 3.3 Graphical presentation of seasonal variation of waste generation in different urban area

Table 3.3 Relative Composition of waste (By income)

Contents	Low income	Medium income	High income
Organic (putrecible), %	40 to 85	20 to 65	20 to 30
Paper, %	1 to 10	15 to 30	15 to 40
Plastics, %	1 to 5	2 to 6	2 to 10
Metal, %	1 to 5	1 to 5	3 to 13
Glass, %	1 to 10	1 to 10	4 to 10
Rubber, leather, etc., %	1 to 5	1 to 5	2 to 10
Other, %	15 to 60	15 to 50	2 to 10
Moisture content, %	40 to 80	40 to 60	5 to 20

Source : (INTOSAI working group on environmental auditing, 2002)



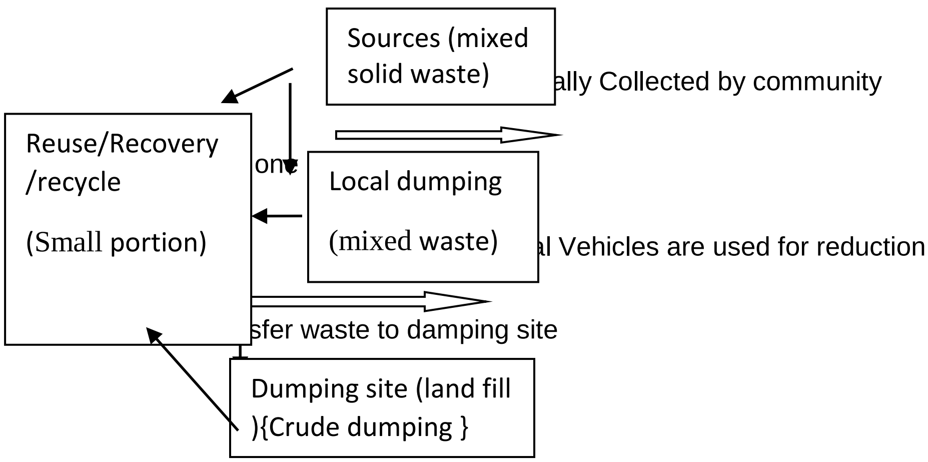
High organic matter>>(more than 70%)
High moisture content>>(more than 50%)
Source : Country Presentation Bangladesh 2nd Meeting of the Regional 3R Forum in Asia 4-6 October 2010Kuala Lumpur, Malaysia

Fig 3.4 Average Physical Composition of Urban Solid Waste In Bangladesh

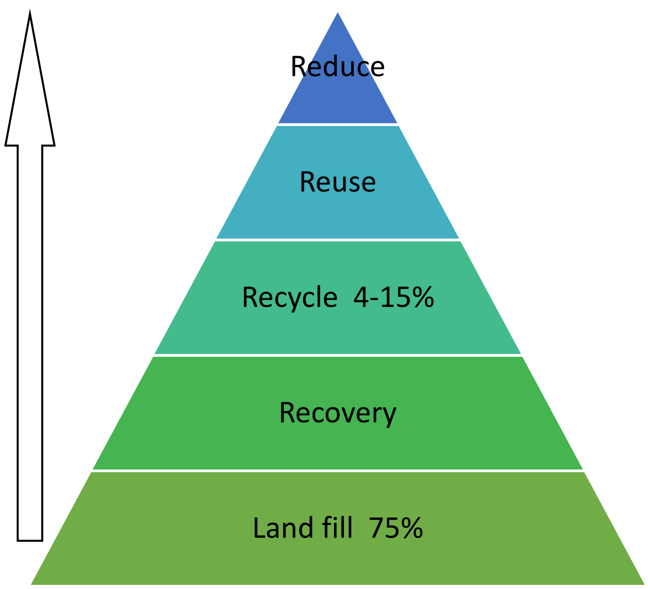
3.1 Present waste management system

InBangladesh though present practice of MSW is not sufficient and effective but its getting develop day by day .Now a day's almost every big city like Dhaka city corporation both north & south established community based waste collection system .In this process community crews collect mixed waste from source by rickshaw or Hand trolley and take into the container or dustbin or local dumping site mostly situated beside main road ,and then city corporation or Municipal workers collect these waste ,loaded them and transfered to the final dumping site. Flow chart & picture shared below

3.1.1 Present waste management flow chart



3.1.2 Present waste management hierarchy (poor practice)



It has been found that in our present waste management process recyclable inorganic waste is collected for recycling between the secondary collection points and the secondary waste collection truck by waste pickers (popularly known as tokais) and municipal workers and it ranges between 4.29% to 11.19% of the collected waste while at landfill site collection of waste for recycling by landfill tokais is between 0.22-1.22%. Total recycling of inorganic waste in the study areas varies between
4.55% to 12.41% of the generated waste whereas the total amount of inorganic waste varies between 12.13% to 28.30% in the waste stream of the study area. This means that between 37.5% to 44% of the inorganic waste is recycled while major portion remains un-recycled due to the fact the inorganic waste at the landfill site becomes too soiled for recycling by the informal sector.Whatever we see again that almost 75 percent waste from total waste generation are remain unproductive which used for low land fill .As Bangladesh situated in tropical region and waste moisture is nearly 50% its will causes the contamination of source ofwater as well as great hazarders for environment.

3.2 Our Proposed waste management system

Our proposed System has three part as like existing practice but difference is ,in our system we emphasize segregation of waste in source so that a systematic practice can be introduce as well as maximum waste can be reused ,recovered and recycled. As a result SWM cost will be reduce since municipal authority have to deal with low volume waste including transfer to the final disposal site. On the other hand both people and government can make revenue by selling compost, bio-gas or electricity. Even environment can be kept sound.

Now in below we will discuss how our proposed system work and for that we divided our system in three part

1. Source
2. Local dumping
3. Final dumping

1. Source: In source we can used 2 different bin for segregation of solid waste based on compostable and non-compostable and in future we can use 3 bin. Bin can be coloured for easy understanding of general people. For compostable colour will be green and for non-compostable colour will be blue .In future we can introduce another bin for hazarders waste . Stored waste will be transferred by Improve van or 2 different van or a van with blue bag/bin. In our country perspective as nearly 80% waste are compostable, we can installed single unit bio-gas plant /compost plant .If it is not possible by individual we can do it community based then waste generation automatically will be reduce and maximum problem (like cost of operation, buying improved van or installing improve local dumping site) of this system will be solved. If waste have to be transport to the local site and cant possible to used improved van we can used bag for non-compostable waste so that informal sector can easily take recyclable waste.


Picture : Improved Rickshaw Van

2. Local Dumping: In this part major portion of recyclable or recoverable waste will be collect by informal sector or tokies as waste is segregated. Segregated compostable waste directly have gone to the compost or bio-gas plant and no compostable to the electricity generation plant. In this process 90% waste from total generation of waste will be reduce. Present transportation system is well enough for this system

DATA COLLECTION AND ANALYSIS

4.1 Estimation of unit solid waste generation rates per week for a residential area (based on load count analysis) :

Location: Uttara (sonargong jonopod)

Sector	Population
9	11121
10	11688
11	18935
12	10181
13	17335
14	15803
Total	85063

Source : Dhaka Bureau of statistics 2011

Approximate population of the area = 85063
No. of vans per week = 32*8*7 = 1792
Average volume of the van = 4.5 ft * 3 ft * 2.25 ft = 30.375 ft^3
Average weight of waste per van = 400 kg
Specific weight = 13.17 kg/ft^3
Observation period = 1 week
Total weight = 1792 * 30.375 * 13.17 = 716869.44 kg/wk
So,
Unit rate = $\frac{716869.44\ kg/wk}{(85063)*(7d/wk)}$

= 1.20 kg/capita/d

RESULTS AND DISCUSSIONS

From Data analysis we got that waste generation rate in Uttara (Sector 9-11) is 1.20 kg/cap/day. We know that waste generation rate in Middle Income population ranged 0.8 to 1.5 kg/cap/day and we got 1.20 kg/cap/day .Uttara is for middle and upper middle class people and we see that data analysis satisfy the ranged.

From the graphical presentation of total population (including urban population) and waste generation with increasing yearly, it is observed that both population and waste generation increase with increasing of years. From graph, it is found that in 2025 the population will be more than 150 million and amount of waste generation will be more than 40000 ton/day.

From the Field Survey it is found that total waste generated in the urban areas of Bangladesh per day is 13,332.89 tons. Based on the total estimated urban population of the year 2005, per capita waste generation rate is computed as 0.41 kg/capita/day.

5.1 Conclusion

Promotion of recycling of both Compostable and Non-compostable waste can reduce the cost of collection, transportation and disposal of waste. It is found in the study that suitable landfill area for waste disposal will hardly be available in near future if the current waste disposal practice continues. . In Bangladesh informal sector is contributing from 3% to 15% recycling of inorganic wastes. If waste recycling gets proper government attention and assistance and if operated in environmentally sound manner, the rate can be increased to meet the UNEP target. The rate of recycling can be further increased through practicing source separation, which needs substantial
awareness raising. Since around 74% of the total generated waste is compostable the amount of waste to be disposed in landfill can be significantly reduced by composting of organic waste. In some parts of the world like Europe, disposal of organic waste in landfill is going to be banned by the year 2010. In the United Nations Environment Programme (UNEP), ‘waste reduction’ is placed in the urban environmental accords with one of its recommended implementation action being ‘zero waste to landfills and incinerators by 2040’. Action 6 of UNEP sets a target for reducing per capita waste disposal to landfill and incineration by 20% in 7 years through “user-friendly” recycling and composting programmes

In addition, revenue can be earned from the sale of compost. Furthermore, harnessing Clean Development Mechanism (CDM) financing through implementing composting project can generate US $ 13.14 million per year from the sale of CERs. To improve the situation, there is a need for effective solid waste management policy for Bangladesh. At present, under the Sustainable Envi ronment Management Program (SEMP), the Ministry of Environment and Forests (MoEF) is preparing a Solid Waste Management Handling Rules. The issues related to waste separation, waste reduction, recycling, public-private and community partnership, appropriate technology, innovative local solutions, harnessing CDM opportunities in waste sector are given special emphasis in rules. As a signatory of UNEP's Green City Accords, Bangladesh is committed to comply with the urban environmental accords. As such, waste reduction is one of the liabilities to implement. Composting and recycling of urban solid waste of Bangladesh is considered as the most suitable as well as financially prospective options for fulfilment of the UNEP accord.

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Application of Adaptive Neuro-Fuzzy Inference System for the Prediction of Heavy Metals in Soil of a Waste Disposal Site in Khulna

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ABSTRACT

The study of heavy metals in soil has increased in the last decades because of their adverse pollution of soil as well as environmental and human health effects. The collection of samples are labored, time consuming and determination of heavy metal concentrations from laboratory is expensive. To these attempts, in the laboratory, the heavy metal concentrations of Pb,Cu, Ni, Zn, Co, Cd, As, Sc, Hg and Mn in soil were measured. In this study, total eighty five (85) soil samples were collected from a selected waste disposal site at old Rajbandh, Khulna. The concentrations of heavy metal in soil of unknown 15 (out of 85) sampling points were predicted using adaptive neuro-fuzzy inference system (ANFIS). To depict the validity of the predicted concentrations from ANFIS, the performance parameters like R-value, RMSE, MAPE, percentage Recovery and GRI were considered. Results reveals ANFIS models were a reliable method to predict heavy metal concentrations in soil with an acceptable degree of robustness and accuracy.

INTRODUCTION

Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Heavy metal poisoning could result, for instance, from drinking water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. In waste disposal site, municipal solid waste (MSW) decomposes and produces three components of solid (degraded waste); liquid (leachate that is infiltrating into the underlying layer) and landfill gas (Sanjida and Rafizul, 2018). Open dumping facilities release huge quantity of harmful as well as poisonous chemicals like heavy metals to the nearby groundwater and underlying soil layer etc. Most of the environmental and human health problems come from the emission of heavy metal elements from the propagated leachate and soil in waste disposal site, landfill gas (LFG), from its non-methanic volatile organic compounds as well as hazardous air pollutants (Talib et al., 2008). In Khulna city, most of the MSWs are collected from door to door without any sorting and dumped in open disposal site at Rajbandh. The emission of toxic metal element from MSW, leachate and soil will be vulnerable to the environmental components and inhabitants. Therefore, study of heavy metals have gained importance for the monitoring and assessment of soil.

A study stated that over the last few years or so, the use of ANFIS has increased in many areas of engineering field. In particular, ANFIS has been applied to many geotechnical engineering problems and have demonstrated some degree of success. A review of the literature reveals that ANFIS has been used successfully for the modelling of soil behaviour, site characterization, settlement of structures, soil permeability and hydraulic conductivity, soil compaction and designing of geotechnical structures in soils (Cabalar et al., 2012). The ANFIS model had been studied to predict the concentrations of Cd in the Filyos River, Turkey (Sonmez et al. 2018). In this study, the application of ANFIS were used to data analysis and prediction. The main objectives of this study are 1) to determine the optimum model in

ANFIS, 2) to predict the concentration of heavy metals in soil of waste disposal site and 3) to show a comparison between the predicted and measured data based on the selected model.

BACKGROUND OF ANFIS

Jang (1993) first introduced the Adaptive neuro-fuzzy inference system (ANFIS). The neuro-fuzzy approach combines ANN and fuzzy logic. It effectively integrates the learning capability of neural networks into a fuzzy inference system (FIS). It can be used to approximate any real continuous function on a compact set to any degree of accuracy (Jang et al., 1997). Depending on the types of inference operations upon if–then rules, most FIS can be classified into three types: Tsukamoto's system, Mamdani's system and Sugeno's system (Kisi 2007). In this study, the first-order Sugeno fuzzy model is used because it has been used widely in engineering problems. The ANFIS model is able to use two different optimization methods (hybrid and back-propagation) to tune member function (MF) and generate fuzzy rules. The hybrid method is a combination of least squares estimation combined with back-propagation method (MATLAB User Manual 2017a). ANFIS model structure represents the overall view of ANFIS operation. It consists of five layers, and the basic functions of each layer are the input, fuzzification, rule inference, normalization and defuzzification (Emamgholizadeh et al., 2014). The equivalent ANFIS architecture of the first order is shown in Figure 1.

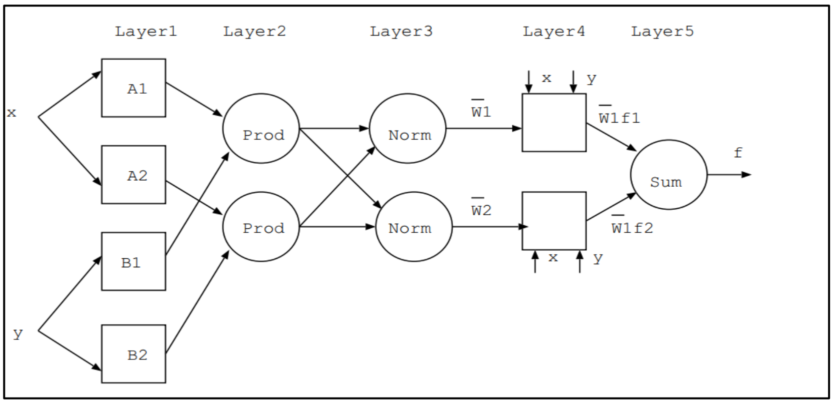

Figure 1 Equivalent ANFIS architecture

The Rules show how the shape of certain membership functions influences the overall result. Figure 2 shows the rules for first-order Takagi–Sugeno fuzzy model with a two input and one output system.

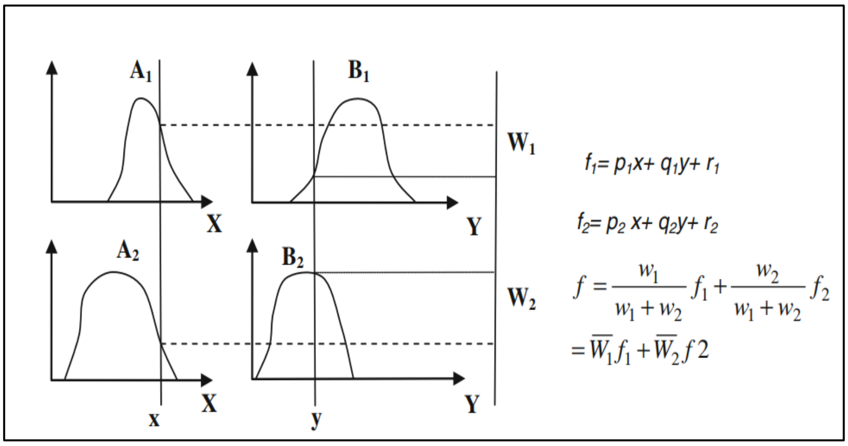

Figure 2 Sugeno's fuzzy if–then rule and fuzzy reasoning mechanism

Where x and y are input variables. A_i and B_i are the linguistic labels (low, medium, high, etc.) characterized by convenient membership functions, f_i are the outputs within the fuzzy region specified by the fuzzy rule; p_i, q_i and r_i are the parameters of the output function (i = 1 or 2). In first-order Sugeno's system, if FIS has two inputs *x* and *y* and one output *f*, a typical rule set with two fuzzy IF/THEN rules. It can be expressed as

Rule 1: If *x* is *A1* and y is *B1*; then $f_1 = p_1x + q_1y + r_1$

Rule 2: If *x* is *A2* and y is *B2*; then $f_2 = p_2x + q_2y + r_2$

RESEARCH METHODOLOGY

The overall methodology of the collection of soil samples, laboratory investigations and the analysis of ANFIS are discussed in the following articles.

Location Area

Khulna is the third established metropolitan city of Bangladesh. It is located in the Khulna Division. It has an area of 4394.45 km² and is bordered on the north by the Jashore district and the Narail district, on the south by the Bay of Bengal, on the east by the Bagerhat District, and on the west by the Satkhira district. The geological location of Khulna is 22.35^0N and 89.30^0E, surrounded by Rupsa, Arpangachhia, Shibsa, Pasur, and the Koyra. Urban development is dribbling into neighbouring zones to the North and West results a huge amount of waste generation (Ali et al., 2004). The increasing population in Khulna city tends to dispose increasing amount of municipal solid waste (MSW). These MSW contain a large amount of metal elements, which get direct contact to the environment. This may result a great threat to the environment and human health. The selected waste disposal site, Rajbandh is the only certified waste dumping site of Khulna shown in Figure 3. Based on aforementioned authenticities, it has become inevitable of comprehensive study of distribution of heavy metal elements in soils ascends in the vicinity of the Rajbandh waste disposal site.

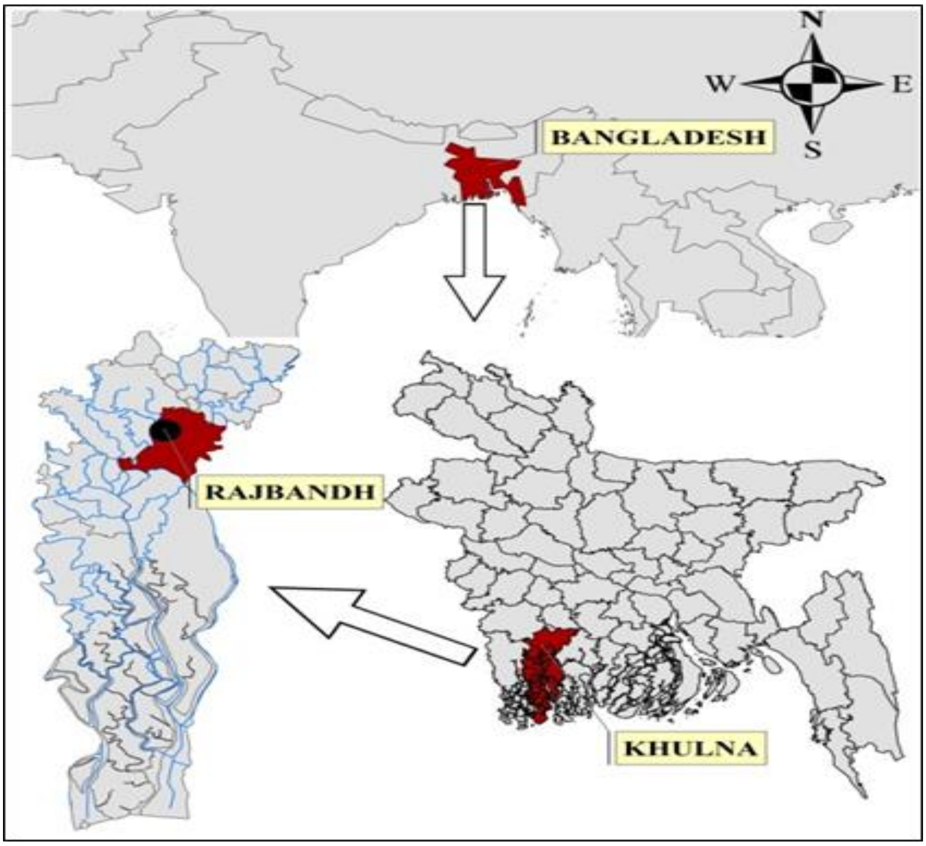

Figure 3 Location map of Rajbandh at Khulna city of Bangladesh

Soil Sampling

In this study, total eighty-five soil samples were collected from the distinct locations of a selected waste disposal site at old Rajbandh, Khulna, Bangladesh. All the samples were collected at a depth of 30 cm from the existing ground surface. The latitude and departure of all the soil-sampling locations was recorded using GPS device, which were later imported into a geographic information system (ArcGIS 10.1). The sampling points were selected maintaining gradual addition of about 10 m distance from the 1st borehole (SS-1) by the subsequent boreholes. The first sampling point, SS-1 is approximately located at the centre of the waste disposal site. Proper care was taken to remove any loose material, debris, coarse aggregates from the bottom of the excavated pit. The soil samples were collected from the bottom of the borehole by excavating the ground manually by using hand shovels. Samples were taken in large polythene bags and eventually transported to the laboratory. Figure 4 depicted the soil sampling locations in waste disposal site at old Rajbandh, Khulna, Bangladesh.

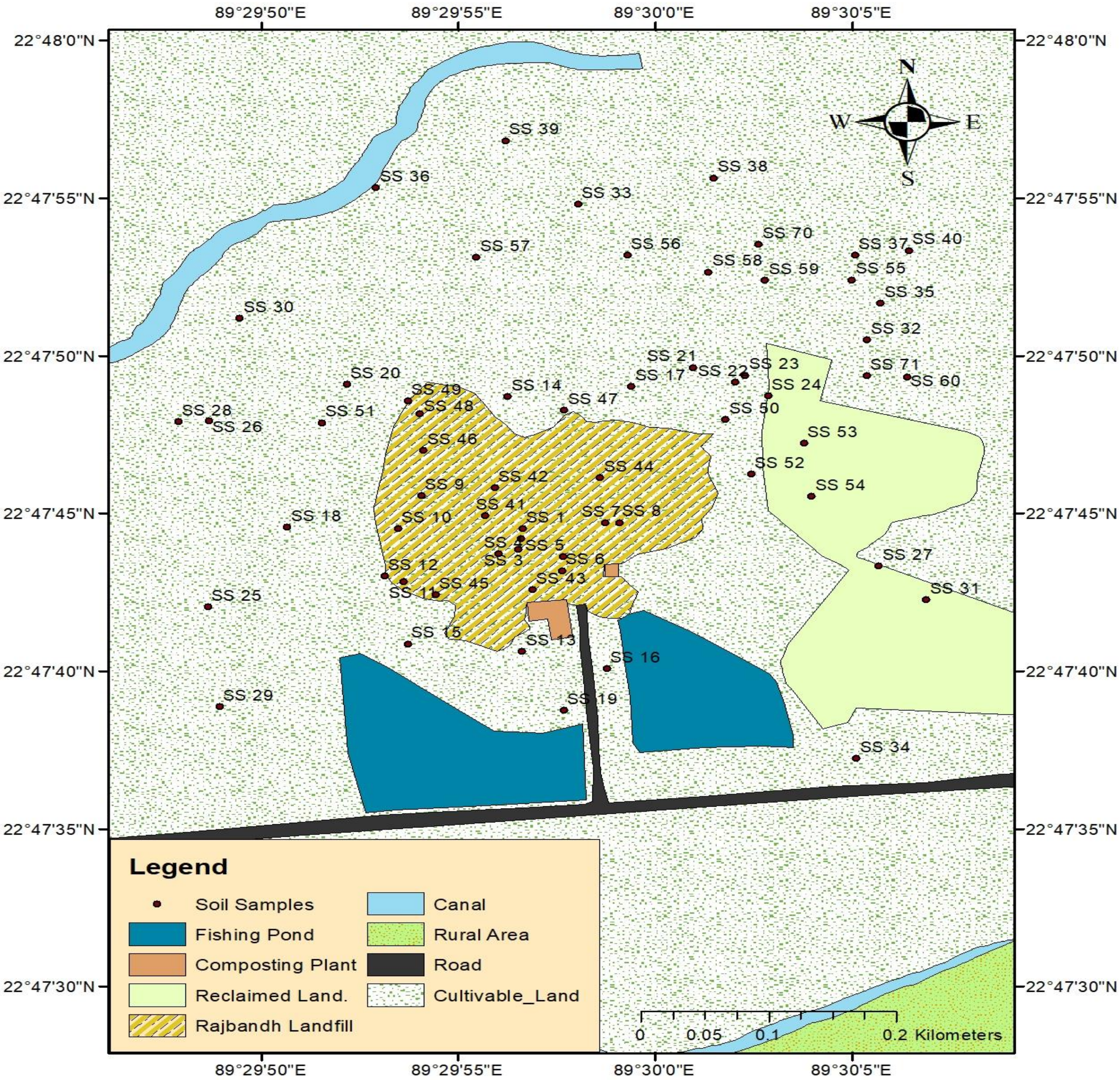

Figure 4 Map showing of soil sampling locations in waste disposal site

Laboratory Investigations

To measure the concentration of heavy metals in soil, laboratory work was done following the standard test method. In laboratory investigation, at first 10 g of each soil sample was taken into a 100 mL conical flask. Already, the flask had been washed with deionized water prepared by adding 6 mL HNO3/HClO4 acid in ratio 2:1 and left overnight. Each sample was kept into the temperature of 150°C for about 90 minutes. Later, temperature was raised to 230°C for 30 minutes. Subsequently, HCl solution was added in ratio 1:1 to the digested sample and re-digested again for another 30 minutes. The digested sample was washed into 100 mL volumetric flask and mixture obtained was cooled down to room temperature In the laboratory, after preparing soil samples with digestion, the concentrations of Pb, Cu, Ni, Zn, Co, Cd, As, Sc, Hg and Mn mg/kg were measured through atomic absorption spectrophotometer (AAS).

Analysis of ANFIS

In ANFIS analysis, 83% (70) of total data for training, while, 17% (15) for testing were assigned. Here, latitude, longitude were considered as input and heavy metal concentrations of Pb,Cu, Ni, Zn, Co, Cd, As, Sc, Hg and Mn in soil as target data. In ANFIS, sub-clustering partitioning (SCP) was performed to fuzzify input data. The input membership function gaussian (Gaussmf) and output membership function linear were considered. ANFIS model was trained through optimization method like back propagation and hybrid, and eventually, hybrid was selected. The selected SCP with gaussmf in ANFIS was executed for the prediction of heavy metal concentrations in soil. The procedure of ANFIS operation through MATLAB was implemented by the flowchart in Figure 5.

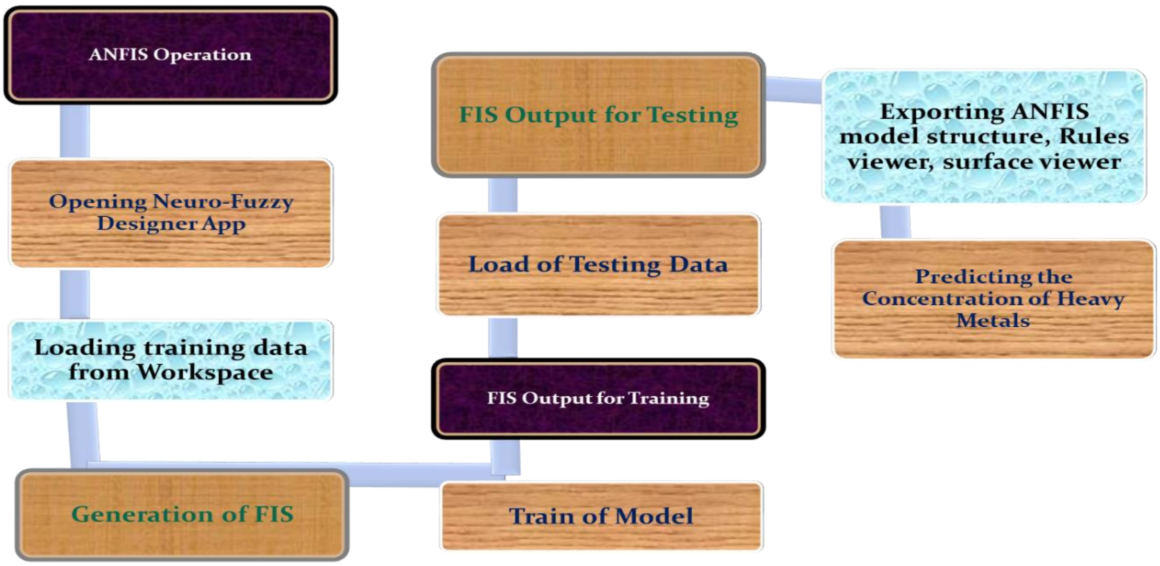

Figure 5 Flowchart of ANFIS model operation

FIS generation and train operation of ANFIS model was shown in Figure 6 that executed all the terms of Neuro-fuzzy Designer app used for the prediction of heavy metal concentrations in soil.

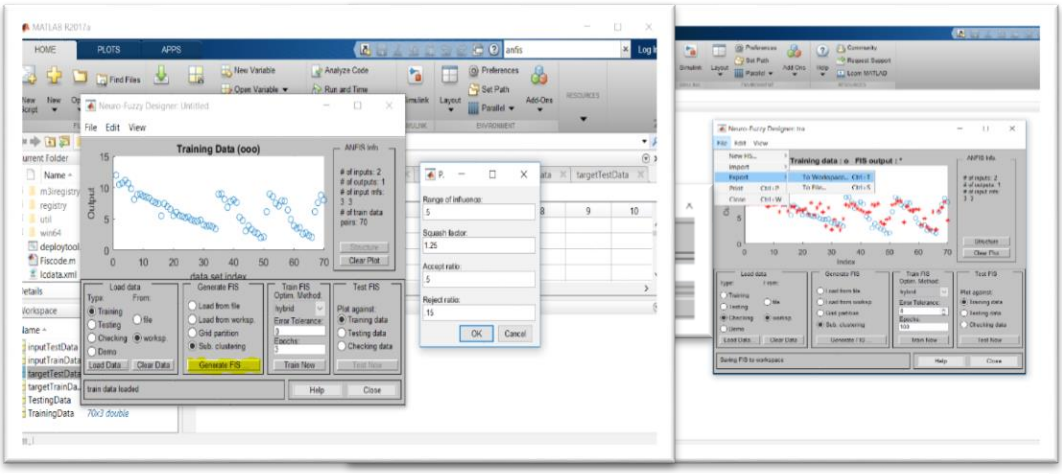

Figure 6 FIS generation and train operation of ANFIS model

To depict the validity of the predicted concentrations from ANFIS, the following performance parameters like R-value, RMSE, MAPE, percentage Recovery and GRI were considered.

Correlation Coefficient, R

A correlation coefficient is the statistical measure of the linear relationship (correlation) between a dependent variable and an independent variable. The “R” represents it that displays in the following Equation (1).

$$R = \frac{n(\sum y.y_p)\ (\sum y)(\sum y_p)}{\sqrt{[n\sum y^2\ (\sum y)^2][n\sum y_p^2\ (\sum y_p)^2]}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where y = observed value, y_p = predicted value, n = number of observations.

A research conducted by Smith (1986) suggested that the value of R lies between 0 to 1. It is also suggested some guidelines for deciding the performance of the model. If |R| ≥ 0.8: a strong correlation exists, 0.2 < |R| < 0.8: correlation exists and |R| ≤ 0.2: a weak correlation exists. When the value of |R| is greater than 0.9, then a very strong correlation exists between the variables.

Root Mean Square Error, RMSE

The root mean square error (RMSE) measures the quality of the fit between the actual and the predicted data of a model. It is represented by the following Equation (2).

$$R\text{MSE} = \sqrt{\frac{\sum_1^n (y - y_p)^2}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where y = observed value, y_p = predicted value, n = number of observations.

RMSE is one of the most frequently used measures of the goodness of fit of generalized regression models. Lower values of RMSE indicate better fit.

Mean Absolute Percentage Error (MAPE)

The MAPE (Mean Absolute Percentage Error) measures the size of the error in percentage terms. It is calculated as the average of the unsigned percentage error, as shown in the following Equation (3):

$$\boldsymbol{MAPE = \frac{1}{n}\sum \frac{|y - y_p|}{|y|} \times 100\,\%} \quad \ldots\ldots\ldots\ldots\ldots (\mathbf{3})$$

Where y = observed value, y_p = predicted value, n = number of observations.

For the MAPE, extreme values occur only at the high end because it is typically based on a right-skewed distribution of absolute percent errors (APE) bounded on the left by zero and unbounded on the right. In a comprehensive analysis of county-level projections, the MAPE was on average higher by about 30–40% than robust measures of central tendency for most methods and projection horizons (Rayer 2007).

Percent Recovery

The percentage recovery means what percentage of measured value is recovered by the predicted value. It is represented by the following Equation (4).

$$\boldsymbol{Persent\ Recovery = \frac{y_p}{y} \times 100} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{4})$$

Where y = observed value, y_p = predicted value.

The importance of recovery can be found in the ICH (International Council for Harmonisation) guidelines as well as in the GLP (Good laboratory practice) guidelines for analytical method validation. Paul D Jones (University of Saskatchewan) suggests that recoveries in the range of 20-200% for internal standard are considered 'acceptable' (depending on the jurisdiction). Food and Drug Administration (FDA), Investopedia declares that recovery should not need to be 100% but should be reproducible.

FDA approved variability limit for Lower Limit of Qualification (LLOQ) is +/- 20%. Therefore, the ideal frame of recovery is 80-120% that represents the robustness of the model.

Geometric Reliability Index (GRI)

A version of the reliability index was defined as the inverse of the coefficient of variation. The reliability index is the shortest distance from the origin of reduced variables (Hasofer and Lind 1974). Using geometry, the reliability index can be measured by the following Equation (5).

$$\boldsymbol{GRI} = \frac{1 + \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\frac{\hat{y}_t - y_t}{\hat{y}_t + y_t}\right)^2}}{1 - \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\frac{\hat{y}_t - y_t}{\hat{y}_t + y_t}\right)^2}} \dots\dots\dots\dots\dots..\dots\dots..(5)$$

Where y_t = observed value, $\hat{y}_t$ = predicted value, n = number of observations.

According to Leggett and Williams (1981). GRI is a statistical method to determine the reliability of a model. The index is a number GRI ≥ 1.

RESULTS AND DISCUSSIONS

The outputs of ANFIS model in terms of model structure, rules viewer, surface viewer and assessment for training data and testing data were analysed and hence discussed in the following articles.

ANFIS Model Structure

The model with SCP of gaussmf (input MF), linear (output MF) and hybrid algorithm (optimisation method) were selected for the prediction of concentration of studied heavy metals in soil. The structures of ANFIS model for Sc and Hg is shown in Figure 7a and in Figure 7b, respectively, for training (70 out of 85 sampling points) and testing (15 out of 85 sampling points). Figure 7 represents the ANFIS model structure consisting of five layers and the basic functions of each layer are the input, fuzzification, rule inference, normalization and defuzzification.

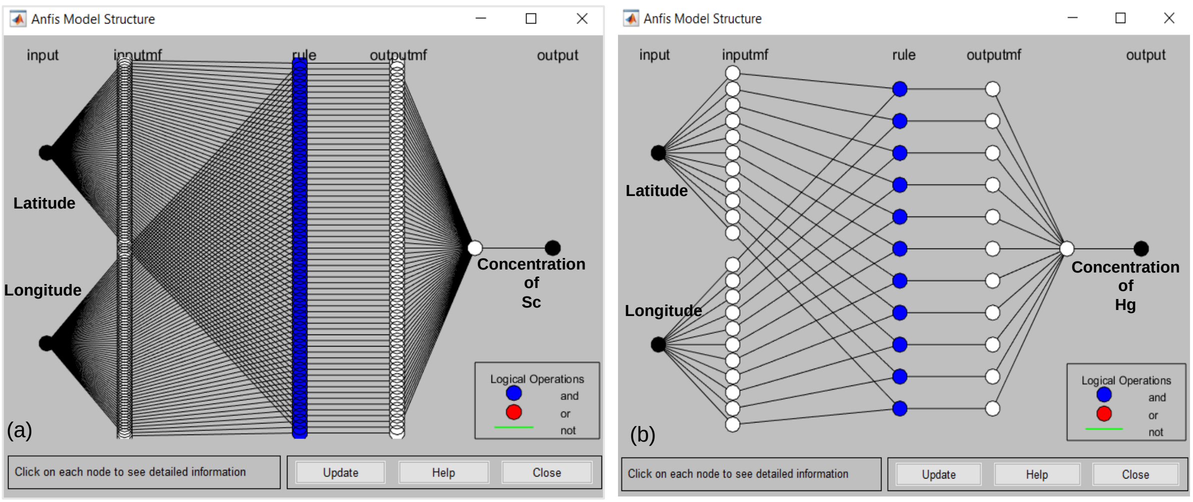

Figure 7 ANFIS model structure for (a) Sc and (b) Hg

Rule Viewer of ANFIS

In this study, ANFIS structure of Sc contained 65 rules (Figure 8a) and Hg contained 11 rules (Figure 8b) with two inputs (latitude and longitude) and one single output (concentration of heavy metals). Rules viewer shows the developed model for Sc (Figure 8a) and Hg (Figure 8b) using particular number of membership functions of type 'gaussmf ' with particular If-then rules. ANFIS model structure for Sc showed comparatively more rules due to the higher intensity of the concentration of Sc than that of Hg. Result reveals the shape of membership function changes for the different number of rules of these two heavy metals.

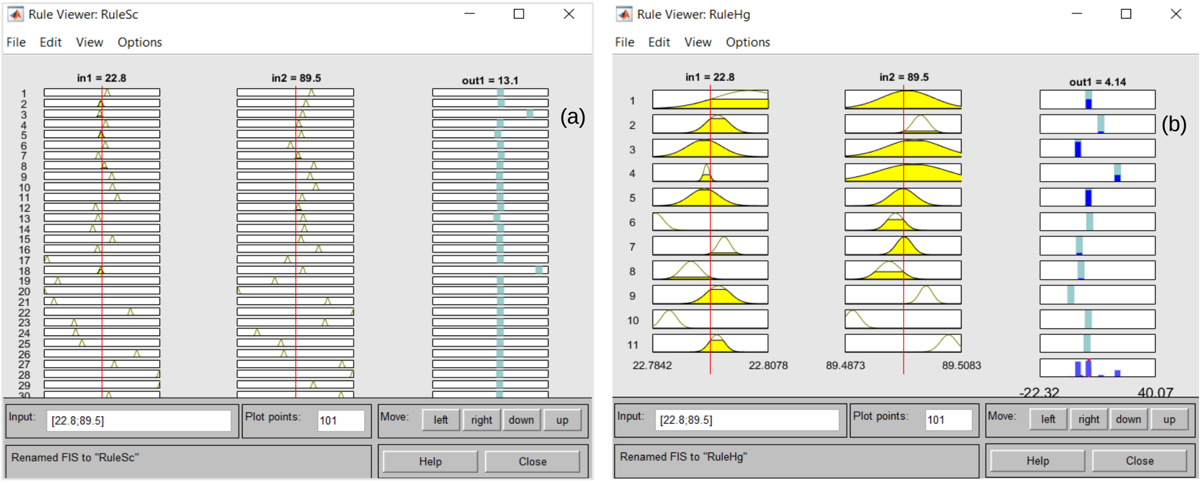

Figure 8 ANFIS rules viewer for (a) Sc and (b) Hg in soil

Surface Viewer of ANFIS

In ANFIS model, surface viewer represents the predicted values of heavy metals in soil. The intensity of the predicted concentrations of Sc (Figure 9a) and Hg (Figure 9b), respectively represent by different colours. In addition, the yellow color in the colorbar represents comparatively the higher intensity of concentration than that of other colours. In Figure 9a, the concentration of Sc varies from 3.75 to 20.22 mg/kg and the centre of the plot represents comparatively the higher values of Sc than that of the other soil sampling points. Figure 9b illustrates the concentration of Hg ranges from 0.57 to 6.77 mg/kg.

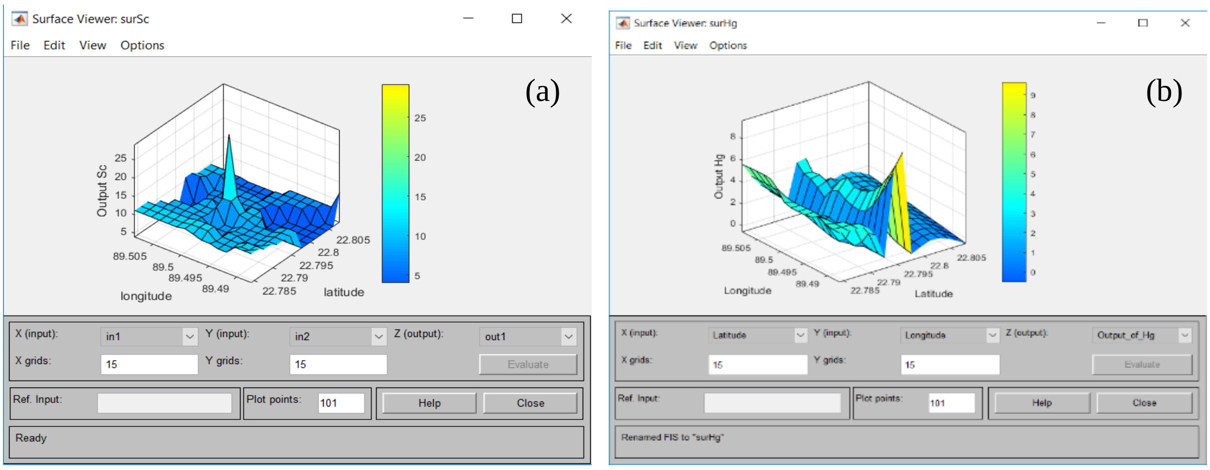

Figure 9 Surface Viewer in ANFIS model for (a) Sc and (b) Hg

Assesment of ANFIS Model Performance

The values of R and RMSE for training and testing data for some studied heavy metals in soil are provided in Table 1. In training, the value of |R| for Pb, Cu, Zn, Co, Cd, As, Sc were found greater than 0.9 indicating very strong correlation between the inputs and outputs. Among all the heavy metals, the maximum R-value of Sc was found 0.999 with the minimum RMSE 0.12 indicating the best correlation in prediction for Sc (shown in Figure 10a). In this figure, most of the data were very close to the fit line with high accuracy. Testing R-value for Sc was found 0.703 with RMSE 2.97 shown in Figure 10b.

Table 1 Variation of R and RMSE for all Heavy Metals

Values for various functions		Pb	Cu	Ni	Zn	Co	Cd	As	Sc	Hg	Mn
R-value	Train	0.99	0.98	0.81	0.99	0.97	0.91	0.98	0.99	0.76	0.86
	Test	0.55	0.86	0.71	0.63	0.58	0.79	0.88	0.70	0.53	0.45
RMSE	Train	1.38	0.63	1.00	0.67	0.60	0.65	0.36	0.12	1.42	3.33
	Test	15.25	2.45	1.17	9.18	2.35	1.17	1.44	2.97	1.95	6.24

In addition, R-value for Pb, Ni, Zn, Co, Cd, As, Sc, Hg and Mn in soil for testing was found between the range of 0.2 < |R| < 0.8 which specified the existing of correlation between the inputs and outputs. Among all the heavy metals in testing, R-value of As was 0.88, which was maximum with RMSE 1.44 as well as R=0.45 for Mn was minimum with RMSE 6.24.

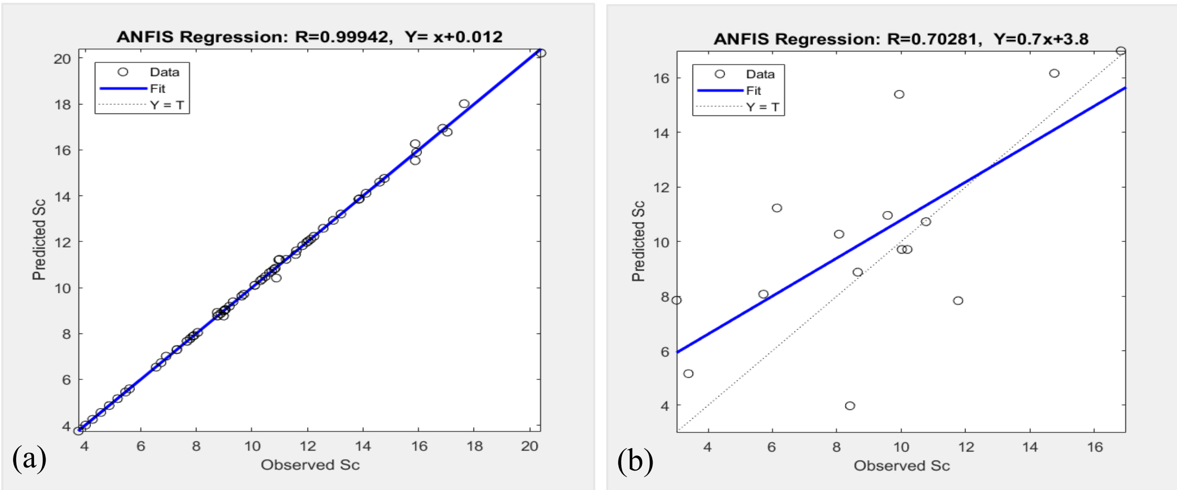

Figure 10 Correlation between observed and predicted values of Sc for (a) training and (b) testing

Table 2 Assessment of testing Heavy Metals using performance parameters

Parameters	Pb	Cu	Ni	Zn	Co	Cd	As	Sc	Hg	Mn
RMSE	14.31	2.45	1.17	9.18	2.35	1.17	1.44	2.97	1.95	2.02
MAPE	41.00	64.12	38.42	38.22	50.51	45.21	59.90	36.00	84.33	70.13
GRI	1.55	1.91	1.46	1.48	1.80	1.55	1.69	1.50	1.97	1.90
%Mean Recovery	130.01	143.23	125.15	124.59	114.86	136.98	151.14	123.43	165.46	151.14

Table 2 represents the assessment of testing sampling points of heavy metals prediction. RMSE is one of the most frequently used measures of the goodness of fit of a generalized regression models. Lower values of RMSE indicate better fit. RMSE of Ni, Cd, As and Hg shows the lower value than that of others heavy metals. Rayer (2007) stated the robustness of MAPE between 30-40%. Among all the heavy metals, MAPE of Ni, Zn and Sc represents the robust prediction. In this study, the values of GRI was found greater than 1 for all studied heavy metals represents the reliability of the prediction model. Moreover, the percentage recovery of studied heavy metals were in the acceptable range and Co was in the robust prediction model.

Comparison of measured and predicted values

The measured and predicted concentration of Sc and Hg for 15 unknown sampling points shown in Figure 11a and 11b, respectively. In both figure, the measured and predicted concentrations for the most of the sampling points were very close to each other.

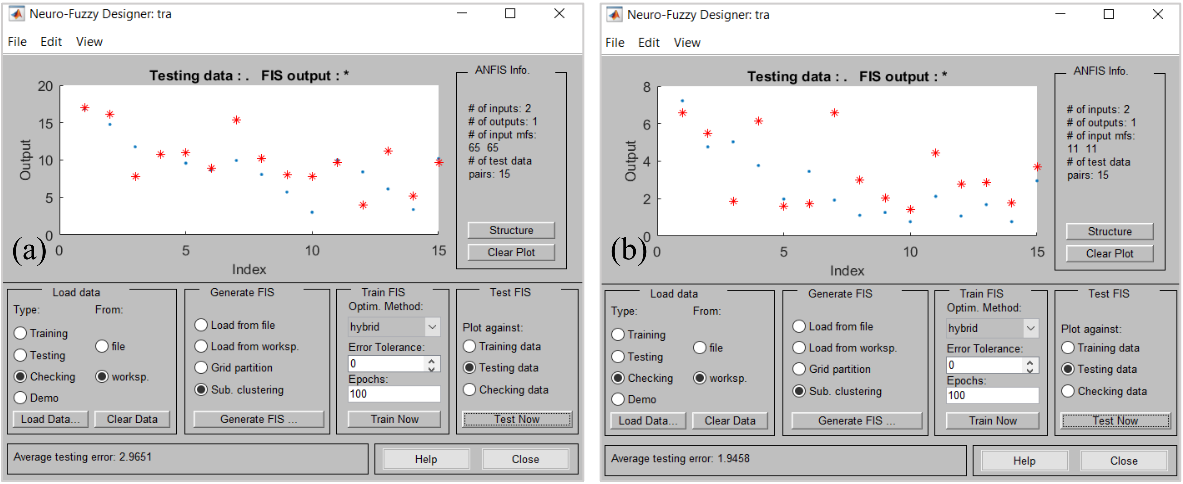

Figure 11 Comparison testing measured and predicted values of for (a) Sc and (b) Hg

CONCLUSION

In this study, ANFIS models were developed to predict the heavy metal concentrations in soil of waste disposal site at Rajbandh, Khulna. ANFIS model can make available the calculation without mathematical modelling and provide a good solution for the problem of the non-linear prediction. It has an adaptive background and use training data to generate a fuzzy inference system. The results demonstrated that suggested ANFIS models were a reliable method to predict heavy metal concentrations in soil with an acceptable degree of robustness and accuracy. Therefore, ANFIS can be used in further researches on soil quality monitoring and assessment.

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A Study on Bangladeshi Fly Ash as a Partial Replacement of Ordinary Portland Cement In Concrete Production Using Different Water Cement Ratio

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ABSTRACT

Fly ash is one of the most common residues produced from coal combustion. Unconditionally released fly ash into the atmosphere allowing environmental pollution. Subsequently, the new concern is to storage and recycling the alarming quantity of fly ash. Now a days, fly ash is become used as a supplementary cementitious material in concrete production and contributes on the hardened properties of concrete through pozzolanic or hydraulic activity, or both. But there is a huge research gap on Bangladeshi fly ash to use as a supplementary cementitious material in concrete production. From this perspective, our studies on Bangladeshi fly ash as a partial replacement of ordinary Portland cement in concrete production. The water cement ratio has a great impact on the strength of concrete. Here we used 0.4, 0.5 and 0.6 water cement ratio in concrete and try to find out the different character of concrete with different water cement ratio. A total of 27 cylinders of diameter 100 mm and 200 mm height with different percentages by weight of ordinary portland cement to fly ash as cementitious material in the order 100:0, 95:5 and 90:10 were cast, tested and their compressive strength were determined subjected to water curing for 28 days. From the experimental study, it can be concluded that Bangladeshi fly ash can used as supplementary cementitious material in concrete production successfully.

Key words: *Bangladeshi Fly Ash, Water-cement ratio, supplementary cementitious material, concrete, compressive strength.*

INTRODUCTION

Fly ash is a very popular material in the production of portland cement as a supplementary cementitious material (SCM). Fly ash has both pozzolans and hydraulic materials, it has been used in conjunction with portland cement to harden concrete through hydraulic or pozzolanic activity, or both. A pozzolan is a siliceous or siliceous-aluminous material which can possesses little or no cementitious value, but when it is in finely divided form, at ordinary temperatures, it chemically reacts with calcium hydroxide in the presence of moisture and form the compounds of cementitious properties. Fly ash, silica fume and a variety of natural pozzolans such as calcined clay and shale, and volcanic ash are commonly used pozzolans in concrete. Since the beginning of the last century, fly ash has been used as a supplementary cementitious material in concrete (Anon 1914). The use of fly ash in concrete production has been growing dramatically with close to 15 million tons in the last 50 years concrete products and grouts in the U.S. in 2005 (ACAA 2006).

In the previous research, fly ash has been used as a partial replacement of the cementitious material component ranging from 15% to 25% by mass. But the actual amount of replacement is may be varies widely depending on the properties of the fly ash, on the application, the geographic climate and location and specification limits. To control the temperature rise in massive structures (such as, dams and foundations) have been used higher levels (30% to 50%). Recently, researcher proved that in the structural applications high dosage levels (40% to 60%) can be used, resulted concrete with good durability and mechanical properties (Marceau 2002). But high dosage levels may be leading with increased set times and slowing the strength development and delays in the rate of construction.

In Bangladesh, only one coal field named Barapukuria coal field is in production but there are 5 other potential coal fields have been identified till date. In 2004, Barapukuria Coal field begin with 390 Million tonnes coal reservation. The production rate of Barapukuria Coal field is 1 million tonnes/year and 65% of produced coal is supplied to the Barapukuria Coal fired Thermal Power. Approximately 10% by mass of the burnt coal produced ash (BCMCL, 2013) in which 80% is estimated as fly ash and the rest is bottom ash. At present every year approximately 52000 million tonnes of fly ash is produced in Bangladesh (Tanim,2013). In Bangladesh, produced fly ash (52000 million tonnes per annum) is dumped off in a dry embankment (dyke). For a densely populated country like Bangladesh, this volume of fly ash (approximately 9.5 million cft) is an astronomical amount to dispose off. In addition, the environmental degradation due to dumping of fly ash aggravates the situation. Previous researcher proved that long-term strength development is improved when fly ash is used and at some age the strength of the fly ash concrete will equal that of the portland cement concrete so long as sufficient curing is provided (Thomas, 2007).

So partial replacement of cementous material in concrete production is a very good alternative to use those fly ashes in Bangladesh. But there is very less study on the Bangladeshi fly ash as a partial replacement of ordinary portland cement in concrete production. Therefore, investigations on the Bangladeshi fly ash as a partial replacement of ordinary portland cement in concrete production are urgent need. In the present study is aimed to determine the compressive strength of fly ash concrete depending on the various content of fly ash by mass of cement and compare them to the compressive strength of conventional concrete. The water cement ratio has a great impact on the strength of concrete. Here we also used 0.4, 0.5 and 0.6 water cement ratio in concrete and try to find out the different character of concrete with different water cement ratio.

Fly ash of that study has been collected from the Barapukuria Coal fired Thermal Power. A total of 27 cylinders of diameter 100 mm and 200 mm height with different percentages by weight of ordinary portland cement to fly ash as cementitious material in the order 100:0, 95:5 and 90:10 were cast, tested and their compressive strength were determined subjected to water curing for 28 days.

MATERIALS

The Ordinary Portland Cement conforming was used for the preparation of test specimens. Fly ash of that study has been collected from the Barapukuria Coal fired Thermal Power. The water cement ratio has a great impact on the strength of concrete. The natural fine aggregate (NFA) used throughout the study was natural river sand. The FM, specific gravity, water absorption and moisture content of sand used in this investigation were 1.23, 2.53, 3.94% and 2.31% respectively.

Table 1: Determination of fineness modulus of local sand

Sieve Size	Opening (mm)	Weight of Materials Retained(mm)	% Retained	Cumulative % Retained	% Finer
No.4	4.76	0	0	0	100
No.8	2.36	1.3	0.26	0.26	99.74
No.16	1.18	2.4	0.48	0.74	99.26
No.30	0.6	4.3	0.86	1.6	98.4
No.50	0.3	164.6	32.88	34.48	65.52
No.100	0.15	259.6	51.86	86.34	13.66
Pan		68.4	13.66	100	0

Weight of sample= 500 gm. and fineness modulus is 1.23.

On the other hand, two type of coarse aggregate were used for this investigation viz, natural aggregate (stone chips) and recycled coarse aggregate (RCA).

The natural coarse aggregate (NCA) was crushed granite angular aggregate and in three particular sizes as 25 mm to 20 mm, 20 mm to 10 mm, and 10 mm to 5 mm, the aggregates were mixed as 5% from 25 mm to 20 mm, 57.5% from 20 mm to 10 mm, and 37.5% from 10 mm to 5 mm as per ASTM C33-93. The aggregates were tested for absorption capacity, specific gravity, unit weight, abrasion and impact value. The specific gravity and absorption capacity are determined as per ASTM C128, unit weight as per ASTM C29, and abrasion value as per ASTM C131. The absorption capacity, specific gravity, unit weight, abrasion and impact value of coarse aggregate are 4.39%, 2.365, 1350 kg/m^3, 30.31% and 17.4% respectively.

EXPERIMENTAL METHODS

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or in shear is of primary importance; the compressive strength is frequently as a measure of these properties. Therefore, the concrete making properties of various ingredients of mix are usually measured in terms of the compressive strength. Compressive strength is also used as a qualitative measure for other properties of hardened concrete. Cylinders of diameter 100 mm and 200 mm height were prepared using the standard molds. The concrete mix is designed as per ACI mix design for the normal concrete. The samples are casted using the three-different water cement ratio. For proper mixing, vibrator is used here in preparation of cylindrical specimen. Total mixing time of concrete was controlled at 5.5 minutes. After mixing concrete, the workability of concrete was measured by slump cone test. Cylinders are demolded after 24 hours from casting and kept in a water tank continuously. A series of test (BS 1881: Part 110:1983 and by ASTM C 192-90a) were carried out by using Universal Testing Machine (UTM) in the laboratory, to determine the compressive strength of concrete cylinder after curing of 28 days in fresh water. The strain of concrete specimens was measured by a strain measurement setup with two dial gauges. The gauge length was 100 mm.

Table 2: List of Test Specimens

No.	Type of Concrete	Specimens Nos.
1	Conventional Concrete(CC)	9
2	Fly ash Concrete with 5% replacement of OPC	9
3	Fly ash Concrete with 10% replacement of OPC	9

(a) (b)

Figure 1: (a) Casted Cylindrical concrete specimen (b) Compressive Strength Test of Concrete

Mix design

There are several different methods of mix design available. Although they are not directly comparable, they do give approximately the relative proportion of materials, and all can yield suitable concrete mixes. The most common method used in North America is that established by ACI Recommended Practice 211.1. It must be remembered, however, that any mix design method will provide approximation of proportions. These must be checked by trial batches in the laboratory or on the field and can then be adjusted as necessary to produce the desired concrete characteristics. With any given set of materials, it may be found that considerable deviation from the ACI recommended practice might be necessary. Once sufficient experience with local materials is acquired, the ACI method should be modified to take their properties into account. In this study, for casting of concrete cylinder use fine aggregate of fineness modulus value 1.23 and the mix ratio for all types of concrete is 1: 1.5: 3. For mix design of concrete, estimation of coarse aggregate content uses the Figure 2 instead of Table 3. Water and cement both are taken by volume. Strength and workability of the concrete greatly depend upon the amount of water. For a proportion of materials, there is a specific amount of water which gives the optimum strength to the concrete. Cement requires about 1/8th to 1/4th of its own weight of water to become completely hydrated. Here we used 0.4, 0.5 and 0.6 water cement ratio in concrete and try to find out the different character of concrete with different water cement ratio.

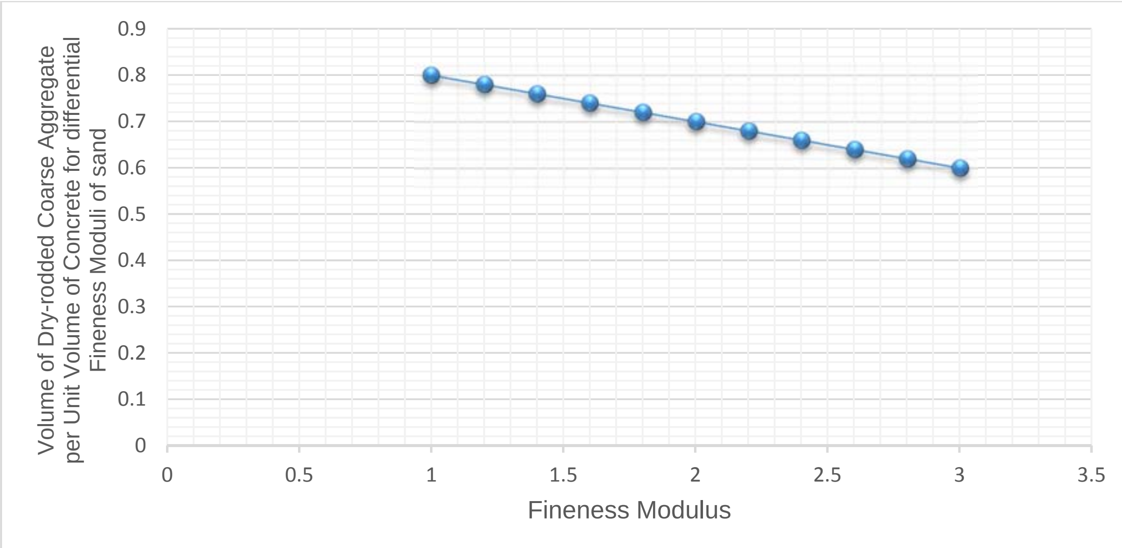

Figure 2: Volume of Dry-rodded Coarse Aggregate per Unit Volume of Concrete for differential Fineness Moduli of sand at maximum aggregate size 20mm (Based on ACI 211.1).

Table 3: Volume Coarse Aggregate per Unit Volume of Concrete (Based on ACI 211.1).

Maximum size of Aggregate	Volume of Dry-rodded Coarse Aggregate per Unit Volume of Concrete for differential Fineness Moduli of sand				
in.	mm	2.4	2.6	2.8	3
3/8	10	0.5	0.48	0.46	0.44
1/2	12.5	0.59	0.57	0.55	0.53
3/4	20	0.66	0.64	0.62	0.6
1	25	0.71	0.69	0.67	0.65
1 1/2	40	0.76	0.74	0.72	0.7
2	50	0.78	0.76	0.74	0.72
3	75	0.82	0.8	0.78	0.76
6	150	0.87	0.85	0.83	0.81

COST ANALYSIS:

Price according to the Bangladesh Market (2018):

Cement = 500.00 TK Per bag (50 kg)
Sand = 1050.00 TK per m^3
Fresh stone chip = 4200.00 TK per m^3

Table 4: Cost per Cubic meter (In taka) of concrete.

Materials	Price (TK) (Conventional Concrete)	Price (TK) (Fly ash Concrete)
Coarse aggregate	3600.00	3600.00
Sand	500.00	500.00
Cement (OPC) and Fly ash	2900.00	2550.00
Total	7000.00	6650.00

So by using fly ash we can save 5% cost and can safe our environment and land as well.

RESULTS :

It can be said from previous research concrete made from recycled aggregate lower its compressive strength.But replacement small portion of coarse aggregate may not effect the compressive strength of concrete Cylinders with different percentages by weight of ordinary portland cement to Bangladeshi fly ash as Cementous material in the order 100:0, 95:5 and 90:10 are 0%, 5% and 10% respectively. Nine different sets containing total number of twenty-seven cylinders respectively were cast. They were differentiated in terms of the type of the type of Water Ratio and Fly Ash used. Which are shown in the tables onward. The comparison on compressive strength of different types of concrete is given below in the graphs:

Table 5: Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.4

Sl No	Specimen notation	Fly Ash	Water Cement Ratio	Compressive Strength (Psi)	Average Compressive Strength (Psi)
1	F0-0.4-1	0%	0.4	3310	3257
2	F0-0.4-2			3220	
3	F0-0.4-3			3240	
4	F05-0.4-1	5%		3010	3033
5	F05-0.4-2			3050	
6	F05-0.4-3			3040	
7	F10-0.4-1	10%		2950	2933
8	F10-0.4-2			2890	
9	F10-0.4-3			2960	

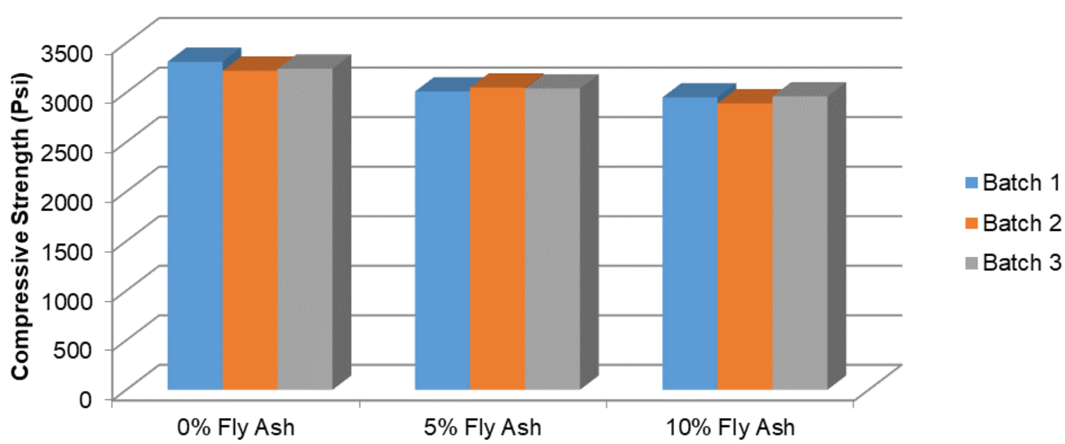

Figure 3: Comparison of Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.4

Table 6: Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.5

Sl No	Specimen notation	Fly Ash	Water Cement Ratio	Compressive Strength (Psi)	Average Compressive Strength (Psi)
1	F0-0.5-1	0%	0.5	2550	2548
2	F0-0.5-2			2580	
3	F0-0.5-3			2515	
4	F05-0.5-1	5%		2433	2428
5	F05-0.5-2			2450	
6	F05-0.5-3			2400	
7	F10-0.5-1	10%		2380	2337
8	F10-0.5-2			2330	
9	F10-0.5-3			2300	

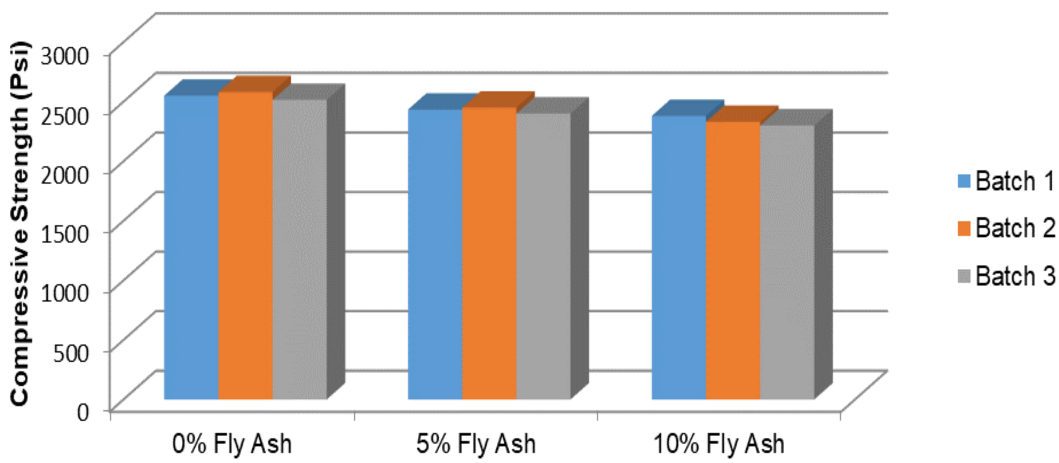

Figure 4: Comparison of Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.5

Table 7: Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.6

Sl No	Specimen notation	Fly Ash	Water Cement Ratio	Compressive Strength (Psi)	Average Compressive Strength (Psi)
1	F0-0.6-1	0%	0.6	2233	2261
2	F0-0.6-2			2250	
3	F0-0.6-3			2300	
4	F05-0.6-1	5%		2133	2128
5	F05-0.6-2			2150	
6	F05-0.6-3			2100	
7	F10-0.6-1	10%		1980	2003
8	F10-0.6-2			2030	
9	F10-0.6-3			2000	

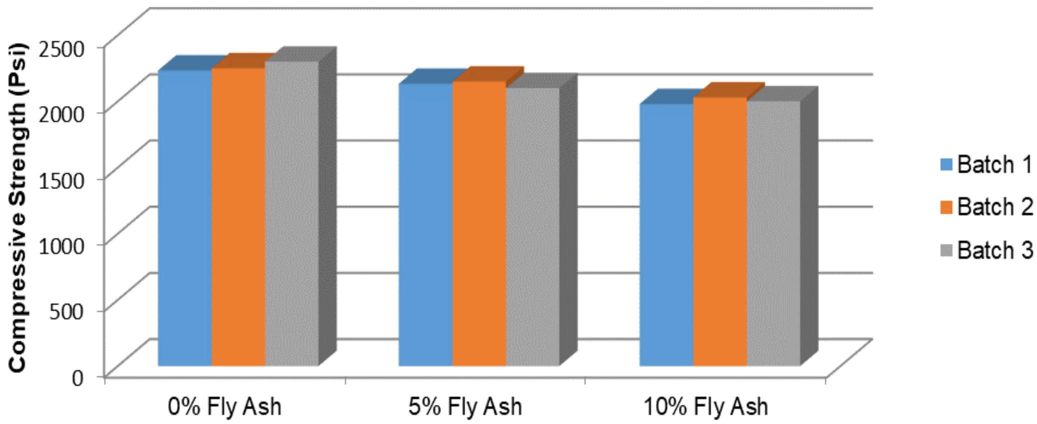

Figure 5: Comparison of Compressive strengh of Conventional concrete and Fly ash concrete with partial replacement of cement using water cement ratio of 0.6

It was observed that fly ash concrete has a lower value of compressive strength than conventional concrete. Concrete made with a mixture of cement and various percentages of fly ash has a decreasing order of compressive strength than conventional concrete. The decrease of compressive strength is found with the increase of percentages replacement but there is not very large difference between partial replacement of concrete and coventional concrete. With every 5% increased partial replacement of cement by fly ash, there is less than 10% decrease of compressive strength.So, partial replacement of treated recycled coarse aggregate is very effective. In addition, the decrease of compressive strength is found with the increase of water cement ratio from 0.4 to 0.5 and 0.6.

CONCLUSIONS :

Based on test results, the following conclusions can be drawn:

- Partially replaced fly ash concrete is cost effective compare to conventional concrete.
- Partially replaced fly ash concrete can be a effective solution to save our environment and land from the coal burnt fly ash in Bangladesh.
- The decrease of compressive strength is found with the increase of water cement ratio from 0.4 to 0.5 and 0.6.
- The concrete made as 5% partial replacement by fly ash is very effective as the compressive strength of concrete made as 5% partial replacement by fly ash close to the compressive strength of conventional concrete, which is only 9.3%, 9.5% and 9.4% less than conventional concrete with water-cement ratio of 0.4, 0.5 and 0.6 respectively.

So, the use of fly ash lead to reduction of compressive strength which may be solved by use of 5% fly ash as a partial replacement of cement in conventional concrete production.

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OPTIMIZATION MUNICIPAL SOLID WASTE COLLECTION ROUTES FOR MINIMUM FUEL CONSUMPTION IN KHULNA CITY BY GIS

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ABSTRACT

Urban solid waste management is considered as one of the most immediate and serious environmental problems confronting municipal authorities in developing countries like Bangladesh. A standard solid waste management should give hygienic, efficient and economic collection, transportation and disposal of solid waste without polluting atmosphere. To ensure this standard management system GIS can be used as an effective tool in selecting suitable disposal sites and identifying the optimum routes for transportation.This study concentrates to develop an optimized route plans for collection and disposal of municipal solid waste (MSW) from secondary disposal sites (SDS) to ultimate disposal sites (UDS) using Geographic Information System (GIS) in Khulna City Corporation (KCC). The present study reveals that there is no systematic time and route plan for the storage, collection and disposal of MSW from SDS to UDS. There are 35 SDSs are available from where Khulna City Corporation (KCC) vehicles are collected the MSW and about 26 Haul Containers (HCs) and 1200 community bins, located on roadsides throughout the city. In this the study the present scenario of waste generation and management, the locations of secondary dumping sides, transport facilities, the types of vehicles were investigated. The co-ordinates of SDSs, KCC garage and UDS were recorded using mobile GPS. After collecting all the relevant information the optimized route plans were developed using ArcGIS v10.2. Thus an attempt is made to propose a sustainable plan through which the existing facilities are properly utilized by providing an appropriate route plans having minimum travel distance.

Introduction

Solid Waste management becomes more complex and sensitive subject in terms of labor cost, environmental pollution and fuel in developing countries, since it affects the daily life of the people (Malakahmad, et al., 2014). Inadequate management of solid waste is an obvious cause for degradation of the environment in most cities of the third world. Human activities create huge amounts of wastes every day, almost in every urban areas. Solid waste collection can be considered as a major part in the process of solid waste management (SWM). The principle element of solid waste collection includes gathering of solid wastes and recyclable materials as well as the transport of these materials to a particular location where the collection vehicle is emptied and where it will be recycled (Tchobanoglous & Theisen, 1993). Labor cost & Fuel price plays a dominant role in the costs of collection and transportation of Municipal Solid Wastes (Dogan & Duleyman, 2013). Once budget for equipment, labor cost and fuel consumption have been determined, shortest routes for collection of solid waste must be laid out so that both collectors and equipment are used effectively. The Geographical Information Systems (GIS) is one of the most dominant and widely used tool to provide treatment, handling and visualization of spatial data, and its application for the optimization of the shortest route for waste collection (Tavares, et al., 2008). As the 3rd largest city in Bangladesh, Khulna is experiencing huge problems in dealing with solid waste generated in the city every day. Khulna is also one of the fast growing industrial and commercial cities that produce about 240 ton of municipal solid wastes per day (Mortuza & Rahman, 1999). The issue of solid waste is not only because of the increasing quantities, but also largely because of an inadequate management system (Tinmaz & Demir, 2006). The main aim of this paper is to identify and propose the optimum route for minimum driving distance of transportation of solid waste and disposal and calculate the amount of fuel consumption for proposed route.

Literature Review

Geographical Information System (GIS) is a popular tool for the identification of shortest route and related studies. GIS is one of the most important and widely used tool for these types of studies as it is capable to store, retrieve and analyze a large amount of geospatial data as well as it can give proper solution for a particular problem which can be easily visualized (Sumiani, et al., 2009). Fuel price is considered as the major cost in solid waste collection and transportation system and its consumption is inevitably associated with undesired pollutants emissions. Environmental benefits and financial savings can be ensured through reduction of fuel consumption for the collection and transportation of solid wastes (Tavares, et al., 2008). Trucks with diesel engine are usually used in the collection and transportation process. Due to fuel consumption, the truck with diesel engine emits a significant amount of air pollutants which are responsible for environmental pollution. So shortest route optimization should be performed in order to decrease the emissions in the solid waste collection and transportation process. This study was performed in Trabzon City. The total length of road network is 416 km and vehicles pass through its about 60% each day. A shortest path model was used in order to optimize solid waste collection/hauling processes to minimize emission. A software was used as an optimization tool. The software provided Geographical Information System (GIS) elements such as numerical pathways, demographic distribution data, container distribution data and solid waste production data. In addition, thematic container layer was having 777 points for the entire city. By using the software, the optimized route was compared with the present route and a comparison was done between the two routes (Apadin & Gonullu, 2008).

Materials and Methods

Primary data were collected to propose options for better solid waste management on study area. Random questionnaire survey was conducted at the study area. The major portion of MSW is dumped to the nearest SDS. From there KCC vehicles collect the wastes and transport it to the UDS of KCC. Some NGOs transfer their collected organic wastes to compost plants. The city authority has some limited numbers of non-motorized rickshaw vans and hand trolleys those are mainly used for the collection of MSW from community bins which is located at roadside and transfer to SDSs. Besides, the drain sludge is also collected by these vans. City authority collects waste from SDS then transfers it to the ultimate disposal site at Rajbandha. With the help of ArcGIS Network Analyst tools following works are done: study on present situation of SDSs and solid waste management system in the study area, a direct observation and survey have been conducted among the local people, local leaders and related organizations, access the existing route of vehicle transport, propose the optimum route.

Observation and Investigation

Field Investigation and Questionnaire Survey

A straight observation and survey have been conducted among the local people, local leaders and related organizations with a questionnaire survey. Study on the local people about their perception and feedback to SWM system organized by KCC and the way other people respond to it is observed. Due to limitation of time and fund, it was not possible to survey the whole of the Khulna city. Instead of taking into consideration the entire households within the study area, sampling technique is applied. 5% of the total households from each area were covered by the study. The questionnaire survey was performed among 200 persons who live in Khulna City.

Investigation of primary and secondary disposal sites

The questions of field survey for gathering the required information about the existing situation of primary point and SDS and answers from city dwellers and other stakeholders were recorded. However, some important issues, present situation of primary point and SDS is presented in followings.

Geographical Information System (GIS) Approach

There are many locations where the municipal bodies are trying hard and to provide best of their services for the betterment of the city. They even can follow their techniques right away and perform their duties in a manner that could run this system perfectly. Over these circumstances, there needs to be an improved and a refined system which is developed with the consideration of all the facts and figures of the situation. This could be achieved by using GIS which could handle different data forms like spatial as well attribute data simultaneously. The system appears to fall short when it comes to its methods to maintain a clean environment and it needs to be upgraded and refined. Solid Waste Management has become the important areas where the challenge arises from time to time. "One of the proper way to create innovative developments in a system is to document and study the existing system and bring the possible reforms by adopting appropriate measures at various levels through introducing innovative and cost-effective solutions" (Orga, 2003).

GIS can make the analysis of the situation along with a future trend could be predicted which will help in planning for the long-term solution. This system proposes the collection of data from different sources and formation of map layers like, ward and city map, demographic map showing the area wise population distribution, MSW generation map of different areas, existing MSW collection and disposal pattern from SDS to UDS, employment distribution in different wards and existing route plan of MSW lifting. From these layers the analysis can be achieved to derive the logistics and spatial planning. There are many suggestions in this spatial planning proposal which are said to be considered while working in GIS, they are:

Identification of exact location of MSW bins with GPS demarcating on the base map; maintaining a record of SDSs; a map showing the road network in different areas; a map showing the distances between the bins; location of the SDSs; recording of available vehicles and equipment for MSW management; allocating a unique number to all the SDSs so it can be easily and quickly located in case of any complaint registered or planning and maintenance; maintaining a record about the type of SDSs and recording of the responsibilities and assignment of work, equipment, vehicles etc. of the MSW maintenance and the logistics information about the transportation involved in the system.

Results and Discussion

Current SWM in Khulna City

The recent survey shows that about 500 tons waste produce daily in Khulna city where Of the total, only 250 to 270 tons are collected and dumped into the open dumping ground at Rajbandha landfills of Batiaghata upazila. The rest does not even reach the dumping ground owing lack of logistic support and Personnel. The remaining 180 tons of uncollected waste are being dumped into drains, open spaces, road-sides and water-bodies, not only blocking the city’s drainage links but also creating an unhealthy and stinking environment. Absence of having dustbins, residents of Khulna city forces to dump wastes into drains, canals and road-sides. In the Khulna city, the main producers of solid waste are residences, whole and retail sale market places including shopping places, streets, hotels and restaurants, hospitals and private clinics, educational institutions, cinemas, bus, railway and launch/steamer Ghats, slaughter houses etc. In the collection system, normally NGOs and CBOs conduct the door to door collection. Now a day’s city corporation authority also conducts door to door collection system in a small area.

Current transportation facility for solid waste management

The present scenario of transportation of solid waste management is given below:

Table 1: No. of vehicles in KCC garage for SWM

Types of Truck	Capacity (Ton)	No. of trucks
1. Dump Trucks	3	15
	5	05
	8	09
2.Container Truck	2~5	10
Total no. of Trucks		45

Source: Field survey, 2018

STS and container point locations in City Corporation map

After getting the data from the survey, it is possible to say that the present management system of solid waste in Khulna City needs modification. The locations of the secondary dumping sites were plotted in GIS.

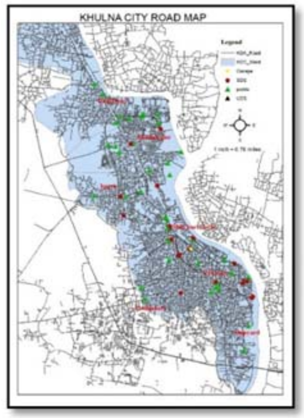

Figure 1: Location of STSs, Container Points, UDS and KCC garage

Optimized routes using GIS

The best route can be defined as the route that has the lowest impedance, where the impedance is chosen by the user. Hence, some conditions were place into consideration for route optimization of

(i) Starts from KCC garage, collect MSW from SDS(s) and stops at UDS;

(ii) Optimum travel distance;

(iii) Least road requirement for vehicle movement; and

(iv) Then the routes were optimized by using network analyst tool of ArcGIS 10.2.

Table 2: Shortest route of transportation for SWM from STS in Khulna city

SL No.	STS Location	Shortest Route Garage>STS>UDS Distance(km)			Total Distance(km)	
		Total Distance	Garage>STS	UDS>Garage	Loaded	unloaded
1	New Market,khulna	10.78	1.2	9.8	9.58	11.00
2	Custom's Gate	13.21	2.1	9.8	11.11	11.90
3	Boyra Bazar	11.86	3.7	9.8	8.16	13.50
4	Boyra Ijor Mor	12.25	3.5	9.8	8.75	13.30
5	Rupsha Fish Market	14.87	3.3	9.8	11.57	13.10
6	Rupsha Truck Terminal	14.78	3.2	9.8	11.58	13.00
7	Rashida Memorial(one side of road)	10.04	1	9.8	9.04	10.80
8	Rashida Memorial(other side of road)	9.73	1	9.8	8.73	10.80
9	Millinum Hotel	10.41	1.1	9.8	9.31	10.90
10	Nirala	9.74	1.7	9.8	8.04	11.50
11	PTI Mor	11.95	1.8	9.8	10.15	11.60
12	Railway Station	10.70	0.5	9.8	10.20	10.30
13	CSS Rupsha Natun Bazar	14.50	2.9	9.8	11.60	12.70
14	Rupsha stand road	14.31	2.8	9.8	11.51	12.60
15	News print, C	17.32	5.4	9.8	11.92	15.20
16	Goyalkhali graveyard	15.73	4.7	9.8	11.03	14.50
17	Mohsin Mor, Daulatpur	19.80	7.3	9.8	12.50	17.10
18	New Market , Khalishpur	16.90	5.3	9.8	11.60	15.10

Table 3: Shortest route of transportation for SWM from Container point in Khulna city

SL No.	Container Point Location	Shortest Route			Total Distance(km)	
		Garage>Container Point>UDS		Distance (km)		
		Total Distance	UDS>Container Point	Garage>Container point	Loaded	Unloaded
1	Janata Hall	26.6	15.9	10.7	31.8	21.4
2	Mohsin Mor, Daulatpur	19.8	12.5	7.3	25	14.6
3	Daulatpur kacha Bazar	18.9	12	6.9	24	13.8
4	Shipyard	16.55	12.05	4.5	24.1	9
5	Rupsha Fish market	14.84	11.54	3.3	23.08	6.6
6	CSS Rupsha Natun Bazar	14.03	11.33	2.7	22.66	5.4
7	Zila School	13.45	11.45	2	22.9	4
8	Nargis Memorial Clinic	13.25	11.15	2.1	22.3	4.2
9	Railway Station	10.6	9.6	1	19.2	2
10	PTI Mor	11.95	10.05	1.9	20.1	3.8
11	Hazi Ismail Road, Moilapota	9.74	8.7	1.04	17.4	2.08
12	Gollamari	9.6	6.6	3	13.2	6
13	250 Bed	15.7	10.1	5.6	20.2	11.2
14	Navy Colony	15.5	10.2	5.3	20.4	10.6
15	Abu Naser Hospital	15.7	10.1	5.6	20.2	11.2
16	People's Jute Mill	17.67	12.03	5.64	24.06	11.28
17	Goalkhali Graveyard	15.65	11.05	4.6	22.1	9.2
18	New Market	11	9.7	1.3	19.4	2.6
19	Chitrali Cinema Hall	17.8	11.9	5.9	23.8	11.8
20	C & B Colony	11.83	10.23	1.6	20.46	3.2
21	Kabir Bot tola,Rd-23	14.83	9.83	5	19.66	10
22	Goal para Power house	19.1	12.79	6.31	25.58	12.62
23	BDR Camp	17.11	11.01	6.1	22.02	12.2
24	Khalishpur kosai khana	17	12	5	24	10
25	Chromic vabon,khalishpur	14.6	10.9	3.7	21.8	7.4
26	Titumir Navy Camp	15.9	11.8	4.1	23.6	8.2
27	2 No. Navy gate	15	11.6	3.4	23.2	6.8
28	7 No. ward	17.34	11.44	5.9	22.88	11.8
29	Jalil sharoni	11	10	1	20	2
30	14 No. Ward	11.9	7.2	4.7	14.4	9.4
31	City INN	10.4	9.2	1.2	18.4	2.4
32	Bania khamar Mor	11.8	6.67	5.13	13.34	10.26
33	Tutpara Graveyard	12.2	9.8	2.4	19.6	4.8
34	Taltola Hospital, Tutpara	13.9	10.77	3.13	21.54	6.26
35	Lobon Chora	17.3	11.9	5.4	23.8	10.8

36	Crecent Jute Mill	18	12.2	5.8	24.4	11.6
37	Circuit House	13	11.2	1.8	22.4	3.6
38	Jora gate	11.6	10.1	1.5	20.2	3
39	Badsha Mia Clinic	10.4	9.4	1	18.8	2
40	Sador Hospital	11.9	10.3	1.6	20.6	3.2
41	Police Training center	43.5	30.8	12.7	61.6	25.4
42	kuet	26.8	16	10.8	32	21.6

Some example of shortest and existing route in map

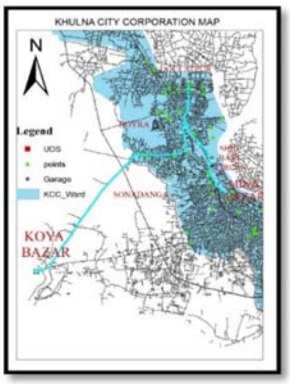

Fig. 2: Shortest route for contain at Cresent Jute Mill.

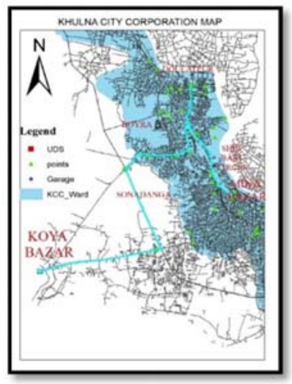

Fig. 3: Existing route for containe at Cresent Jute Mill.

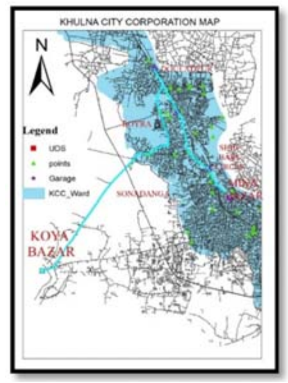

Fig. 4: Shortest route for container point at Doulatpur Kacca Bazar.

Fig. 5: Existing route for container point at Doulatpur kacca bazar.

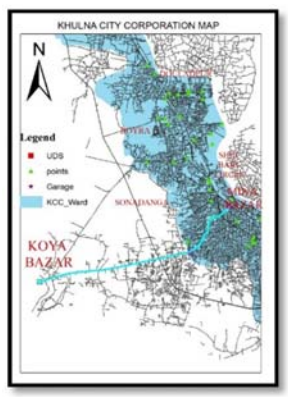

Fig. 6: Shortest route for container point at Gollamari.

Fig. 7: Existing route for container point at Gollamari.

Fuel calculation for STS

Table 4: Fuel and Cost calculation of existing route for STS

Serial No.	STS Location	Existing Route					
		Total Distance		Fuel Require(litre)			Cost(Tk)
		Loaded	unloaded	Loaded	unloaded	Total	
1	New Market,khulna	10.92	11.00	1.82	1.10	2.92	190
2	Custom's Gate	12.00	11.90	2.00	1.19	3.19	207
3	Boyra Bazar	12.20	13.50	2.03	1.35	3.38	220
4	Boyra Ijor Mor	12.35	13.30	2.06	1.33	3.39	220

5	Rupsha Fish Market	12.05	13.10	2.01	1.31	3.32	216
6	Rupsha Truck Terminal	12.10	13.00	2.02	1.30	3.32	216
7	Rashida Memorial(one side of road)	9.50	10.80	1.58	1.08	2.66	173
8	Rashida Memorial(other side of road)	9.50	10.80	1.58	1.08	2.66	173
9	Millinum Hotel	9.31	10.90	1.55	1.09	2.64	172
10	Nirala	8.04	11.50	1.34	1.15	2.49	162
11	PTI Mor	11.00	11.60	1.83	1.16	2.99	195
12	Railway Station	10.20	10.30	1.70	1.03	2.73	177
13	CSS Rupsha Natun Bazar	12.50	12.70	2.08	1.27	3.35	218
14	Rupsha stand road	12.30	12.60	2.05	1.26	3.31	215
15	News print, C	16.30	15.20	2.72	1.52	4.24	275
16	Goyalkhali graveyard	14.00	14.50	2.33	1.45	3.78	246
17	Mohsin Mor, Daulatpur	15.90	17.10	2.65	1.71	4.36	283
18	New Market, Khalishpur	14.70	15.10	2.45	1.51	3.96	257
			Total Fuel Require=			59	3816

Table 5: Fuel and Cost calculation of shortest route for STS

Serial No.	STS Location	Shortest Route					
		Total Distance		Fuel Require(litre)			Cost(Tk)
		Loaded	unloaded	Loaded	unloaded	Total	
1	New Market,khulna	9.58	11.00	1.60	1.10	2.70	175
2	Custom's Gate	11.11	11.90	1.85	1.19	3.04	198
3	Boyra Bazar	8.16	13.50	1.36	1.35	2.71	176
4	Boyra Ijor Mor	8.75	13.30	1.46	1.33	2.79	181
5	Rupsha Fish Market	11.57	13.10	1.93	1.31	3.24	210
6	Rupsha Truck Terminal	11.58	13.00	1.93	1.30	3.23	210
7	Rashida Memorial(one side of road)	9.04	10.80	1.51	1.08	2.59	168
8	Rashida Memorial(other side of road)	8.73	10.80	1.45	1.08	2.53	165
9	Millinum Hotel	9.31	10.90	1.55	1.09	2.64	172
10	Nirala	8.04	11.50	1.34	1.15	2.49	162
11	PTI Mor	10.15	11.60	1.69	1.16	2.85	185
12	Railway Station	10.20	10.30	1.70	1.03	2.73	177
13	CSS Rupsha Natun Bazar	11.60	12.70	1.93	1.27	3.20	208
14	Rupsha stand road	11.51	12.60	1.92	1.26	3.18	207
15	News print, C	11.92	15.20	1.99	1.52	3.51	228
16	Goyalkhali graveyard	11.03	14.50	1.84	1.45	3.29	214
17	Mohsin Mor, Daulatpur	12.50	17.10	2.08	1.71	3.79	247
18	New Market , Khalishpur	11.60	15.10	1.93	1.51	3.44	224
			Total Fuel Require =			54	3507

Table 6: Total fuel and cost of Existing and shortest route

	Total Fuel Require	Total cost
Existing Route	59	3816
Shortest Route	54	3507
Difference	5	309

Table 7: Existing cost according to KCC.

Total amount of Trip	Fuel Require per Trip (litre)	Total amount of Fuel (litre)	Total Cost (taka)

18	6	108	7020

Table 8: Comparison between Shortest and existing route

Total Fuel(litre)			Total Cost(taka)		
Existing Route	Shortest Route	Fuel Save	Existing Route	Shortest Route	Cost Save
108	54	54	7020	3507	3513

Fuel calculation for container point

Table 9: Fuel and Cost calculation of Existing route for Container Point

Serial No.	Container Point Location	Existing Route					
		Total Distance(km)		Fuel required(litre)			Cost(Tk)
		Loaded	Unloaded	Loaded	unloaded	Total	
1	Janata Hall	37.6	21.4	6.27	2.14	8.41	546
2	Mohsin Mor, Daulatpur	31.8	14.6	5.30	1.46	6.76	439
3	Daulatpur kacha Bazar	30.8	13.8	5.13	1.38	6.51	423
4	Shipyard	26.48	9	4.41	0.90	5.31	345
5	Rupsha Fish market	27.64	6.6	4.61	0.66	5.27	342
6	CSS Rupsha Natun Bazar	24.28	5.4	4.05	0.54	4.59	298
7	Zila School	23.3	4	3.88	0.40	4.28	278
8	Nargis Memorial Clinic	22.76	4.2	3.79	0.42	4.21	274
9	Railway Station	19.4	2	3.23	0.20	3.43	223
10	PTI Mor	20.42	3.8	3.40	0.38	3.78	246
11	Hazi Ismail Road, Moilapota	18.4	2.08	3.07	0.21	3.27	213
12	Gollamari	13.48	6	2.25	0.60	2.85	185
13	250 Bed	21.02	11.2	3.50	1.12	4.62	301
14	Navy Colony	23.2	10.6	3.87	1.06	4.93	320
15	Abu Naser Hospital	21.02	11.2	3.50	1.12	4.62	301
16	People's Jute Mill	24.8	11.28	4.13	1.13	5.26	342
17	Goalkhali Graveyard	23.42	9.2	3.90	0.92	4.82	314
18	New Market	22.2	2.6	3.70	0.26	3.96	257
19	Chitrali Cinema Hall	25.66	11.8	4.28	1.18	5.46	355
20	C & B Colony	22.46	3.2	3.74	0.32	4.06	264
21	Kabir Bot tola,Rd-23	21.2	10	3.53	1.00	4.53	295
22	Goal para Power house	31.38	12.62	5.23	1.26	6.49	422
23	BDR Camp	23.4	12.2	3.90	1.22	5.12	333
24	Khalishpur kosai khana	29.7	10	4.95	1.00	5.95	387
25	Chromic vabon,khalishpur	28	7.4	4.67	0.74	5.41	351
26	Titumir Navy Camp	29.8	8.2	4.97	0.82	5.79	376
27	2 No. Navy gate	28.6	6.8	4.77	0.68	5.45	354
28	7 No. ward	28.6	11.8	4.77	1.18	5.95	387
29	Jalil sharoni	20.24	2	3.37	0.20	3.57	232
30	14 No. Ward	18.2	9.4	3.03	0.94	3.97	258
31	City INN	20.2	2.4	3.37	0.24	3.61	234
32	Bania khamar Mor	14.14	10.26	2.36	1.03	3.38	220
33	Tutpara Graveyard	20.4	4.8	3.40	0.48	3.88	252
34	Taltola Hospital, Tutpara	22.54	6.26	3.76	0.63	4.38	285
35	Lobon Chora	24.2	10.8	4.03	1.08	5.11	332
36	Crecent Jute Mill	30.8	11.6	5.13	1.16	6.29	409
37	Circuit House	23	3.6	3.83	0.36	4.19	273
38	Jora gate	22.4	3	3.73	0.30	4.03	262

39	Badsha Mia Clinic	19	2	3.17	0.20	3.37	219
40	Sador Hospital	21.8	3.2	3.63	0.32	3.95	257
41	PoliceTraining center	67.6	25.4	11.27	2.54	13.81	897
42	kuet	38.2	21.6	6.37	2.16	27.97	1818
			Total Fuel Require =			233	15121

Table 10: Fuel and Cost calculation of shortest route for Container Point.

Serial No.	Container Point Location	Shortest Route					Cost(Tk)
		Total Distance(km)		Fuel required(litre)			
		Loaded	Unloaded	Loaded	unloaded	Total	
1	Janata Hall	31.8	21.4	5.30	2.14	7.44	484
2	Mohsin Mor, Daulatpur	25	14.6	4.17	1.46	5.63	366
3	Daulatpur kacha Bazar	24	13.8	4.00	1.38	5.38	350
4	Shipyard	24.1	9	4.02	0.90	4.92	320
5	Rupsha Fish market	23.08	6.6	3.85	0.66	4.51	293
6	CSS Rupsha Natun Bazar	22.66	5.4	3.78	0.54	4.32	281
7	Zila School	22.9	4	3.82	0.40	4.22	274
8	Nargis Memorial Clinic	22.3	4.2	3.72	0.42	4.14	269
9	Railway Station	19.2	2	3.20	0.20	3.40	221
10	PTI Mor	20.1	3.8	3.35	0.38	3.73	242
11	Hazi Ismail Road, Moilapota	17.4	2.08	2.90	0.21	3.11	202
12	Gollamari	13.2	6	2.20	0.60	2.80	182
13	250 Bed Hospital	20.2	11.2	3.37	1.10	4.47	290
14	Navy Colony	20.4	10.6	3.40	1.06	4.46	290
15	Abu Naser Hospital	20.2	11.2	3.37	1.12	4.49	292
16	People's Jute Mill	24.06	11.28	4.01	1.13	5.14	334
17	Goalkhali Graveyard	22.1	9.2	3.68	0.92	4.60	299
18	New Market	19.4	2.6	3.23	0.26	3.49	227
19	Chitrali Cinema Hall	23.8	11.8	3.97	1.18	5.15	335
20	C & B Colony	20.46	3.2	3.41	0.32	3.73	242
21	Kabir Bot tola,Rd-23	19.66	10	3.28	1.00	4.28	278
22	Goal para Power house	25.58	12.62	4.26	1.26	5.53	359
23	BDR Camp	22.02	12.2	3.67	1.22	4.89	318
24	Khalishpur kosai khana	24	10	4.00	1.00	5.00	325
25	Chromic vabon,khalishpur	21.8	7.4	3.63	0.74	4.37	284
26	Titumir Navy Camp	23.6	8.2	3.93	0.82	4.75	309
27	2 No. Navy gate	23.2	6.8	3.87	0.68	4.55	296
28	7 No. ward	22.88	11.8	3.81	1.18	4.99	325
29	Jalil sharoni	20	2	3.33	0.20	3.53	230
30	14 No. Ward	14.4	9.4	2.40	0.94	3.34	217
31	City Inn Hotel	18.4	2.4	3.07	0.24	3.31	215
32	Bania khamar Mor	13.34	10.26	2.22	1.03	3.25	211
33	Tutpara Graveyard	19.6	4.8	3.27	0.48	3.75	244
34	Taltola Hospital, Tutpara	21.54	6.26	3.59	0.63	4.22	274
35	Lobon Chora	23.8	10.8	3.97	1.08	5.05	328
36	Crecent Jute Mill	24.4	11.6	4.07	1.16	5.23	340
37	Circuit House	22.4	3.6	3.73	0.36	4.09	266
38	Jora gate	20.2	3	3.37	0.30	3.67	238
39	Badsha Mia Clinic	18.8	2	3.13	0.20	3.33	217
40	Sador Hospital	20.6	3.2	3.43	0.32	3.75	244
41	PoliceTraining center	61.6	25.4	10.27	2.54	12.81	832
42	KUET	32	21.6	5.33	2.16	7.49	487
				Total Fuel Require =		194	12628

Table 11: Total fuel and cost of Existing and shortest route

	Total Fuel Require	Total cost
Existing Route	233	15121
Shortest Route	194	12628
Difference	39	2493

Table 12: Existing cost according to KCC.

Total amount of Trip	Fuel Require per Trip (litre)	Total amount of Fuel (litre)	Total Cost (taka)
42	6	252	16380

Table 13: Comparison between Shortest and existing route

Total Fuel(litre)			Total Cost(taka)		
Existing Route	Shortest Route	Fuel Save	Existing Route	Shortest Route	Cost Save
252	194	58	16830	12628	3752

From the field survey it was concluded that there were 60 SDS, among them 18 are open and 42 are haul containers. The capacity of the containers is 2-3 ton. There are a total of 40 trucks allocated for transportation of solid wastes in KCC. After pointing out the SDS, KCC garage and UDS in GIS, the network analysis was performed using shape files for Khulna city. From analysis shortest route for each SDS were calculated. Existing route for each SDS has been plotted in GIS. Total driving distance for shortest route was 1725 km. Total driving distance for existing route was 1866 km. Fuel required for MSW transportation has been calculated for both shortest and existing route. After comparing fuel required for shortest route and existing route, shortest route was consumed 248 litre. Existing route was consumed 341 litre. Shortest route was saved 93 litre fuel.

Conclusion

In this study it was intended to investigate the SDSs from the questionnaire survey and field observation. There are different routes for the different categories of SDSs and similar types of vehicles. Details about the waste collection vehicle distance and SDS was provided in this study. The estimated distances of the routes were also taken from GIS. These statistics were given to have the idea of the new waste management system. It was intended to plan an efficient waste collection route for transportation of waste to the UDS from SDS. Also, this study provides the amount of consumed fuel per day. Which will save both money and fuel.

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Experimental Investigations on Recycled Coarse Aggregate as a Full or Partial Replacement of Coarse Aggregate in Concrete Production Using High FM Fine Aggregates

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ABSTRACT

Recycled coarse aggregate (RCA) is produced by crushing the demolition waste from concrete structures. The construction and demolition waste are primarily used for landfill sites which are causing significant damage to the environment and developing serious problems. The use of the RCAs created from processing of construction and demolition waste in new construction has become more important over the last two decades as it conserve the non-renewable natural resource of virgin aggregates. With a view to the above needs, the present study is aimed to determine the strength properties of RCA concrete depending on the various content of RCA, and to compare them to the strength properties of concrete made with conventional coarse aggregates (CCA). The fine aggregates of high FM of 3.0 was used for recycled and conventional concrete. After performing the compressive strength test, it was found that concrete made with full replaced RCA have less strength than concrete made with CCA but not much. But partial replaced RCA concretes are showing comparable strength with CCA concrete whereas it is cheaper than CCA aggregate concrete. So, RCA can be used as a partially replacement of CCA in concrete production. In addition, full replacement of RCA can be used in structures of less importance such temporary walls, base of roads etc.

Key words: *Recycled coarse aggregate (RCA), fine aggregate of FM 3.0, Partially replaced RCA, Concrete, Compressive Strength.*

INTRODUCTION

Concrete consumption in the world is estimated at two and a half tons per capita per year (equivalent to 17.5 billion tons for 7 billion population in the world) (CAMBUREAU, 2008; Mehta, 2009). To make this huge volume of concrete 2.62 billion tons of cement, 13.12 billion tons of aggregate, 1.75 billion tons of water are necessary. Generally, aggregates are collected by cutting mountains or breaking river gravels or boulders, or by breaking clay bricks. A significant amount of natural resource can be saved if the demolished concrete is recycled for new constructions. In addition to the saving of natural resources, recycling of demolished concrete will also provide other benefits, such as creation of additional business opportunities, saving cost of disposal, saving money for local government and other purchaser, helping local government to meet the goal of reducing disposal, etc. At present, the amount of global demolished concrete is estimated at 2~3 billion tons (Torring and Lauritzen, 2002). Sixty to seventy percent of demolished concrete is used as sub-base aggregate for road construction (Yanagibashi et al, 2002). By recycling of demolished concrete, 20% of normal aggregates can be saved. It is also estimated that in the next ten years, the amount of demolished concrete will be increased to 7.5~12.5 billion tons (Torring and Lauritzen, 2002). If technology and public acceptance of using recycled aggregate are developed, there will be no requirement for normal aggregate, if 100% of demolished concrete is recycled for new construction.

In Bangladesh, the volume of demolished concrete is increasing due to the deterioration of concrete structures as well as the replacement of many low-rise buildings by relatively high-rise buildings due to the booming of real estate business. Disposal of the demolished concrete is becoming a great concern to the developers of the buildings. If the demolished concrete is used for new construction, the disposal problem will be solved, the demand for new aggregates will be reduced, and finally consumption of the natural resources for making aggregate will be reduced. In some project sites, it was also found that a portion of the demolished concrete is used as aggregate in foundation works without any research on the recycled aggregates. In most of the old buildings, brick chips were used as coarse aggregate of concrete. Studies related to the recycling of demolished concrete are generally found for stone chips made concrete (Zega et al, 2010; Kou et al, 2011). A reduction of 17% in the compressive strength of the concrete, at a replacement ratio of 33%, is reported by Montgomery. Compared to natural aggregate concrete the compressive strength of recycled aggregate was decreased by 18.76%. The recycled aggregate treated with water has increased 4.93%, nitric acid by 11.88%, sulphuric acid increased by 5.38% and hydrochloric acid increased by 7.17% than the recycled aggregate(G. Murali et al.).Therefore, investigations on recycling of demolished concrete are necessary.

In the present study is aimed to determine the strength of recycled coarse aggregate concrete depending on the various content of recycled coarse aggregate, and compare them to the compressive strength of concrete made with conventional aggregate i.e. stone chips and concrete made with recycled coarse aggregate. Demolished concrete produced by crushing old laboratory concrete specimens of compressive strength 3000 psi. Before making concrete, the aggregates were investigated for absorption capacity, unit weight, and abrasion. Standard grading of the aggregates were controlled. Cylinder concrete specimens of diameter 150 mm and height 300 mm were made and tested for compressive strength. Besides, the maximum utilization of recycled aggregate was considered in place of conventional aggregate to attain acceptable quality of concrete for reducing the construction cost of new concrete structure.

MATERIALS

The Ordinary Portland Cement conforming was used for the preparation of test specimens. The natural fine aggregate (NFA) used throughout the study was natural river sand. The FM, specific gravity, water absorption and moisture content of sand used in this investigation were 3.0, 2.74, 3.04% and 2.31% respectively.

Table 1: Determination of fineness modulus of local sand

Sieve Size	Opening (mm)	Weight of Materials Retained(mm)	% Retained	Cumulative % Retained	% Finer
No.4	4.76	0	0	0	100
No.8	2.36	18.5	3.7	3.7	96.3
No.16	1.18	72.2	14.44	18.14	81.86
No.30	0.6	337.3	67.46	85.60	14.4
No.50	0.3	44.9	8.98	94.58	5.42
No.100	0.15	19.4	3.88	99.46	1.54
Pan		7.7	1.54	100	0

Weight of sample= 500 gm. and fineness modulus is 3.

On the other hand, Two type of coarse aggregate were used for this investigation viz, natural aggregate (stone chips) and recycled coarse aggregate (RCA).

EXPERIMENTAL METHODS

Demolished concrete blocks were collected from the broken concrete. The collected concrete samples were broken into pieces manually in three particular sizes as 25 mm to 20 mm, 20 mm to 10 mm, and 10 mm to 5 mm, the aggregates were mixed as 5% from 25 mm to 20 mm, 57.5% from 20 mm to 10 mm, and 37.5% from 10 mm to 5 mm as per ASTM C33-93. The aggregates were tested for absorption capacity, specific gravity, unit weight, abrasion and impact value. The specific gravity and absorption capacity are determined as per ASTM C128, unit weight as per ASTM C29, and abrasion value as per ASTM C131.

The absorption capacity, specific gravity, unit weight, abrasion and impact value 5.92%, 2.365, 1350 kg/m^3, 30.31%, 17.4%.

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or in shear is of primary importance; the compressive strength is frequently as a measure of these properties. Therefore, the concrete making properties of various ingredients of mix are usually measured in terms of the compressive strength. Compressive strength is also used as a qualitative measure for other properties of hardened concrete. Cylinders of diameter 150 mm and 300 mm height were prepared using the standard molds. The concrete mix is designed as per ACI mix design for the normal concrete. The grade of concrete which we adopted was 3000 psi with water cement ratio of 0.68. The samples are casted using the three different aggregate. For proper mixing, vibrator are used here in preparation of cylindrical specimen. Total mixing time of concrete was controlled at 5.5 minutes. After mixing concrete, the workability of concrete was measured by slump cone test. Cylinders are demolded after 24 hours from casting and kept in a water tank continuously. A series of test (BS 1881: Part 110:1983 and by ASTM C 192-90a) were carried out by using Universal Testing Machine (UTM) in the laboratory, to determine the compressive strength of recycled concrete cylinder after curing of 7 days and 28 days in fresh water. The strain of concrete specimens was measured by a strain measurement setup with two dial gauges. The gauge length was 100 mm.

Table 2: List of Test Specimens:

No.	Type of Concrete	Specimens Nos.
1	Conventional Concrete(CC)	6
2	Recycled Coarse Aggregate Concrete(RCAC)	6
3	10% partial replaced Recycled Coarse Aggregate Concrete (PRRC-10%)	6

(a) (b)

Figure 1: (a) Casted Cylindrical concrete specimen (b) Compressive Strength Test of Concrete

Mix design

There are a number of different methods of mix design available. Although they are not directly comparable, they do give approximately the relative proportion of materials, and all are capable of yielding suitable concrete mixes. The most common method used in North America is that established by ACI Recommended Practice 211.1. It must be remembered, however, that any mix design method will provide approximation of proportions. These must be checked by trial batches in the laboratory or on the field and can then be adjusted as necessary to produce the desired concrete characteristics. With any given set of materials, it may be found that considerable deviation from the ACI recommended practice might be necessary. Once sufficient experience with local materials is acquired, the ACI method should be modified to take their properties into account. In this studies, for casting of concrete cylinder use fine aggregate of fineness modulus value 3 and the mix ratio for all types of concrete is 1: 1.5:3. For mix design of concrete, estimation of coarse aggregate content use the Figure 2 instead of Table 3.

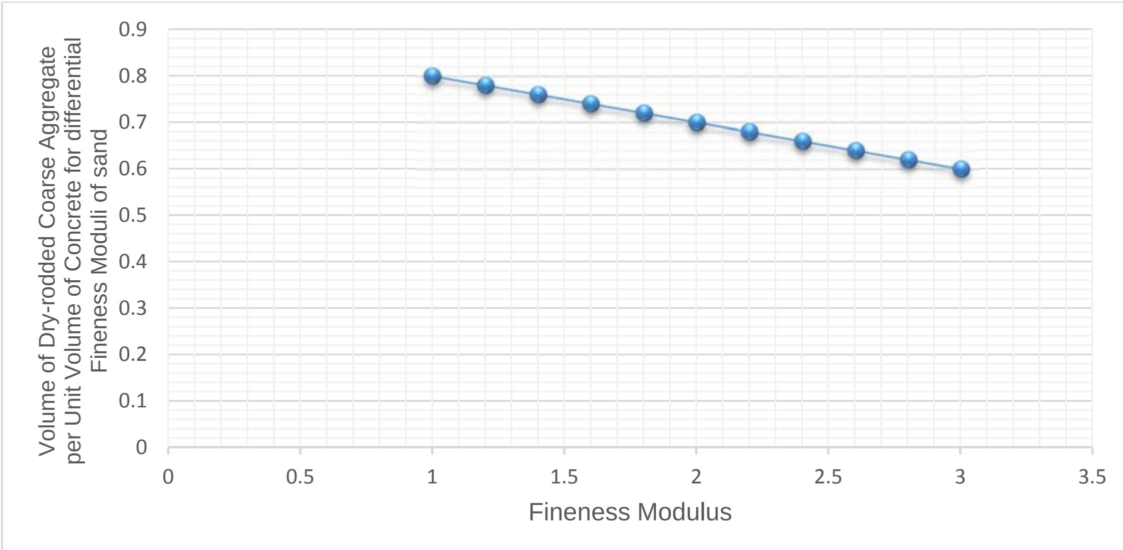

Figure 2: Volume of Dry-rodded Coarse Aggregate per Unit Volume of Concrete for differential Fineness Moduli of sand at maximum aggregate size 20mm (Based on ACI 211.1).

Table 3: Volume Coarse Aggregate per Unit Volume of Concrete (Based on ACI 211.1).

Maximum size of Aggregate	Volume of Dry-rodded Coarse Aggregate per Unit Volume of Concrete for differential Fineness Moduli of sand				
in.	mm	2.4	2.6	2.8	3
3/8	10	0.5	0.48	0.46	0.44
1/2	12.5	0.59	0.57	0.55	0.53
3/4	20	0.66	0.64	0.62	0.6
1	25	0.71	0.69	0.67	0.65
1 1/2	40	0.76	0.74	0.72	0.7
2	50	0.78	0.76	0.74	0.72
3	75	0.82	0.8	0.78	0.76
6	150	0.87	0.85	0.83	0.81

COST ANALYSIS:

Price according to the Bangladesh Market (2018):

Cement = 500.00 TK Per bag (50 kg)
Sand = 1050.00 TK per m^3
Fresh stone chip = 4200.00 TK per m^3
Recycled coarse chip = 1150.00 TK per m^3

Table 4: Cost per Cubic meter (In taka) of plain concrete.

Materials	Price (TK) (Fresh coarse aggregate)	Price (TK) (Recycled coarse aggregate)
Coarse aggregate	3600.00	990.00*
Sand	450.00	450.00
Cement (OPC)	3214.00	3214.00
Total	7264.00	4654.00

*Manually broken & transportation cost.
If we use recycled stone chips, safe 36% cost than use of fress stone chips.

RESULTS :

It can be said from previous research concrete made from recycled aggregate lower its compressive strength.But replacement small portion of coarse aggregate may not effect the compressive strength of concrete. The comparison on workability and compressive strength of different types of concrete is given below in the graphs:

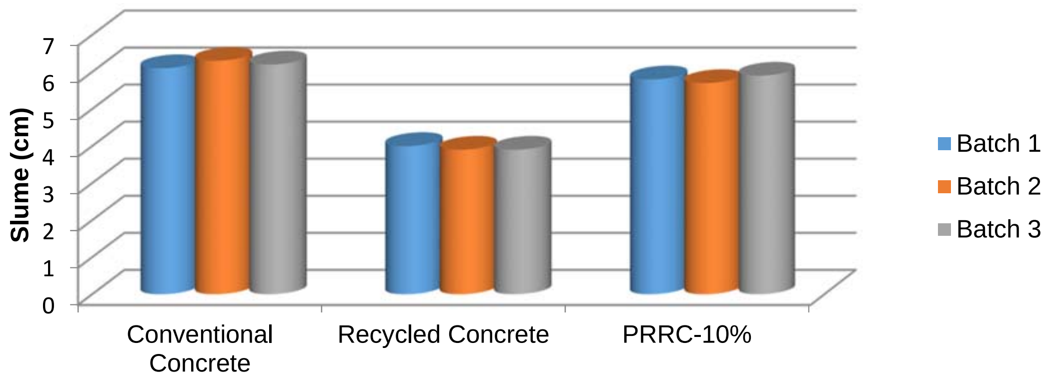

Figure 2: Comparison of Workability of Concrete at W/C=0.46.

Table 5: Compressive strength of Conventional concrete Recycled Concrete using water cement ratio of 0.46.

Sl No	Specimen	Curing Days	Water Cement Ratio	Compressive Strength (Psi)	Average Compressive Strength (Psi)
1	Conventional Concrete	7	0.46	2650	2667
2				2750	
3				2600	
4	Recycled Concrete	7		2000	2000
5				2100	
6				1900	
7	Partially Replace Recycled Concrete (PRRC-10%	7		2360	2380
8				2400	
9				2380	
10	Conventional Concrete	28		3750	3700
11				3600	
12				3750	
13	Recycled Concrete	28		2650	2600
14				2500	
15				2650	
16	Partially Replace Recycled Concrete (PRRC-10%)	28		3540	3490
17				3460	
18				3470	

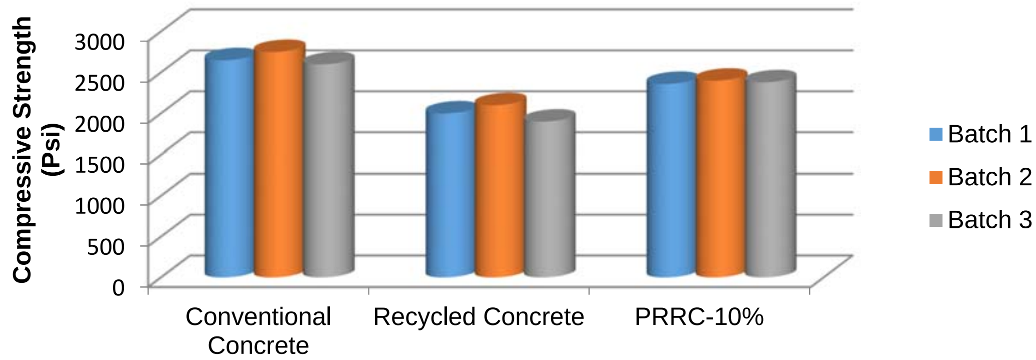

Figure 3: Comprison of Compressive strengh of Concretes at 7 days

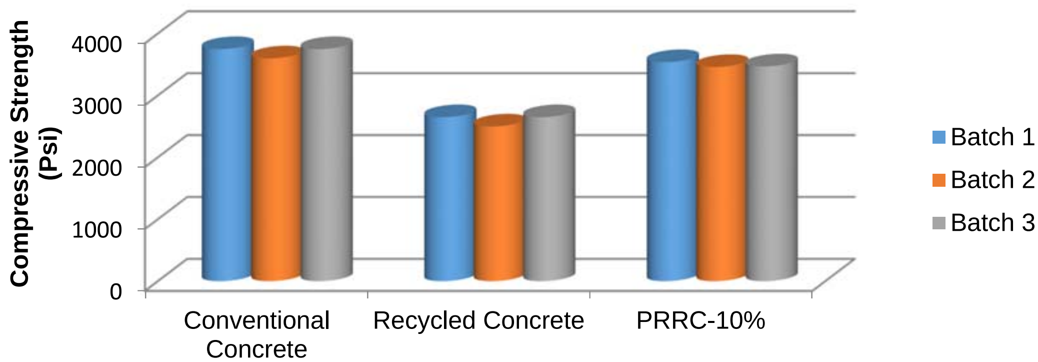

Figure 4: Comprison of Compressive strengh of Concretes at 28 days

The recycled concrete have the lower workability compare to the conventional concrete but the workability of 10% partially replace recycled concrete is very close to the workability of the conventional concrete. It was observed that concrete made with recycled coarse aggregate has a lower value of compressive strength than conventional concrete. The compressive strength of concrete has been decresed by 25% at 7 days due to replacement of coarse aggregate by recycled aggregate. In addition, the compressive strength of concrete has been decresed by 30% at 28 days due to replacement of coarse aggregate by recycled aggregate. But on the other hand, 10% partially replace recycled concrete is showing a very good comparable compressive strength. The compressive strength of 10% partially replace recycled concrete is only 10.8% and 5.7% at 7 days and 28 days respectively less than conventional concrete.

CONCLUSIONS :

On the basis of test results, the following conclusions can be drawn:

- It was observed a small amount of workability has been decreased due to replacement of coarse aggregate by recycled aggregate.
- The compressive strength of concrete has been decresed by 25% at 7 days and 30% at 28 days due to replacement of coarse aggregate by recycled aggregate.
- The compressive strength of concrete has been decresed by 10.8% at 7 days and 5.7% at 28 days due to 10% partial replacement of coarse aggregate by recycled aggregate.

By the replacement of coarse aggregate by recycled aggregate in conventional concrete production, the compressive strength of concrete has been decresed but not a significant amout. So that, this replacement of coarse aggregate by recycled aggregate can be done in less important structure and where the concrete of less compressive strength has been required. In addition, the use of recycled concrete aggregate lead to reduction of compressive strength which may be solved by use of recycled coarse aggregate as a 10% partial replacement of coarse aggregate in conventional concrete production.

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PLASTIC WASTE RECYCLING IN KHULNA CITY AND PROPOSAL FOR IMPROVEMENT

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ABSTRACT

Management of plastic waste has become a serious issue in recent years. The used plastic is a threat for marine life and responsible for reduction of fertility of soil and ground water contamination. Because of durability, lightweight and cheap rate the product of plastic has become popular. For these reasons the amount of plastic waste has been increasing recent years in Khulna city. Bottle, jars, bucket and plastic bags are the main form of waste plastic. Recycling can reduce the quantity of Plastic Waste. In this study the existing recycling process of plastic waste in Khulna city is thoroughly observed. From the filed investigation, it has been found that daily 15tonsof plastic wastes are collected. Among those 14.8 tons of plastic wastes are recycled and the amount of waste labelsaround 0.2tons were found to be disposed directly to natural environment. Traditional plastic recycling system was found in Khulna city where the label of plastic bottles is not included in recycling process. Thus, improved plastic waste recycling system such as Mechanical recycling and Chemical recycling would increase the quality and efficiency of plastic waste management in Khulna city.

Keywords: *Plastic wastes, recycling, waste levels, mechanical recycling, chemical recycling, fast pyrolysis.*

INTRODUCTION

Plastic products become a part of our daily activities due to some of its special features like insolubility in water, resistance to corrosion and electricity, easiness of fabrication by heating and molding, long durability, light in weight. Plastics are generally made of carbon, hydrogen, oxygen, nitrogen, chlorine and sulfur. There are two types of plastic thermoplastic and thermosetting. Thermoplastics are linear or nearly cross-linked polymer. There is no chemical change inThermoplastics when it is heated. And the thermosetting plastics are heavily cross linked. In the thermosetting process, a chemical reaction occurs that is irreversible(Klein, 2012). Thermosets can melt and take shape once; after they have solidified, they remain solid for rest longer time(Shimo, 2014). The idea of plastic first came at 1860 when Phelan and Celluloid, a US Pool and BilliardCompany declared prize for the substitute of natural ivory and John Wesley Hyattinvented the first synthetic plastic in 1869. The first manmade plastic was created by Alexander Parkes who publicly demonstrated it atthe 1862 Great International Exhibition in London(Bellis, 2017). The material, called Parkesine, was anorganic material derived from cellulose that once heated could be molded and retained its shape when cooled.(Bellis, 2017). After that john Wesley Hyatt invented celluloid which is derived from cellulose and alcoholized camphor. In 1907 Leo Baekeland invented the first synthetic plastic named Bakelite.Plastic industries flourish commercially in the year 1960 and facing a transition from 1980 to 1986 due to the world economic instability and oil price hike

(Thompson et al., 2009); (Andrady & Neal, 2009);(Knight, 2014); (British Plastics Federation, 2014). The idea of plastic recycling on the other hand began to take shape in 1990s in United states and elsewhere(Shimo, 2014). The plastic was introduced in south Asian region in 1974. From early 1982, polythene bags get it market at every class of people in Bangladesh and within 5 years it turned into a threat to the natural environment of this country ((Halden, 2010); (Leeuwen, 2013)). In this consequence, the Ministry of Environment and Forest Bangladesh banned the commercial distribution, transportation, sales and uses of polythene bags with less than 55 μm in thickness from January 2002 throughout the country and the people of all classes accept this change in a positive manner(Mourshed et al., 2017).

With the increase of industrial advancement and population growth rate the amount of plastic waste is increasing. In 2015 the global production of plastics rose to 322 million tons, a 3.5% increase from the volume for 2014(Maris et al., 2018). The researcher found that currently about 1.7–1.9 billion metric tons/annum (BMTPA) waste is generated worldwide(Modak et al., 2010) and it will reach to 27 BMTPA within 2050 and almost one-third of this wastewill be contributed by the countries of Asia alone(Nations, 2010). Among this huge waste generation, about 50–70% is collected for disposal and uncontrolled landfilling is account for 15% of the collected waste(Modak et al., 2010);(Ramos et al., 2012)The environmental effect of this waste becoming intensifies with the presence of plastic litter which contributes almost 5% of the municipal solid wastes(Sharmin et al., 2016). The per capita consumption of plastic driven products is 100 and 20 kg bythe people from the North-America and Asia respectively (Gourmelon, 2015). The disposal of waste plastics has become a major worldwide problem due to its non-biodegradable property which makes safe and easy disposal complex. Indeed, large amounts of plastic waste have been introduced into the environment through its production and disposal, resulting in its accumulation in ecosystems across the globe, and especially in the ocean(Neufeld et al., 2016).(Jambeck et al., 2015)showed that 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, with 4.8 to 12.7 million MT entering the ocean.Using landfill sites for dumping of plastics is a non-sustainable and environmentally unfriendly option. Although plastic waste management is a global problem, different strategies have been developed in countries and/or continents. It is necessary the disposal or decomposition of plastic waste. The disposal methods Include land filling, mechanical recycling, biological recycling, thermal recycling, and chemical recycling (Cleetus et al., 2013).First plastic industry in Bangladesh started their journey in 1960's by making plastic toys, photo frame and plastic spare parts for the jute mills using handmade mold(Shimo, 2014). From the 2000's plastic recycling takes place through locally developed machines such as shredder, ex- truder and the companies started making plastic chairs, tables and water tank by rotation molding machine (Shimo, 2014). Day by day the plastic industry increases with the increase of the population along with the plastic waste increasing. From a study about the plastic consumption in the urban areas of Bangladesh, it was found that the per capita plastic consumption was 2.07 kg in the year 2005 and sharply increased to 3.5 kg in 2014(Waste Concern, 2015).Khulna is the 3rd largest city in Bangladesh. With the increase of industrial, household and commercial activities, the amount of plastic waste is also increasing in Khulna city. Here, the recycling industries use mechanical recycling process, but most of the steps of this process aremanually assisted. The aim of this research is to observe the current status of plastic waste management practices in Khulna City Corporation (KCC) area and suggest proposal for improvement of existing process.

METHODOLOGY

This study consists of finding out the location of plastic recycling Industry, filed investigation of those industry, observing the whole process of recycling, knowing about the selling practice of recycled plastic, at last the proposal for improvement for the present process.

Selection of study area

Khulna is the 3rd largest city of Bangladesh. It is situated south-western part of Bangladesh between22˚47'16" to 22˚52' north latitude and 89˚31'36" to 89˚34'35" east longitude(Ahsan et al., 2009) is shown in figure 1. The area of Khulna district is 4394 km^2 and the Khulna city area is 20.6 km^2. The population of Khulna city is 1.6 million. Khulna is one of the cleanest cities in the Bangladesh but due to increase in residential, commercial and industrial activities the plastic waste is increasing day byday. Because of improper management the plastics waste cause harm for the environment. So, it has become a vital need for a proper management process of plastic waste.

Survey procedure

In Khulna city the recycling is done by individual recycling industries. It was observed that recycling industries are not situated everywhere of the city. They are located some places of the city name of those places areSonadanga, Zero point, Sheikpara, Rupsa, Lobonchora, Goyalkhali, 1No Navy gate, Jora Gate, Shipyard Gate, Khalispur, Daulatpur, Apil Gate, Fultola. A questionnaire survey has done to know about the present recycling system of plastic waste.Total number of recycling industries in Khulna city has been determined.

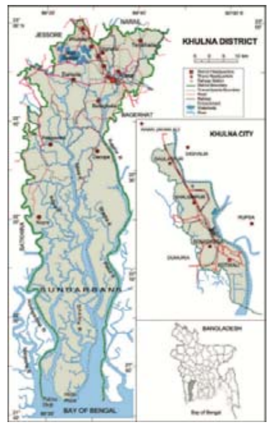

Figure1: Map of Khulna city(M. A. Ahmed & Moniruzzaman, 2018)

Waste management scenario on Khulna city

The total amount of solid waste generation in Khulna city is 550 tons/day and among these the amount of Polythene and Plastics waste is 17.1 tons/day(A. M. Ahmed et al., 2017).But from the survey it is found that the amount of collected plastic waste is 15 ton/day. KCC is the main administration for management of waste in Khulna city. The conservancy department of city corporation has a great contribution for the collection, transportation and disposal of waste in Khulna city. The city corporation authority collects waste form the road side dustbins made of masonry. The numbers of dustbins are approximately 1200. KCC staff collects waste only from two wards (administrative areas). The householders and some non-government Organizations are collected waste from house to dustbin. The KCC collect these wastes and send them to the secondary disposal site by non-motorized vehicles. At last the waste is send to the final disposal site at Rajbandh. Most of the plastic waste from dustbin and other sources are collected by tokai and feriwalain Khulna city.

RESULTS AND DISCUSSION

There are two types of plastic recycling industries in Khulna city. One type makes new product from waste plastic or from shredded plastic. And another makes shredded plastic and after packaging the major part is exported to foreign countries and a minor part is sent to some big plastic industries within the country. The flow diagram for various steps of first type plastic recycling industry in Khulna city are shown in figure 2.

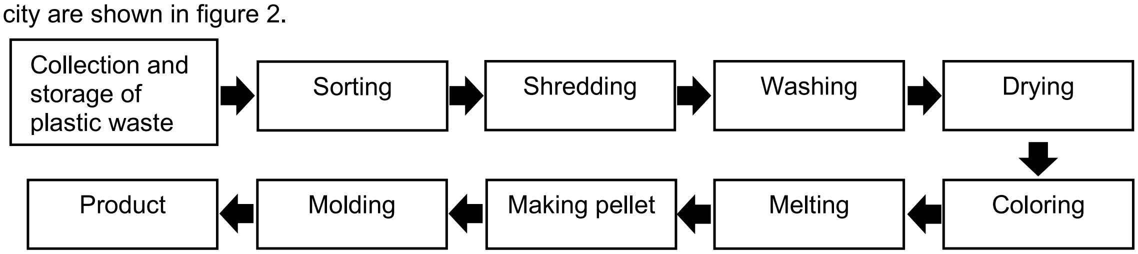

Figure 2: Typical flow diagram of plastic waste recycling infirst type recycling industryKhulna city



Collection and storageSorting Cutting



Washing Drying Color



Melting Making Pellet Molding

Product

Figure 3: Various steps of plastic recycling in first type plastic recycling industry in Khulna city

Collection and storage of plastic waste

Plastics are collected by tokai and feriwala in Khulna city. They sell these wastes to the primary dealer and the primary dealer sell these wastes to the secondary dealer. The secondary dealer sells them to the recycling industry. Industry store them a place.

Sorting: Sorting is done by manual method. The level of plastic bottles is separated form bottle**.**They are not used in recycling. This sorting is generally done by eye inception. They separate theplastic based on their color. More efficiency of this step increases the profit of the recycling.

Shredding: Shredding are done by machine. This machine consists of a motor, a cutter, a conical shape basket. Through the basket the plastics are supplied to the machine

Washing: After shredding the plastics are put in house of water mixed with caustic soda, salt and washed by manual method. Most of the industry use this process.

Drying: After washing shredded plastics are dried in drying machine or under sunlight. Most of the industry use the sunlight for drying the shredded plastic. But in the rainy season they use electric fan for drying the washed shredded plastics.

Coloring: After drying the shredded plastics are mixed with color. Color are mixed based on requirement. From survey it is found that mostly blue, red, black, green color are used for producing grit pot, baby toy etc.

Melting: The flakes are fed into the extruder at large diameter end of the screw and compressed as they arecarried toward the extrusion die. The combined heat from flow friction and supplemental heating bands causes the resin to melt and volatile contaminants are vented from the mixture. Immediately before the die the melted plastic passes through a fine screen that removes remaining solid impurities; this step is known as melting(Moniruzzaman et al., 2012).

Making pellet: After melting through machine, the plastics are put into water bath and make the strands of plastic. This strands become cool. Then these strands are passed thorough a pellet making machine and this machine cut these strands in small uniform pieces.

Product: These pellets are sometimes sold to another industry or put them to inject mold to produce various types of product with the market demand by using mold. In Khulna only grit pot and rope are made from plastic.The flow diagram for various steps of second type plastic recycling industry in Khulna city are shown in figure 4

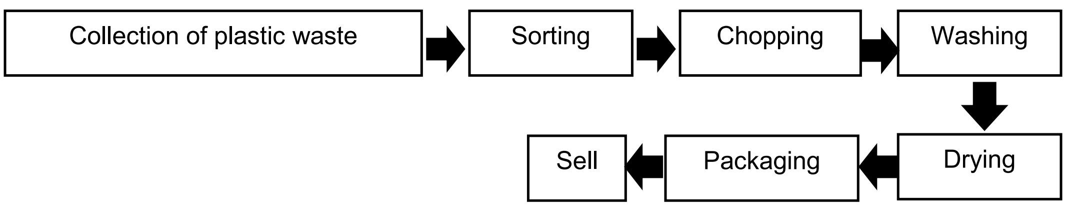

Figure 4: Typical flow diagram of recycling process in second type plastic recycling industry in Khulna city

All the steps are similar to the first type plastic recycling industry except packaging and selling practice. Some pictures of packaging practice and selling practice of second type plastic recycling industry in Khulna city are shown below in figure 5.

Packaging practice of shredded plasticSelling practice of packaged plastic

Figure 5: Packaging practice and selling practice of second type plastic recycling industry

Packaging and selling practice for shredded plastics

After drying the shredded plastics are packaged in 25 kg bag.After packaging the owners of industry import & export these bags. Those bags are mainly export to India and China.

Disposal practice for waste label

The labels are collected in basket during the sorting and after sorting worker throw them in nearest drain or nearest dustbin.

Table 1: Collected plastic waste, recycled waste and waste labels not included in recycling process

Serial no	Industry name	Location	Total collected plastic kg/month	Recycled Plastic wastes (kg/month)	Waste level (kg/month)
01	Metro Plastic	Sonadanga	20000	19590	410
02	J. N. Pet flask	Sonadanga	20000	19590	410
03	Mayer Doya Enterprise	Sonadanga	19000	18610	390
04	Makka Plastic	Sonadanga	19000	18610	390
05	Bismillah Plastic	Sonadanga	19000	18610	390
06	Khaja Plastic	Sonadanga	18000	17631	369
07	Sharif Enterprise	Sonadanga	18000	17631	369
08	Modina Plastic	Sonadanga	18000	17631	369
10	Mukta Plastic	Sonadanga	17000	16651	349
11	Jui Plastic	Sonadanga	17000	16651	349
09	Monoyara Enterprise	Sonadanga	17000	16651	349
12	Lipro Plastic	Moilapota	17000	16651	349
13	Siam Plastic	Sheikhpara	18000	17631	369
14	Sumaya Recycling	Goyalkhali	18000	17631	369
15	Anika Plastic	Goyalkhali	18000	17631	369
16	Modina Plastic Cutting Center	Goyalkhali	17000	16651	349
17	Muniya Enterprise	Goyalkhali	15000	14692	308
18	Hasif Traders	Zero point	17000	16651	349
19	Green Recycle and Packaging	Shipyard gate	15000	14692	308
20	Taha Plastic Industry	Lobonchora	15000	14692	308
21	Jhontu Plastic Cutting	Rupsha bridge	15000	14692	308
22	VaiVai Plastic Cutting Center	Joragate	14000	13713	287
23	Masers Jihad Traders	1 no Navy gate	14000	13713	287
24	Ma Babar Doya plastic	Khalishpur	16000	15672	328
25	Surrma plastic	Doulatpur	15000	14692	308
26	B.B. Traders	Aphil gate	14000	13713	287
27	Mithila Plastic Cutting Center	Fultola	14000	13713	287

It has been found that the amount of plastic waste increase towards the city center. In Khulna city the primary collector of waste plastic is Tokai and Feriwala. They sell them to the local plastic waste dealer in cheap rate. They local dealer sell them to the recycling industry. Also, waste comes from the various locations of Khulna district. This is the main reason of increasing the amount plastic towards the city center.it is found that the amount of plastic waste label is increased towards the city center.

PROPOSAL FOR BETEER PLASTIC RECYLING PRACTICES

Upgrade Mechanical recycling

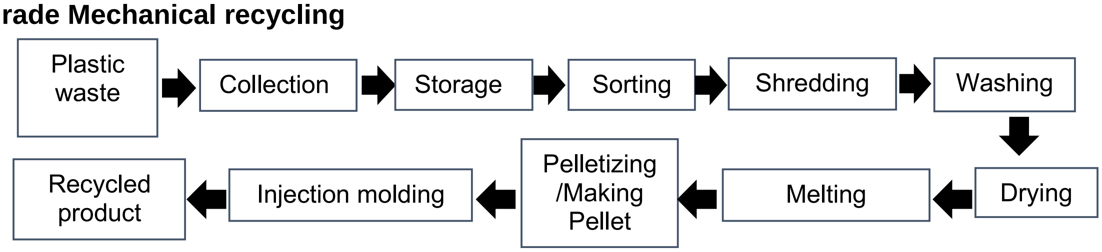

Figure 6:Steps of Upgrade mechanical recycling of plastic waste

In upgrade mechanical Process plastic collection and storage system are same. Sorting, Washing, Dryingare different from the existing process. All others process is almost same.

Sorting

At first, the plastic bottle’s lebel is removed by Label Remover machine. After that the sorting is done.There are various types of sorting process such as FT-NIR (Fourier Transform Near Infrared), Tribo-electric(electrostatic) separation etc. In case of Khulna city, the FT-NIR process of plastic waste sorting for recycling would be preferable. This process separated the mix plastics into PET (Polyethylene Terephthalate) and HDPE (High-Density Polyethylene). These two types of plastics are mostly collected in Khulna city. By Optical color recognition the PET is sorted into clear, blue and green.All those plastic passes through a cabin and well-trained operators check whether the separation is correct or not. After sorting the plastics are sometimes baled for transport offsite.For automatic separation of plastic,FT-NIR is widely used technique; But it has some limitations(Ragaert et al., 2017)

- It is an optical surface technique. Anything which leads to afalse reading will give a false result such as dirt in plastic bottle.
- Products made up of more than one polymer (for example multilayer packaging), will be detected as the one that is presentedtowards the sensor at time of sensing
- NIR cannot identify black or dark products.

Washing and drying

Washing is done by mechanical washer. Drying is done by mechanical drier. Figure 7 show a figure of mechanical washer and a mechanical drier.

Mechanical washer Mechanical drier

Figure 7: Picture of mechanical washer and Mechanical drier

Chemical recycling (Fast pyrolysis)

Various chemical processes currently available in the chemical industry for plastics recycling. Among that fast pyrolysis would be suitable for plastic waste recycling in Khulna city. A wide range of plastic material can be used in fast pyrolysis method in the feedstock. Fast pyrolysis includes all kinds of plastic such as the unwashed, unsorted, or which are hard to recycle. Both shredded and larger pieces of plastic can use in feedstock. At the beginning of fast pyrolysis process waste plastic material is put into a hopper with a forklift. The materials which can be loaded include fuel tanks, plastic car bumpers, component holders, product packaging, agricultural film, and pharmaceutical packaging and so on (Mourshed et al., 2017). Natural gas is used to generate heat. The process started once the hopper is in the reactor. A catalyst is used to break down the hydrocarbon into a shorter chain of molecules. When gasses are started to produce that are not collected as fuel are used to produce heat and keep the process going. The fuel oil and diesel are condensed from a gaseous state into a liquid state, which is collected as the process continues (Mourshed et al., 2017). The process is controlled by an automated system as shown in figure 8. Conversion of waste plastic material into liquid fuels is a feasible process. Also, the rate of fuel does not vary widely along the period ((Jones et al., 2009), (Wright et al., 2010)). The plastic material is heated rapidly to 450–600 °C in the absence of air (Wright et al., 2010). In these process charcoal, liquid tar, and organic vapors are produced. Oil is generated by condensing this vapor. Fast pyrolysis is very important because a clean liquid is produced in fast pyrolysis which can be used for many applications. In 2003, a researcher from Bangladesh have already performed fast pyrolysis technique utilizing waste plastic (Islam et al., 2004). The lab scale research and pilot plant that have already successfully been accomplished in Bangladesh. it holds substantial prospects for proper management of plastic waste in Khulna city.

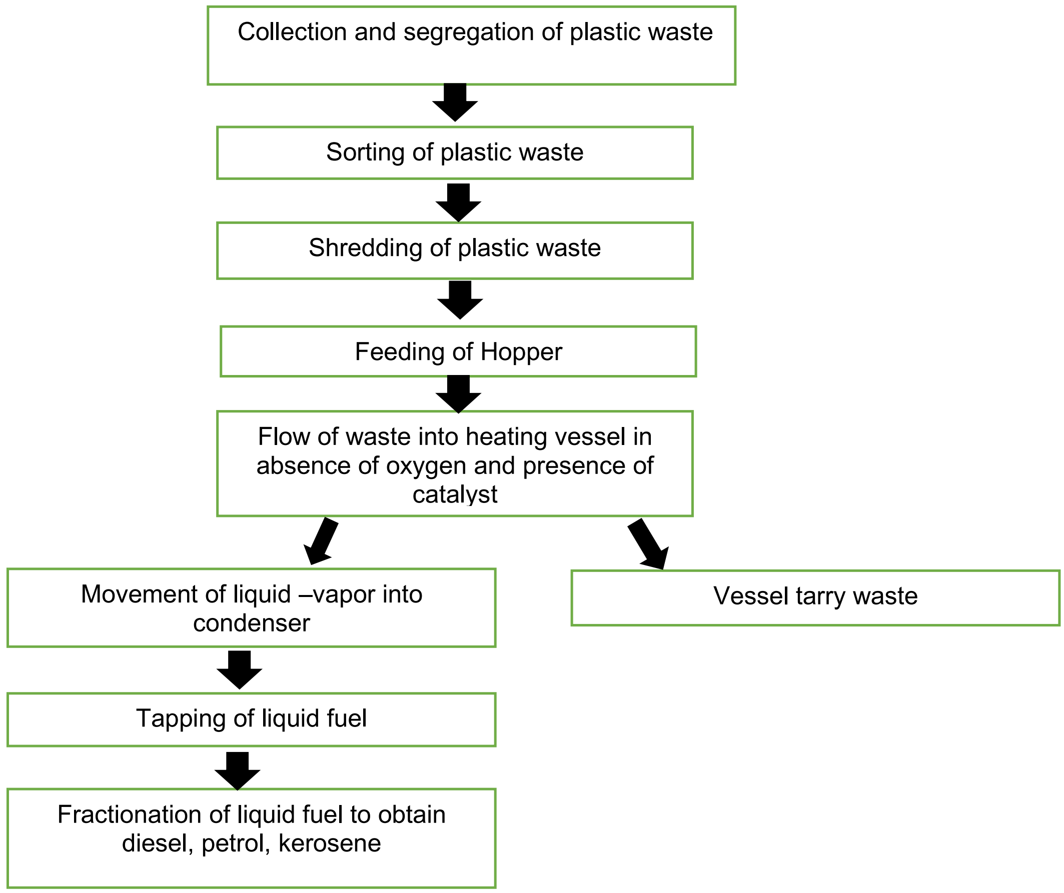

Figure 8: Flow diagram of fast pyrolysis process(Wright et al., 2010)

Proposal for recycling of waste labels

The labels of plastic bottles are considered as useless wastes and not included in the recycling process. Although plastic is a non-biodegradable material but after long time it may become a vital problem for the environment. The waste plastic labels can't be used as a single recyclable material but would be a mixer element in low quality productslike plastic pot, toilet vessel, bicycle pedals, etc.

CONCLUSIONS

Enormous amount of plastic waste is being producedin Khulna city. In this survey 27 plastic industrieswere identified in 14 specific areas of Khulna city. Two types of recycling industries were found in Khulna city.One type makes new product from waste plastic or from shredded plastic. And another makes shredded plastic and after packaging the major part is exported to foreign countries and a minor part is sent to some big plastic industries within the country. Daily collection of plastic is around 15tons and daily recycled amount is approximately 14.8 tons.In Khulna city the labels of plastic bottles are considered to be useless and not included in the recycling process.Daily amount of collectedwaste labels is about 0.2 tons.The recycling industries are entirely managed by private sector.Theplastic waste recycling scheme would have a significant positive impact on the environment because the recycling work is considered as a source of renewable energy.This study suggests the adaptation of upgraded and automated mechanical recycling of waste plastics as well as fast pyrolysis process for chemical conversion waste plastics to new products which would be suitable for Khulna city perspective.

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RISK ASSESSMENT OF SOLID WASTE DISPOSAL ON GROUND WATER QUALITY AROUND RAJBANDH DUMPING SITE

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ABSTRACT

Groundwater samples were collected from tube-wells from Rajbandh dumping site as well as its adjoining area.Concentration of physico-chemical parameters including heavy metals (As, Fe, Mn, Zn, Cu) and microbiological parameters TC and FC were determined in groundwater sample inside Hogladanga landfill. Among physico-chemical parameters alkalinity (259 mg/L), Cl^-(438 mg/L), E.C (960 µS), TDS (902 mg/L)etcmean values were obtained from test results. BOD (0.9 mg/L) and COD (16.78 mg/L) level were also determined. These values actually indicate that groundwater is moderately affected by leachate percolation. For these reason risk assessments was necessary. So, risk assessment was done on those parameters which were exceeded the allowable concentration level referred by DPHE (1936) according to USEPA guidelines (1989) considering ingestion and dermal pathways. The chronic daily intake (CDI), hazard quotient (HQ), hazard index (HI) were evaluated. Furthermore, to check uncertainty of exposure parameters and risk values, Monte Carlo Simulation (MCS) was used. RME showed relatively more risk values than that of CTE values.

Keywords*: groundwater contamination, risk assessment, hazard quotient (HQ), hazard index (HI), Monte Carlo simulation (MCS).*

INTRODUCTION

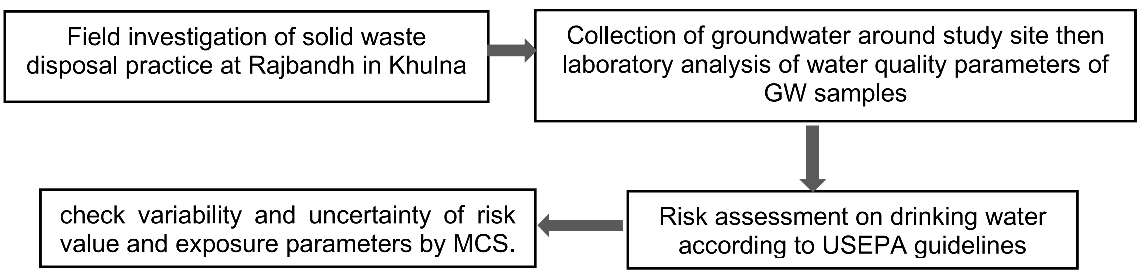
Now-a-days solid waste disposal in the surrounding environment has increased a large amount due to rapid urbanization and industrialization. Population is increasing day by day and undeliberate improvements and waste disorder in Bangladesh city perspectives have created environmental deterioration because huge amount of waste generation and its unplanned disposal in the landfill.Without considering any scientific process, the wastes are sent to the disposal sites mainly low-lying areas, usually by the roadsides thus creating severe impacts on environment and public health. Khulna is the 3rd largest metropolitan industrial and port city in Bangladesh. The enhancement of business and financial activities resulted in a sharp increase in city population. So, the amount of solid waste generation has increased with population. Khulna city corporation (KCC) and community based NGOs are taking care of only 42% of the total waste generated while the rest of them are unaccompanied (Ahsan et.al, 2009). These wastes either dumped in open space or improperly landfilled which is likely to contaminate groundwater.

Landfills have been identified as one of the major threats to groundwater resources(Mor et.al, 2006). Water that has percolated through a solid and leached out some of the materials called leachate generates due to the decomposition of wastes. Leachate percolate the groundwater and causes contamination which pollute the drinking water and cause diseases among the dwellers around dumping site. Contamination of ground water by landfill can spread risk among the dwellers.

Risk analysis is a part of every decision we make. To assess health risk assessment water ingestion and dermal contact were considered according to USEPA guideline (1989). The chronic

daily intake (CDI), hazard quotient (HQ), hazard index (HI) were determined. Health risk assessment procedure provides clear and systematic form of quantitative (or semi-quantitative) description of health and environment risk(Pangkaj et.al, 2018).Risk analysis mainly done on children’s because they behave differently from adults and they have very little control over environment. Children health problems occur frequently due to the contamination of drinking water. Central tendency exposure (CTE) and reasonable maximum exposure (RME) were considered for risk analysis and the differences are given in(USEPA, 1992). The numeric expressions for risk assessment obtained from the USEPA Risk methodology (Kyame et. al, 2016). Monte Carlo simulation (MCS) is a technique for characterizing variability and uncertainty by repeating of risk equation inputs. MCS can see all the possible outcomes of one’s decisions and assess the impact of risk. The results of risk assessment should always contain both the “number” and the “measure of uncertainty” (Biesiada, 2001).
So, the main concept of this paper was to quantify the concentrations and health risk effect associated with heavy metals (As, Fe, Mn, Zn, Cu) as well as physico-chemical parametersdue to groundwater contamination among the dwellers around Rajbandhdumping site specially for children considering central tendency exposure (CTE) and reasonable maximum exposure (RME) for non-carcinogenic condition because children are more vulnerable than adults to environmental risks.

METHODOLOGY



Selection of study area

Municipal solid waste (MSW) dumping system is divided into two parts one is open dumping system and another is sanitary landfill. Sanitary landfill is one of the decisive and safe facilities for the disposal of MSW. A pilot scale sanitary landfill is situated at Rajbandh(Islam et al., 2013) Khulna in the north side of Khulna-Satkhirahighway and 8 km far from the city center.A broad reconnaissance surveys were done and then groundwaters were collected from tube-wells from 4 locations around landfill site.

Location:

Latitude: 22º47’43.17’’
Longitude: 89º29’58.35”

Fig 1: Selected study area at Rajbandh from google earth

Analytical methods

After the sampling, the samples were immediately transferred to the laboratory and were stored in Refrigerator. The analysis was started without any delay in the lab based on APHA (1994) methods. All the samples like physico-chemical parameters, heavy metals and total coliform (TC) and faecal coliform (FC) were analyzed by APHA (1994) methods. In case of physico-chemical parameters includes color, nitrate (NO_3^-) (reagent: NitaVer 3 Nitrate), Electro-conductivity (EC)(instrument: EC meter), phosphate (PO_4^{3-}) (reagent: PhosVer 3 Phosphate), sulphate (SO_4^{2-}) (reagent: SulfaVer 4 sulfate) were tested by DR2700 Spectrophotometer. On the other hand, in case of heavy metals includes arsenic (As) (reagent: sulfonic acid and zinc powder, method: strip test method), iron (Fe) (reagent: FerroVer Iron), manganese (Mn) (reagent: buffer powder citrate and sodium periodate)were tested by DR2700 Spectrophotometer (Preprogrammed methods: >130 Pre-programmed Water Analysis methods, Wavelength accuracy: +/- 1.5 nm, wavelength range: (400-900)nm). Zn, Cu were tested by AA 7000 Series Atomic Absorption Spectrophotometers. pH was tested by pH meter. Turbidity was tested by Turbidimeter. Hardness, chloride (Cl^-), alkalinity was tested by titration. COD was tested by closed reflux method and was used COD calibration curve.TC and FC were tested by membrane filtration method.TDS was tested by gravimetric method.BOD test was done by 5-days BOD test method.

Risk assessment process

Risk assessment process was done on which parameters were exceeded allowable limit referred by DPHE (1936). It is customary(Biesiada, 2001) to distinguish the following stages of risk assessment process:

- Hazard identification
- Exposure assessment
- Evaluation of dose-response relationship
- And finally risk characterization and uncertainty analysis

The human health risk assessment methodologies for aquatic ecosystems has been described literature (Kyame et.al, 2016). The ingestion and dermal absorption are common for water exposure (Kyame et al., 2016). The numeric expressions for risk assessment as obtained from the USEPA Risk Assessment Guidance for Superfund (RAGS) methodology (Kyame et. al, 2016) are given as follows:

CDI_{ing}= (1)

CDI_{derm}= $\frac{Cw \ x \ SA \ x \ CF}{\quad}$ (2)

Where CDI_{ing} = chronic daily intake (mg/kg/day), Cw = metal concentration in water (mg/L), WIR = water ingestion rate (L/day), ABSs = absorption factor (%), SA = surface area available for contact (cm^2), CF = volumetric conversion factor for water (L/cm^3), PC = metal specific dermal permeability constant (cm/hours), ET = exposure time (hours/event), EF = exposure frequency (days/year), ED = exposure duration (years), BW = body weight (kg), AT = average time (days).

The values of several factors (body weight, ingestion rate, body surface area etc) or parameters (contact frequency, contact duration, lifetime exposure) with various exposure pathways for Central Tendency Exposure(CTE) and Reasonable Maximum Exposure (RME) were followed by RAGS (USEPA, 1989). These exposure parameters have specified value for specific conditions is shown below:

Table 1: Values of exposure parameters for risk assessment used in this study

Exposure pathway	Child				References
	Variable	CTE value	RME value	Unit	
Water dermal contact	SA	5140	5140	Cm^2/event	USEPA Handbook 2001
	ABS	1	1	Unit less	
	ET	8	8	Hours/day	
	EF	200	225	Days/year	
	ED	5	5	Years	
	BW	13.2	13.2	Kg	
	AT	365*ED (non-carcinogenic condition)		Days	
Water ingestion	WIR	1.8	1.8	L/day	(RAGS, 2013)
	ABS	1	1	Unit less	USEPA Handbook 2001
	EF	200	225	Days/day	
	ED	6	6	Years	
	BW	13.2	13.2	Kg	
	AT	365*ED (non-carcinogenic condition)		Days	

The values of permeability constant (PC), RfDsin case of dermal and ingestion for different heavy metals are given in table 2.

Table 2: Dermal permeability (PC) values and RfD for non-carcinogenic risk of different heavy metals

Parameters	PC (cm/hr)	RfDing (mg/kg-day)	RfDderm (mg/kg-day)	References
As	1.00E-03	3.00E-03	1.23E-04	(Masok et.al, 2017) (Li & Zhang, 2010) (USEPA, 1989)
Fe	1.00E-03	9E-03	7E-01	
Mn	1.00E-03	4.60E-02	1.84E-03	
Zn	6.00E-04	3.00E-01	6.00E-02	
Cu	1.00E-03	4.00E-02	1.20E-02	

Toxicity assessment

Heavy metals are responsible for toxicological risk than physico-chemical and biological parameters. In broad sense toxicity is the knowledge of poisons and finding the dose and response of the receptors to cause a health risk. From toxicological point of view, risk is divided into two parts one is carcinogenic risk and the other is non-carcinogenic risk. Essentially all chemicals can cause non-carcinogenic adverse health effects if given at a high enough doses (Pangkaj et.al, 2018). No unfavorable effect is executed in case of sufficiently low amount of dose. The reference dose (RfD) is considered for non-carcinogenic condition and was followed from RAGS (USEPA, 1989).

Health risk assessment

The riskwhich can cause by physico-chemical parameters or heavy metals otherwise, biological parameters. The constituents which can bring risk among the dwellers around dumping site were identified by hazard quotient (HQ). The formula is given below:

HQ = (3)

Where dose = CDI_{ing}/ CDI_{derm}values of different parameters, RfD= Reference dose. Hazard quotient greater than 1 provides evidence that apotential health risk associated with chronic exposure to agiven substance does exist. Otherwise, it is assumed thatthe risk is at acceptable level(Biesiada, 2001).

To evaluate the overall potential for non-carcinogenic effects posed by more than one heavy metal, the computed HQs for each heavy metal are expressed as a Hazard Index (HI)by equation 4 (Masok et.al, 2017).

$HI_{ing/derm}$ (4)

Where $HI_{ing/derm}$ is hazard index via ingestion, dermal (unit less).

Monte Carlo Simulation (MCS) technique

MCS is a technique for characterizing variability and uncertainty by repeating of risk equation inputs. In case of variability, it refers water consumption capacity per day are different between the consumers and this may also due to differences in exposures.

On the other hand, different ages people drink different amount of water per day but how much water can bring risk due to water intake is uncertain is called uncertainty. MCS deals with those two parameters.

RESULTS AND DISCUSSION

At first the concentration of water quality parameters (20nos) were determined in the laboratory and compared with allowable limit referred by DPHE (1936)for groundwater sample in location 1 at the center of the landfill. The data are shown in table 3

Table 3: Obtained value of water quality parameters

Water Quality parameters	Obtained value	Bangladesh standards	Comments
pH	7.2	6.5- 8.5	Acceptable
Color (Pt- Co units)	16	15	Not acceptable
Turbidity (NTU)	4.44	10	Acceptable
Hardness (mg/L as $CaCO_3$)	213	200-500	Acceptable
Alkalinity (mg/L)	295	200	Acceptable
Arsenic (mg/L)	Nil	0.05	Acceptable
Nitrate (mg/L)	0.2	10	Acceptable
Chloride (mg/L)	420	150-600	Acceptable
Iron (mg/L)	0.47	0.3-1	Acceptable
TDS (mg/L)	860	1000	Acceptable
BOD_5 ppm	0.9	0.2	Not acceptable
COD ppm	16.78	4	Not acceptable
Conductivity (µS)	1400	-µs/cm	Not acceptable
Phosphate (mg/L)	0.54	6	Acceptable
Manganese (mg/L)	0.5	0.1	Not acceptable
FC (N/100mL)	45	Nil	Not acceptable
TC (N/ 100mL)	100	Nil	not acceptable

Sulfate (mg/L)	0.00	400	Acceptable
Cu (mg/L)	0.1	1	Acceptable
Zn (mg/L)	0.1	5	Acceptable

From the obtained data it is noticed that the concentration of some parameters are exceeded the allowable limit and risk assessment process was done for those parameters according to USEPA guidelines. Table 4 represent CTE, non-carcinogenic condition for children.

Table 4: Summary of Health risk assessment for physico- chemical, heavy metals and biological parameters in GW1 for Central Tendency Exposure condition (CTE), (non-carcinogenic condition)

Parameters	CDI (Child)		RfD_{ing}	RfD_{derm}	HQ (Child)		Total HQ
	Ingestion	Dermal			Ingestion	Dermal	
Alkalinity	22.042	0.504	200	200	0.110	2.52E-03	0.123
BOD	67.2E-03	1.54E-03	0.2	0.2	0.336	7.7E-03	0.344
Fe	35.12E-03	8.02E-04	9.00E-03	7.00E-01	3.902	1.15E-03	3.903
As	0.00	0.00	3.00E-04	1.23E-04	0.00	0.00	0.00
Chloride	31.382	0.717	250	250	0.126	2.68E-03	0.128
COD	1.254	0.028	4	4	0.322	7E-03	0.33
Mn	0.0374	8.53E-04	4.60E-02	1.84E-03	0.813	0.464	1.277
Cu	7.47E-03	1.71E-04	4.00E-02	1.20E-02	0.187	0.014	0.201
Zn	7.47E-03	1.02E-04	3.00E-01	6.00E-02	0.025	1.7E-03	0.027

The above sample calculations are done on Hogladanga landfill (location1) groundwater sample, because it is located in severe location. From the calculation it is said that, Fe and Mn cross the risk limit. BOD, COD are in moderate conditions and the rest of all are within limit. RfD for ingestion and dermal in case of physico-chemical parameters and biological parameters are considered their allowable limit by converting mg/L unit to mg/kg/day unit. Then the water samples were collected from Joykhali landfill (location 2), Progati Secondary School, Hogladanga (location 3) and R.S.O Hasari and culture (location 4). Mainly heavy metals were tested on these samples, because final variability and uncertainty mainly done on heavy metals.

Table 5: Concentration of heavy metals and physico-chemical parameters in groundwater samples

Parameters	Locations		
	Joykhali landfill	ProgatiSecondary School, Hogladanga.	R.S.O Hasari and culture
As (mg/L)	Nil	Nil	Nil
Fe (mg/L)	0.23	0.32	0.09
Mn (mg/L)	0.10	0.10	0.00
Turbidity (NTU)	2.11	3.01	1.95
pH	7.60	7.64	7.82
E.C (μS)	538	1102	800

Chloride (mg/L)	230	600	500
Alkalinity (mg/L as CaCO3)	255	260	225
TDS	486	1280	980

Uncertainty analysis (using 1-D Monte Carlo Simulation)

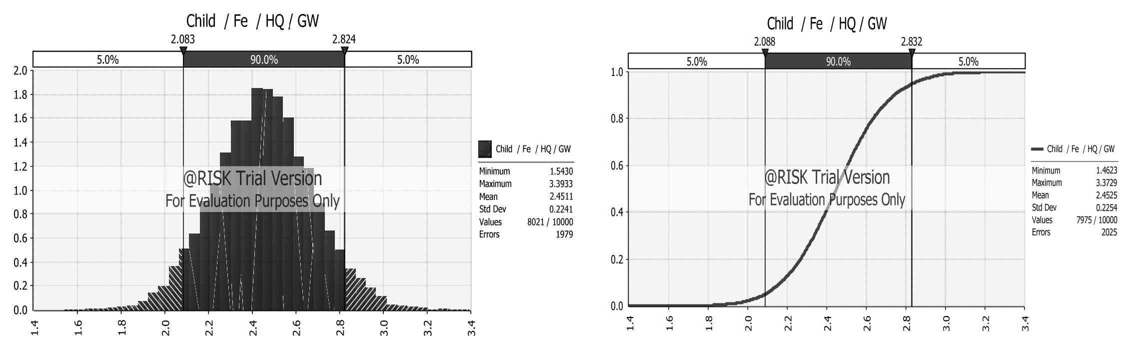
For the uncertainty analysis by MCS some calculations were made on Fe, Mn and As because these are heavy metals and MCS mainly deals with heavy metals. Hazard quotient (HQ) and hazard index (HI) were calculated based on mean condition and are shown below.

Table 6: Tabulated value of HQ and HI on heavy metals (Fe, Mn, As) for MCS operation

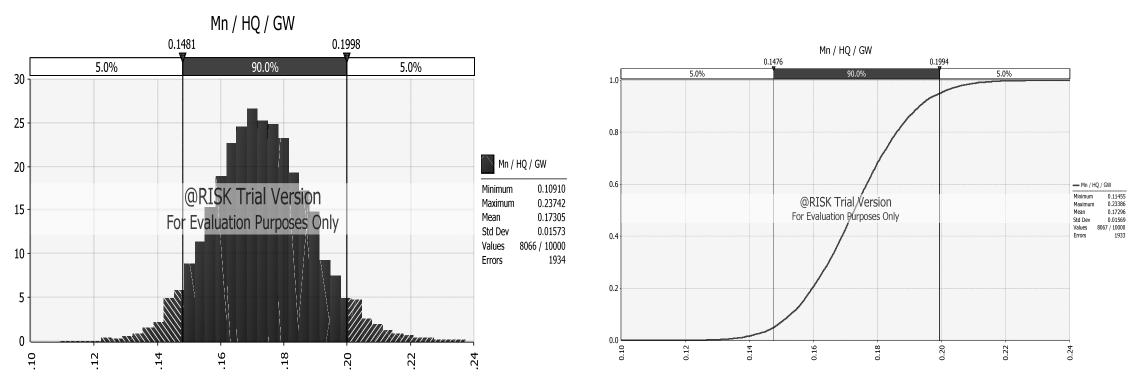
		Locations	Fe	Mn	As	HI
CHILD	CTE	GW1	0.47	0.5	0	
		GW2	0.23	0.1	0	
		GW3	0.32	0.1	0	
		GW4	0.09	0	0	
		Min	0.09	0	0	
		Max	0.47	0.5	0	
		Mean	0.2775	0.175	0	
	Ingestion	CDI (min)	6.72E-03	0.00E+00	0.00E+00	
		CDI (max)	3.51E-02	3.74E-02	0.00E+00	
		CDI (mean)	2.07E-02	1.31E-02	0.00E+00	
		HQ (min)	7.47E-01	0.00E+00	0.00E+00	
		HQ (max)	3.90E+00	8.12E-01	0.00E+00	
		HQ (mean)	2.30E+00	2.84E-01	0.00E+00	2.59E+00
	Dermal	CDI (min)	1.54E-04	0.00E+00	0.00E+00	
		CDI (max)	8.02E-04	8.53E-04	0.00E+00	
		CDI (mean)	4.74E-04	2.99E-04	0.00E+00	
		HQ (min)	2.19E-04	0.00E+00	0.00E+00	
		HQ (max)	1.15E-03	4.64E-01	0.00E+00	
		HQ (mean)	6.77E-04	1.62E-01	0.00E+00	1.83E-01
	HI		2.30E+00	4.47E-01	0.00E+00	

	RME					HI
CHILD	Ingestion	CDI (min)	7.57E-03	0.00E+00	0.00E+00	
		CDI (max)	3.95E-02	4.20E-02	0.00E+00	
		CDI (mean)	2.33E-02	1.47E-02	0.00E+00	
		HQ (min)	8.41E-01	0.00E+00	0.00E+00	
		HQ (max)	4.39E+00	9.14E-01	0.00E+00	
		HQ (mean)	2.59E+00	3.20E-01	0.00E+00	2.91E+00
	Dermal	CDI (min)	1.73E-04	0.00E+00	0.00E+00	
		CDI (max)	9.03E-04	9.60E-04	0.00E+00	
		CDI (mean)	5.33E-04	3.36E-04	0.00E+00	
		HQ (min)	2.47E-04	0.00E+00	0.00E+00	
		HQ (max)	1.29E-03	5.22E-01	0.00E+00	
		HQ (mean)	7.61E-04	1.83E-01	0.00E+00	1.83E-01
	HI		2.59E+00	5.02E-01	0.00E+00	

In MCS, discursive values are selected for each of the tasks, based on the range of estimates. The model is calculated based on these discursive values. The result of the model is recorded, and the operation is revolved. A typical MCS calculates the model hundreds or thousands of times, each time usingseveral discursively- selected values. When the simulation is complete, a large number of results from the model are obtained, each based on discursive input values. These results are used to describe the expectancy or probability of reaching various results in the model. The analysis of uncertainty of exposure parameters and risk outputs were executed using 1-D MCS @Risk 7.5 with 10000 times iterations. In figure 2 the height of the bars (the y-axis) represents the relative frequency of Iron and Manganese and the spread of the bars (the x-axis) is the varying amounts of them.
The normal distribution of HQ for Fe and Mn in case of water ingestion and dermal contact is shown in Figure 2 with the values of minimum, maximum, mean and standard deviation. The total normal distribution is represented by both the PDF and CDF which represented the summary of statistics, but are useful for conveying different information. From figure 2 both (a) and (b) 90% CI values indicating that after considering the uncertainties on the risk parameters of HQ for Fe and Mn in case of water ingestion and dermal contact it can be confidently said that the true HQ should lies between 2.083 to 2.824 and 0.1481 to 0.1998.



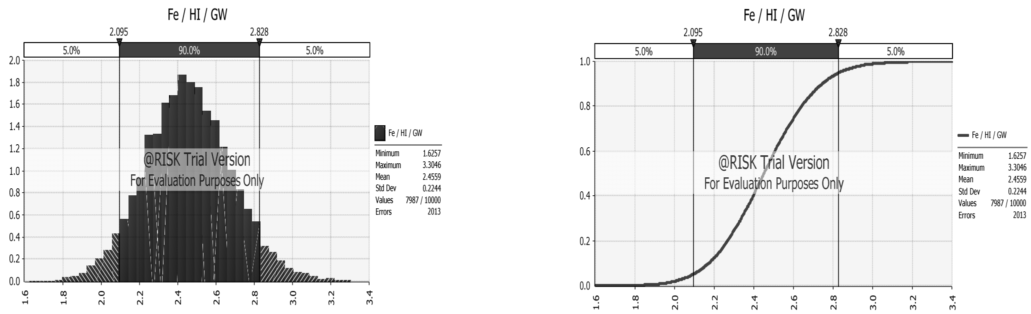
(a)



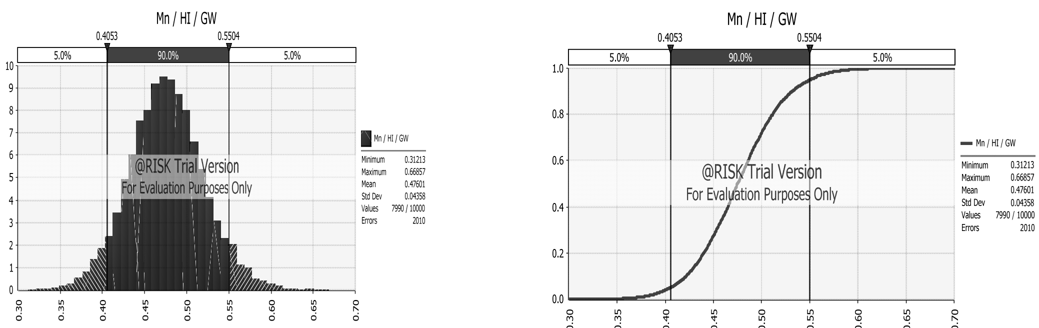
(b)

Figure 2: Normal distribution of HQ of Fe and Mn of child for (a) ingestion (b) dermal for GW also Bell-shaped curve represents the PDF and S-shaped curve represents the CDF

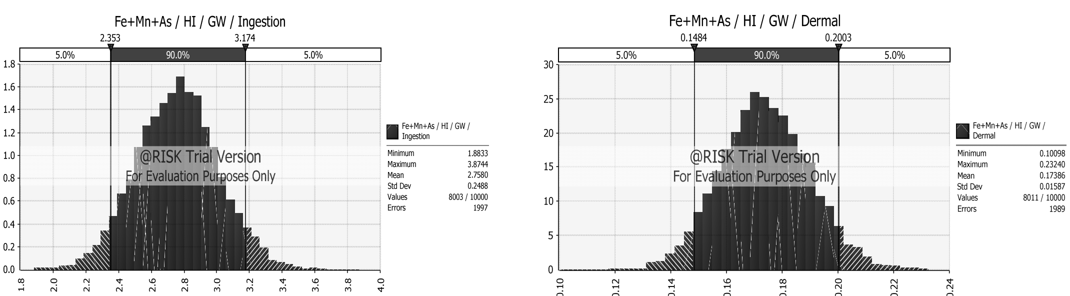
Hazard Index (HI) means the sum of the HQs for multiple substances or multiple exposures pathways from Environmental Terminology (2014) by Arizona Department of Environmental Quality. The hazard index cannot be translated to a probability that adverse effects will occur, and is not likely to be proportional to risk. Graphical representation of risk parameters (HI) are shown in figure 3.



(a)



(b)



(c)

Figure 3: Normal distribution of HI of Fe and Mn of child for GW also Bell-shaped curve represents the PDF and S-shaped curve represents the CDF

CONCLUSIONS

The moderately high concentration of E.C, chloride, alkalinity, TDS in groundwater near landfill deteriorates the drinking water quality. Further, the presence of Chloride, NO_3^-, BOD and COD can be used as tracer with leachate percolation. The First sample was moderately found to be bacteriological unsafe. As there is no other possible reason for high concentration of these parameters, it can be concluded that leachate has significant influence on groundwater quality near the area of Rajbandh landfill site. The tested results also indicate that the concentration of these water quality parameters have greatly reduced from landfill zone to surrounding area.Further risk assessment process has done on those parameters which have crossed the allowable limit. Results reveals that Fe and Mn have crossed the risk limitand the rest of all parameters are within limit. HQ value of Fe and Mn are greater than 1 for ingestion where the acceptable limit of HQ is 1 for non-carcinogenic health effect. The concentration of Arsenic (As) was nil for all locations. In case of HI the value of Fe is greater than 1 both CTE and RME conditions. Also, in case of pathway HI is greater than 1 for ingestion. So, result reveals that Fe and Mn can spread risk through water ingestion over a long period.The result of MCS was given in the form of a probability distribution of risk. The idea of MCS in health risk assessment regarding the exposure to heavy metals in groundwater was illustrated.The accommodation of some another heavy metals can bring more specific risk assessment.

ACKNOWLEDGEMENT

This research was funded by Faculty of Civil Engineering, KUET as well as by providing sufficient lab facilities.

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MANAGEMENT AND RECYCLING OF ELECTRONIC WASTE IN KHULNA CITY

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ABSTRACT

Electronic waste recycling management is very important for sustainable development of a city as well as a country. Electronic waste (e-waste) is becoming a great crisis for the society of Bangladesh. Recycling activity in Bangladesh is mainly performed by the waste collector and dealers from different area as the local government is no concerned and sell them in the recycling shop. To overcome these problems and to make the e-waste management system effective recycle may be the best way in case of developing countries because it serves in two ways, reduce e-wastes and generate resources. In this research, waste generation rate and recycling approach of e-waste was investigated by field survey and questioner survey in the Khulna city of Bangladesh. A complete assessment on e-waste collectors to the recycling shops in the private sector was performed. At first, the survey was conducted among the primary e-waste collectors to find out the amount of e-waste they collect daily and their financial condition. Then the number and location of the e-waste recycling shops in Khulna were identified. The collected information was used to estimate the amount of recyclable e-waste daily collected in Khulna city, the number of workers involved in recycling and the amount of recycled products. After the total work, it was found that about 4011 kg of recyclable e-waste was generated daily in Khulna city. There were about 352 shops and 3107 people involved in the e-waste recycling process. About 45% or 1877 kg e-waste are used for recycling purpose. Among that only 12 % are recycled in Khulna city and the rest of the recyclable waste is sent to Dhaka, the capital city of Bangladesh as raw material for the new product.

Key words: e-waste, waste management, recycling, Khulna city, environmental effect.

INTRODUCTION

The electronic waste generation is increasing day by day due to rapid urbanization and population increase in most of the developing countries as well as in Bangladesh. Electronic waste includes waste electronic goods which are not useable for their purpose. Electronic products nearing the end of their useful life when they are not working regarded as waste. Television box, Digital video box, computer parts, circuit board, mobile phone are some example of e-waste. This product must be reused or recycled to avoid hazardous condition. Electronic abandons is one of the developing segments of our total waste stream. Without proper management of electronic waste may cause serious harmful effect on environment and human health, though these reuse and repair of those waste in the developing country are very likely. Lead containing glass such as CRTs, may contain pollutants such as lead, cadmium, beryllium etc. (Ramachandra and Saira, 2004). leaches from the landfill and contaminate groundwater. Even in developed countries waste collectors and peoples associated with the recycling process is in the unsafe exposure may create serious health hazard. In Dhaka (the capital of Bangladesh) Around 1,20,000 urban poor from the informal sector have been found to be involved in the e-waste recycling trade chain (Riyad, 2014). Rapid changes in technology and low prices of electronics have resulted in huge amount of electronic waste around the globe. In United States Around 500 million computers became outmoded between 1997 and 2007 and 610 million computers had been outmoded in Japan by the end of December 2010(Hicks, 2005). According to BEMMA (Bangladesh Electric Manufacturer and Merchandiser Association); Around 3.2 million tons of electronic products each year is consumed in Bangladesh (ESDO, 2010). 20 to 30 percent of the total waste are recycled and the rest is released in open space sometimes in landfills. (Ahmed, 2010).

E-WASTE AND E-WASTE LIFE CYCLE

E-waste Life Cycle

"Electronic waste" may be defined as rejected computers, mobile phone, refrigerator, office and household electronic equipment, entertaining device electronics such as television sets etc. This definition includes the electronics unfit for further use. Computer and television monitor contain high concentration of lead and phosphors are another source of e-waste. E-waste containing products such as Televisions and computer monitors, Computers and computer monitors and key boards, Bulbs, Telephones, cellular phones and other wireless devices, Video cameras, Fax and copy machines, Video game VCRs and DVD players etc.

The e-waste life cycle consists of Electrical and Electronic Equipment (EEE) i.e. production, sales, consumption. Waste of Electrical and Electronic Equipment (WEEE) consists of generation, treatment, disposal and finally in the landfill site. The life cycle of e-waste is shown in figure 1.

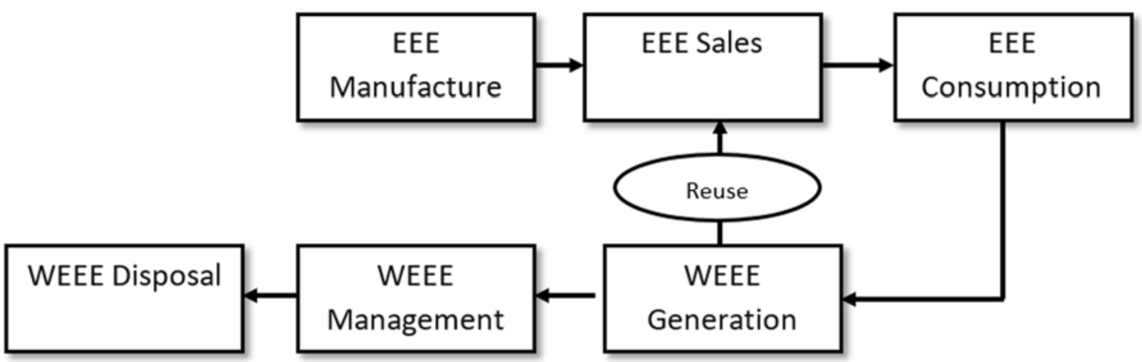

Figure 1 Life Cycle of Electrical and Electronic Equipment

OBJECTIVES OF THE STUDY

The paper is, however, more focused on the following objectives;

- To determine the total amount of electronic wastes that has been generated in Khulna city,
- To analyze the management system and recycling pattern of electronic wastes.
- To describe the harmful impact of electronic wastes on the environment and health of the people in Bangladesh.
- To suggest for sustainable e-waste management.

METHODOLOGY

Study Area

Khulna is the 3rd largest city of Bangladesh, is located in the south-western part of the country. It is situated below the tropic of cancer, around the intersection of latitude 22.49-degree North and longitude 89.34-degree East (KCC 2005). The population of Khulna city is 1.5 million (KCC 2005). The area of Khulna city is 47 square km and it is divided into 31 wards. A large number of e-waste collection are there in Khulna city. Most of the shops are situated at sheikpara area in Khulna city. Fulbarigate, Dowlotpur, Alamnagar, Goalkhali, Bastuhara, Sheikpara are the place where mainly the e-waste recycling shops in the city are located. Mainly those places were visited to collect the primary data through field observation, direct measurement and questionnaire survey.

DATA COLLECTION PLANNING

To perform a study on the existing recycling process in Khulna city a reconnaissance surveys was conducted. This survey was conducted among those people who are related with the recycling process such as e-waste collectors, shopkeepers and workers of waste shops, workers and owners of recycling industries etc. This total survey is done in different stages which may be classified in three main categories.

- Survey among primary e-waste collectors
- Survey at the e-waste recycles shops
- Survey at the e-waste recycles factories

Primary e-waste collectors

Primary e-waste collectors collect the e- waste from house or dustbins or other place and sell to the e-waste recycle shops. But they collect the e-waste as a mixed waste with glass, plastic, paper, metal etc. Two types of primary e-waste collectors arc found in KhuIna city area. The- waste picker and house to house e-waste collectors locally named feriwala. The feriwala collect waste from streets, municipal bins and other places. Information about the primary e-waste collectors are collected from their working places and information about the feriwala is collected in two ways, firstly the shop where the feriwala sell their e-waste and secondly direct conversation with them.

Waste recycling shops

The e-waste recycle shops are situated in more or less clustered form in different parts of the city. These shops are located by roaming through the main roads of the city. It is easy to find out the clusters of e-waste recycling shops but it is difficult to find out the actual number of shops as some scattered shops may not be counted. At this stage of the survey total 348 shops are found. The shops were categorized according to their e-waste handled per day as shown in **Table 1**.

Table-1: Shops category according to their waste generation rate.

Category	E-waste handled(Kg/day)	Number of shops
Large	>20	2
Medium	10-20	15
Small	<10	10

Waste recycling factories

Most of the e-waste is sent to Dhaka for processing. Only a small amount of e-waste is processed in local factories. These factories are located at the sheikpara area of Khulna city.

DATA ANALYSIS

Waste recycling shops are categorized and field survey was conducted to collect the data. It is not possible to take detailed information about all the shops because everyone does not agree to provide data, all shops are not opened at a time and there is time limitation also. After categorizing the shops detailed information about each category are collected. To collect the information a questionnaire form is developed and then filled up by direct measurement with the shop owners or workers. These information includes the quantity of e-waste material, type of e-waste, the number of workers, their working hour, their salary, the collection process of e-waste, buying and selling places etc. The detail information of the location of the e-waste recycling shops, number of worker and their salary, number of shops and their waste generation rate are shown in Table 2.

Table 2 E-waste generation collection rate, number of worker and their average salary of e-waste recycling shops in Khulna according to their location.

Location	Types of shops	No. of shops	Amount of e-waste (Kg/day)	No. of workers	Average salary (TK)
Fulbarigate	Small	10	64	30	3200
Dowlotpur	Small	16	124	48	4000
	Medium	5	92	28	4200
Alamnagar	Small	10	72	30	4000
	Medium	15	195	75	4200
	Large	2	46	18	4500
Goalkhali	Small	2	16	5	3500
	Medium	5	83	24	4200
Bastuhara	Small	18	103	54	3800
	Medium	2	30	10	3800
	Large	1	22	8	4200
Sheikpara	Small	120	960	362	4200
	Medium	76	1247	382	4200
	Large	20	520	159	4700
Others	Small	37	222	111	3800
	Medium	10	144	50	3800
	Large	3	71	24	4200

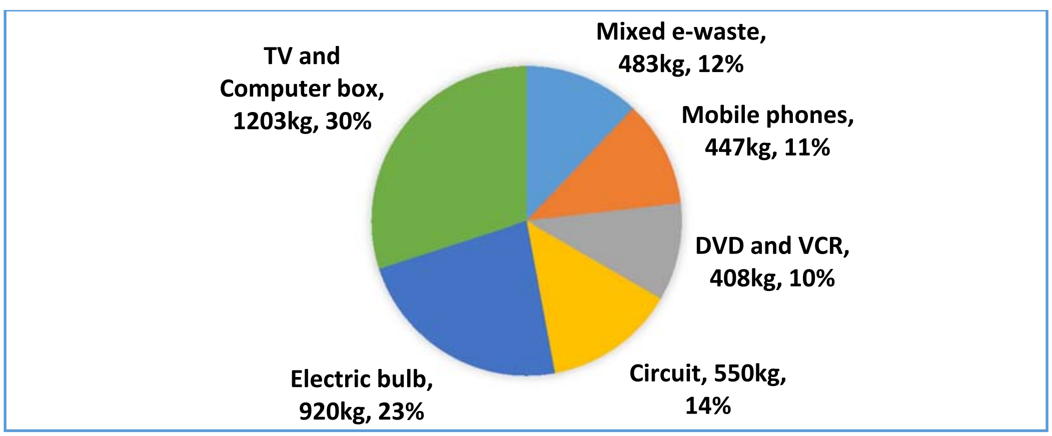

Figure 1. Percentange and amount of different types of electronic waste in Khulna city.

The percentage of different types of waste such as TV and Computer, Electric bulb, Circuit, DVD and VCR, Mobile phones and mixed e-waste were 30%, 23%,14%, 10%, 11% and 12% as shown in Figure 1. The wastes are collected by the waste collectors and feriwala and sold it to the recycling dealers at different prices. Finally, it was collected by recycling factories. The Price of e-waste at different recycling levels are shown in Table 3.

Table 3 Price of e-waste at different recycling levels.

Type	Waste collectors(Tk/Kg)	Feriwala(Tk/Kg)	Recycling dealers(Tk/Kg)	Recycling factories(Tk/Kg)
Television and Computer box	0	1.5	3-10	20-25
Circuit	0	50-60	80-100	200-350
Electric bulb	0	1-2	2-5	6-10
Mobile phone	0	80-120	150-200	250-300
DVD/VCR	0	20-30	40-50	60-70
Mixed waste	0	5-8	12-15	20-25

DISCUSSION

E- Waste Management in Khulna: A Recent Scenario

The twentieth century marked the beginning of use of equipment's like radio, television and a ground breaking discovery - the first computer. With the development of science and technology resulted in availability of electronic products at cheap prices. New electronic appliances have infiltrated every aspect of our daily lives, providing society with more comfort, health and security, with easy and faster information acquisition and exchange (Satish Sinha 2010). Wastes are normally collected from general household, commercial site and departmental stores by the waste picker or feriwala. Collected wastes are primarily deposited in the open-air or in closed Storehouses. Normally the storage system is undisciplined. Then the collected wastes are sold in the recycling shops and sorted on the basis of their category. In this shop mainly iron, aluminum, plastic, glass wastes are collected in smaller portion. After collection of the e-waste some portion of them are sent to Dhaka (capital of Bangladesh), some are sold in local market, some are sent to the local industries and remaining portion are dumped in the landfill site by Khulna city corporation.

IMPACT DUE TO E-WASTE HAZARD

Improper disposal of e-waste in open spaces without apposite measures cause serious environmental pollution. A lack of information and awareness in the handling and recycling of these waste products can leave people exposed to health hazards. A study shows that the samples of pollutants obtained from e-waste caused significant increases in both IL-8 (Interleukin-8) and ROS (Reactive Oxygen Species) levels indicators of an inflammatory response and oxidative stress respectively may lead to DNA damage (Yang et al. ,2011). From e-waste containing materials such as mercury, lead, cadmium many problems may arises brain disorders, Kidney, renal and neurological damage, Mental retardation, Behavioral problems, Hearing impairment Lung damage, Fragility of bones, High blood pressure, Nerve and brain damage, Kidney and liver disease etc. (ESDO,2010). E-waste is also harmful for our farming land and considerably reduce productivity of the land. Leachate from e-wastes landfilling site may pollute the ground water. If the Cathode Ray Tube(CRT) is crushed and burned, it creates serious pollution in the air (Ramachandra and Saira, 2004). In Bangladesh due to the lack of proper laws and regulation it is dumped illegally or in landfill without treatment. Sometimes wastes are dumped in the river which may contaminated ground water with lethal chemicals.

CONCLUTION

From the total survey and above estimation can be concluded-

- About 4011 kg of electronic waste are collected in Khulna city daily. Major portion of which is TV and Computer box, Electric bulb.
- The collection of electronic waste is satisfactory in Khulna city but the processing of the e-waste is poor. The e-waste recycling factories are not found in Khulna city.
- About 45% or 1877 kg e-waste are used for recycling purpose. Among this only 12% are recycled in Khulna city and rest of the recyclable waste is sent to Dhaka for further processing. In Khulna only precious metal such as aluminum, copper are separated from e-waste.
- About 3107 people are involved in collection, recycling process in Khulna city. They work about 8 hours daily and earn 2500 to 5000Tk per month. Most of the workers are male. The actual number of primary waste collectors is hard to identify.

E-waste is increasing day by day so proper disposal and recycling is a basic need. As a way forward, it can suggest the following recommendations:

- To conduct an extensive inventory of the level for all of the city connected with recycling process.
- To develop law and guidelines for the management of recycling process and disposal system.
- To launch well-organized collection system.
- To introduce an Environment friendly management system at different stage recycling.
- To raise awareness among the general population and waste collectors.

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COMPARITIVE ASSESSMENT OF SEWAGE TREATMENT SYSTEMS AT KHALISHPUR AREA IN KHULNA CITY

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ABSTRACT

The increasing amount of sewage wastes is a universal problem and encountered by all developing countries. It is a complex issue in urban areas owing to population levels, rapid economic growth and rise in community living standard. It also accelerates the generation rate of sewage water. This paper presents a review of the various approaches to sewage treatment process at Khalishpur area in Khulna city. With the help of SNV Netherland development organization, three sewage treatment systems had been installed and operated at the study area. Laboratory analysis had been carried out for determining the quality of raw sewage samples and treated effluents collected from different locations of sewage treatment facilities. The experimental results for BOD in raw sewage were found to be 114~282 mg/L while in treated effluent 66~84 mg/L.TSS values were observed in the range of 560~6750 mg/L and 160~243 mg/l for raw sewage and treated effluent, respectively. FC has been found 600~1800 N/100ml for raw sewage and 50~850 N/100ml for treated effluent. The BOD, TSS and FC values were far beyond the limit of Bangladesh standards for sewage discharge in inland water bodies. This research work finally discussed about the effectiveness of existing sewage treatment performance in the study area.

KEYWORDS: Sewage disposal, Septic tank, Khulna City, Anaerobic baffled reactor

INTRODUCTION

Due to unaffordable cost of construction, most of the drains in the towns and cities are open and as a result they are misused, sometimes serving as defecating sites for homes without adequate toilet facility (Adu-ahyiah & Anku, 2001).Sewage water management is one of the major environmental issues of recent times. Waste is produced by all human being, but the amount is very large for humans. So it is our responsibility to manage it efficiently. Due to rapid urbanization, industrialization and massive growth of population waste management has become more critical nowadays. Normally if the quantity of waste water is small, nature can cope with it but if large amount of wastewater and sewage are not treated then nature can't endure it. Normally sewers are discharged into lake, river, and stream. But now in developed countries it is not directly discharged into it. At first the water is treated then it is discharged. In most of the case in Bangladesh though there is soak well in office building, there is hardly any septic tank in residential or private building. Though the population is increasing in an alarming rate the area is same. In major cities of Bangladesh the buildings are congested so there is not enough area for the treatment process. So the management process should be done carefully keeping in mind of the little space. Waste produced by residential buildings should be treated before discharging to the environment. Sewage is of two kinds one is black water, which is from toilet and the other is gray water, which is from domestic uses except toilets. Bangladesh provides a striking example of progress to meet the Millennium Development Goal (MDG) - 7 to halve, by 2015, the "proportion of urban population with access to improved sanitation". Open defecation has reduced from 19% in 2000 to 3% in 2012, though 53% of households still do not use improved sanitation (WHO-UNICEF, 2014). Blockage of drainage systems occurred for wastewater overflow during rainy season. In consequence, self-purification capacity of receiving water bodies is overloaded and it causes surface and ground water pollution, impacting directly to the health of community, reducing the value of environment(Systems, 2002). Progress in reducing open defecation and use of improved sanitation in Bangladesh has been remarkable. Only 4% of the population are practicing open defecation, 15% of the population are using unimproved latrines, 25% of the population are sharing improved latrines and 56% of the population are using improved latrines (WHO-UNICEF, 2014). According to JMP, open defecation reduced from 34% in 1990 to 3% in 2012 and now it said to be of 1% (WHO-UNICEF, 2014).Conventional wastewater treatment plant needs large space for treating vast quantities of wastewater and also requires very high initial as well as operation and maintenance cost that Khulna municipality faces structural and financial adjustment problems (Shuma rani saha, 2014). Sewage/Wastewater treatment involves breakdown of complex organic compounds in the wastewater into simpler compounds that are stable and nuisance-free, either physio-chemically and or by using micro-organisms (Cheremisinoff, n.d.). Methods of wastewater treatment were first developed in response to the adverse conditions caused by the discharge of wastewater to the environment and the concern for public health. Further, as cities became larger; limited land was available for wastewater treatment and disposal, principally by irrigation and intermittent filtration. Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies(Spellman, 2010).

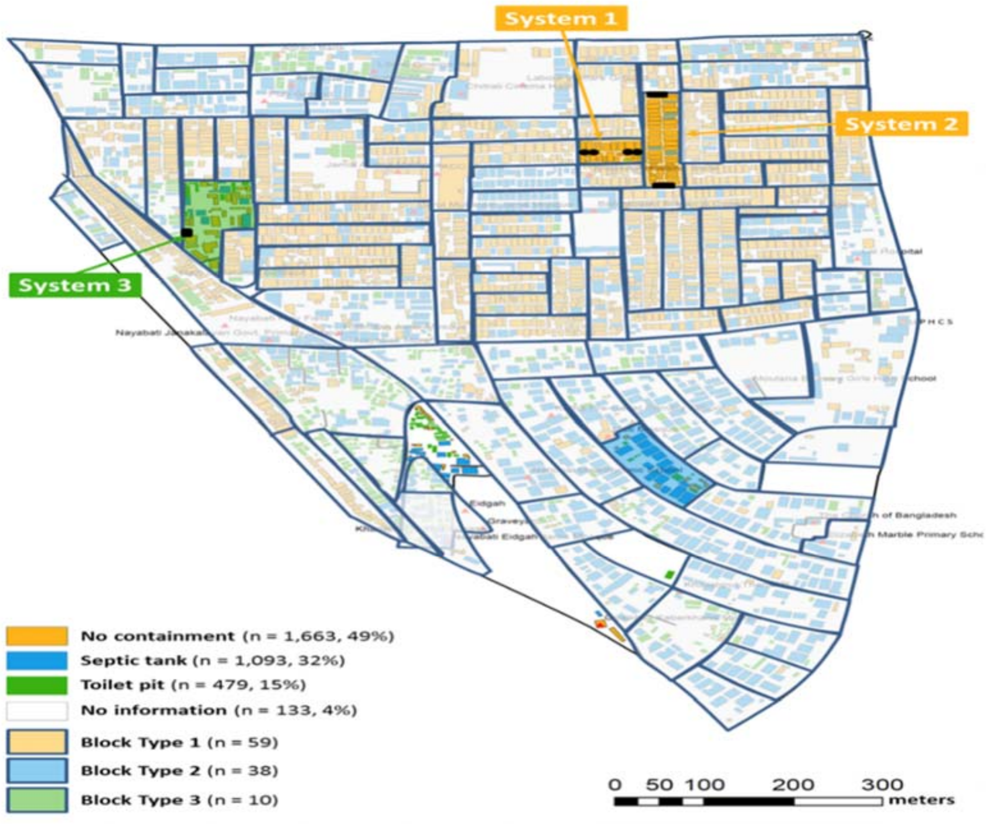
Khulna is the third largest city of Bangladesh located in the south-western part of the country and lies in the delta of the river Ganges. The city has an estimated population of 1.6 million and total number of household is 66,257 (SNV, 2014). Human deposits about 70 g per capita per day of solids into water and also produce more and more waste water daily. Direct or indirect contact to wastewater and fecal sludge is associated with microbial and chemical hazards, which frequently result in adverse effect both on humans and animals. Khulna City Corporation (KCC) is adversely affected by the influence of sewage water. This city has no sewer network. The household sanitation is predominantly on-site technologies, 68.4% septic tanks and 31.6% pits(Foundation, 2011), which require regular emptying. But formal emptying is rare as most are directly connected to surface water drains or water bodies. In many developed countries, fecal sludge is often allowed to accumulate in poorly designed plant whereas this scenario is not very common in the developing countries. Without proper management, fecal sludge is often allowed to accumulate in poorly designed pits and wastewater is discharged into storm drains and open water, or is dumped into waterways, wasteland, and unsanitary dumping sites (Water and Sanitation Program, 2014).The major obstacle on the way to successful implementation of any sewage treatment process in middle and low income countries are the stake holders. In Khulna as well as Bangladesh, the key stakeholders are household's users and owners, municipal authority, pit or septic tank emptier or sweepers, government, local or international organizations and NGOs with sanitation activities. Adequate water and wastewater management, essential for human health and economic Development, poses a major challenge to many countries around the globe. Whereas in Industrialized countries water and wastewater control had reached a fairly high Standard, in lower and middle income countries1 severe problems with respect to water Supply and wastewater management are still apparent (Hophmayer-Tokich, 2006). As the water supply system is given the first priority, waste water treatment is lagging behind and is becoming a major issue in different cities in a developing country like Bangladesh. The main aim of this paper is to investigate the existing treatment systems, assessment of raw sewage and effluent sewage quality through different treatment systems in small space.

METHODOLOGY

Field survey was done on sewage disposal practice (various treatment options/direct disposal) at ward no 10 khalishpur. Observed the works done by different NGO and governmental institution like in this case, 3 systems were observed which was implemented by a non-government organization named SNV, a Netherland development organization. Identification of detailed design methodology for various sewage treatment process was done. Raw and treated sewage samples was collected from various treatment process. Laboratory analysis of collected sewage samples was done. Comparison of sewage water quality parameters of directly disposed water and water processed from the systems was accomplished.

Selection of study area

After the independence in 1971 there was no reformation of the pipes that were used in khalishpur area. Among all the wards in Khulna, The wards under khalishpur have the worst sanitation system. The sewerage system is directly connected to the drain which is very harmful. Most of the residential building don't have any soak pit. That's why the BOD and fecal coliform limit for wastewater crosses the allowable limit and causes different diseases to different people. Here sewage and waste from residential buildings are dumped beside their residence as there is hardly any sewerage systems or dumping place for management. That's why the area under ward no.10 was selected to be surveyed.



Sewage Treatment process:

System 1 is termed as Modular Ring. There are rings instead of baffle chamber. The rings are of 5 ft. dia. There are 10 rings side by side in which there are 7 rings installed vertically. These rings are jointed together and here up-flow treatment process is used.

Figure 2: System 1- modular ring (source: SNV)

System 2 and System 3 are mixed containment. Those are installed in places where there is no septic tank. The first part of these systems is settler or septic tank. Then, there is baffle chamber where up-flow is used. Baffle walls direct the wastewater flow between the compartments from top to bottom following up wards again. After the septic tank portion, the pipes are laid downwards where sedimentation occur. Successively, the filter media are rounded brush where bacteria come in contact with the fiber of brush and get attached to it. The materials such as gravel, rocks, cinder or specially formed plastic pieces are used as filter media which provide additional surface area for bacterial growth and digestion of dissolved organic matter. These systems are laid on the drain line in between two building of a colony. A central septic tank has been constructed.

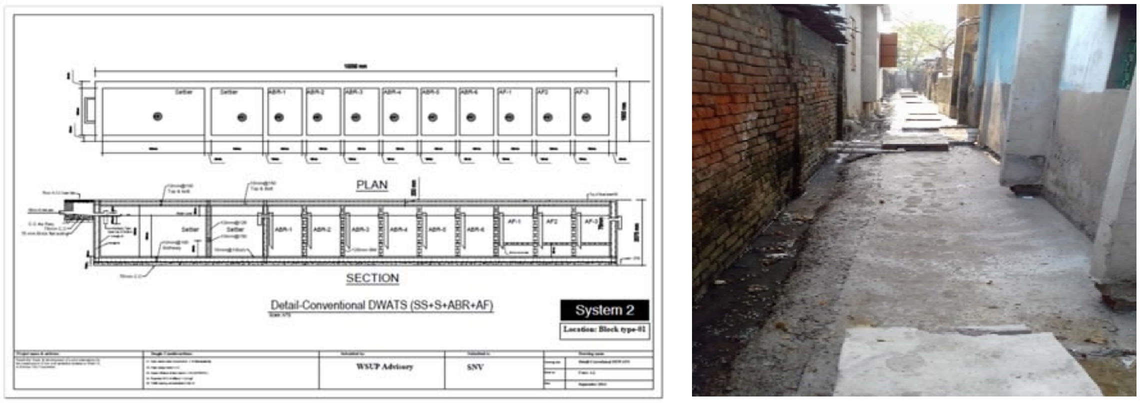


Figure 3: system2- mixed containment, no septic tank (source: SNV)

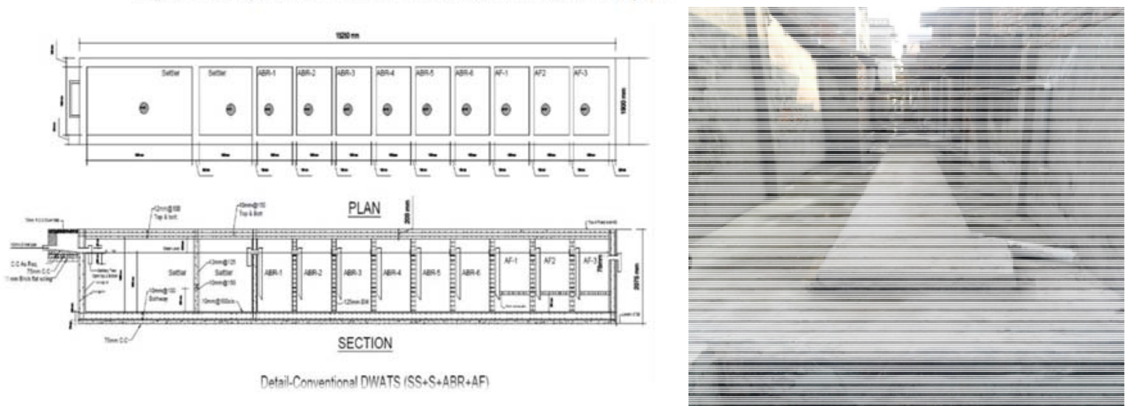


Figure 4: system 3- mixed containment, small quantity of septic tank (source: SNV)

RESULTS AND DISCUSSION:

Normally, pH depends on Carbon dioxide concentration, Acid, Dissolved Minerals and Temperature of wastewater. Decomposition of organic matter also lowers the pH value. The pH value of raw sewage and treated effluent were found to be in the range of 7.85 to 8.25 (Table 1). The amount of total solids were very high in both raw sewage and treated effluent. However, the sludge volume index (SVI) was found to be remarkably less in treated effluent. Electrical conductivity is a good indicator of the total salinity, it still does not deliver any information about the ion composition in the water. The value of EC was observed maximum in both raw and treated samples of system 2. The values of alkalinity was evaluated very close for all influent and effluent samples for all the systems.

Table 1: values of parameters for raw and treated sewage water

Water Quality Parameters	Unit	System-1 raw	System-1 treated	System-2 raw	System-2 treated	System-3 raw	System-3 treated
TDS	(mg/l)	1820	3110	3650	3380	2690	2520
TS	(mg/l)	8570	3190	4290	3730	3250	2993
SVI	(ml)	29.0	0.4	4.0	0.6	4.5	0.1
pH		8.25	8.21	8.07	8.15	7.92	7.85
Fe	(mg/l)	nil	.1	nil	nil	.02	.01
NO_3	(mg/l)	nil	nil	nil	nil	nil	nil
Alkalinity	(mg/L as $CaCO_3$)	675	750	815	775	650	640
EC	(mS/cm)	3.03	3.32	3.83	3.49	2.83	2.78

The BOD_5 values in raw sewage were found to be 114-282 mg/l and in treated effluent 66-84 mg/l while the Bangladesh standard limit is 40 mg/l (Figure 5). The test results indicate that the sewage treatment systems removed the biodegradable organic matters around 50-70% but still the effluent quality was not satisfactory with regards to national standard for sewage disposal in inland water bodies. Thus, the sewage treatment systems adopted in Khalishpur area of Khulna City Corporation need further improvement in unit process operation and maintenance whichever deem effective for their improved performance ensuring safe and sustainable environment.

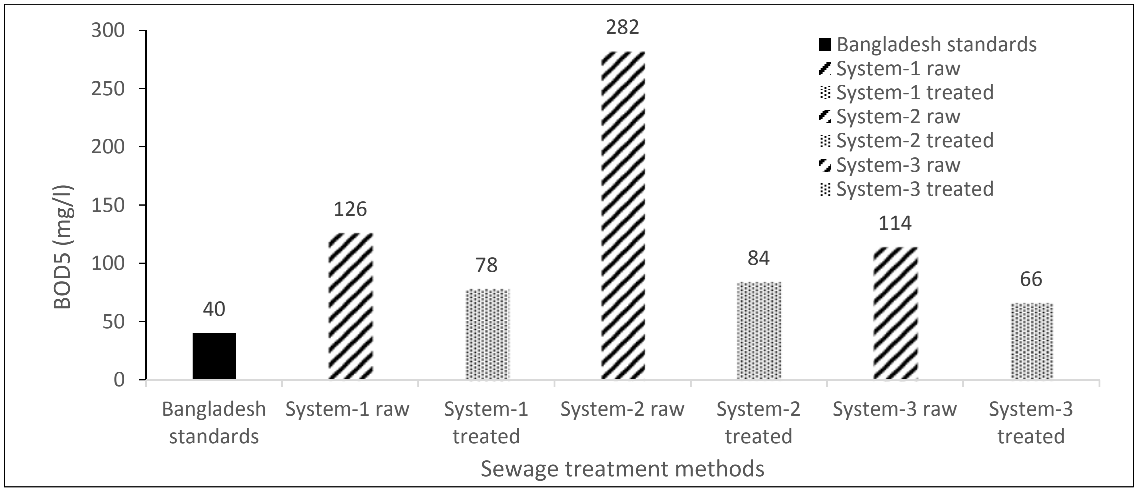


Fig 5: BOD_5 values of raw and treated sewage water in different systems

COD includes both biodegradable and non-biodegradable organic matters. The COD test oxidizes materials that microorganisms cannot metabolize in 5 days or that are toxic. Here, the COD value is remarkably higher than BOD_5 (Figure 6). The observed COD value in treated effluent was found to be varied between 387 mg/L and 160 mg/L. This high concentration could be due to presence of additional non-biodegradable organic matters in sewage. The sewage wastewater treatment through the adopted system shown considerable reduction in COD concentration and the mean removal efficiency was around 51%.

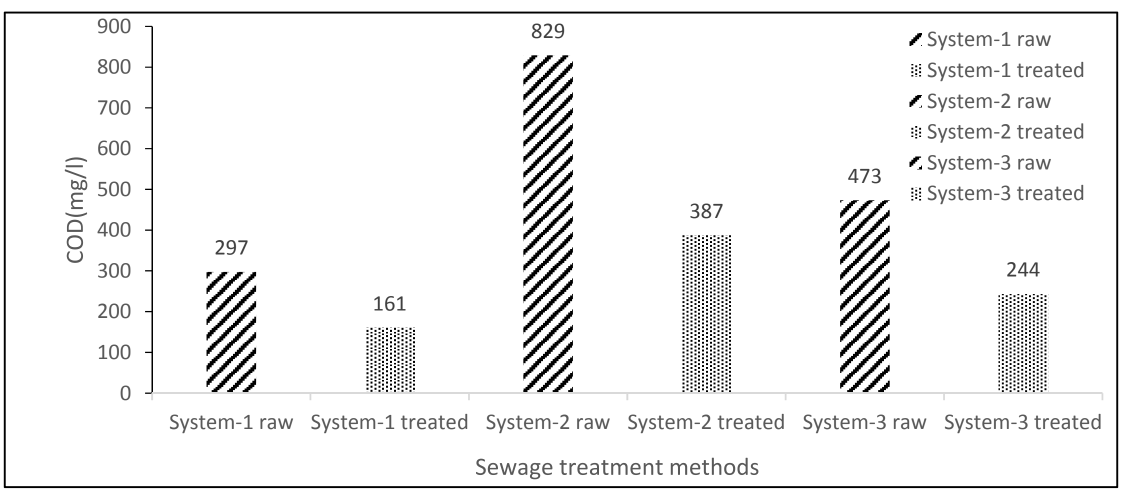


Figure 6: COD values of raw and treated sewage water in different systems

Sewage generally contains less than 0.5% solids, the rest is water, still the nuisance caused by the solids cannot be overlooked, as these solids are highly degradable and therefore need proper disposal. Total suspended solids (TSS) are particles that are larger than 2 microns existing in the water column. Here in raw sewage the amount of suspended solids is very high. The estimation of suspended solids, both organic and inorganic, gives a general description of the load on sedimentation and grit removal system during sewage treatment. Though its value is high in raw sewage water, after treatment its value has come down to a large extent. As the wastewater flows through the treatment system, there was a significant drop (more than *90%* removal) of suspended solids (Figure 7). Though the values come down to a great extent the values for system 2 and system 3 effluent were beyond the limit.

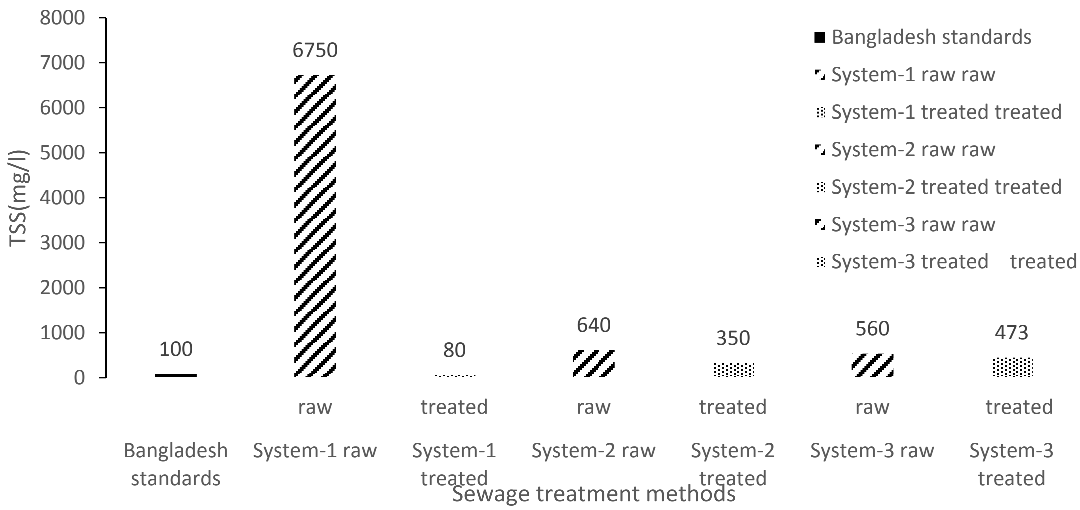


Figure 7: TSS values of raw and treated sewage water in different systems

Coliforms, E. coli and Enterococcus bacteria are the "indicator" organisms generally measured to evaluate microbiological quality of water. The number of FC(E.coli) in raw sewage were found to be in between 600-1800(N/100ml) and in treated effluent 50-750(N/100ml) while the Bangladesh standard limit is 1000(N/100ml) (Figure 8). The number of fecal coliform is over the range for system 1 and system 2 raw sewage. After being treated the effluent quality was satisfactory with regards to national standard for sewage disposal in inland water bodies. The bacteria removal efficiency was around 75%.

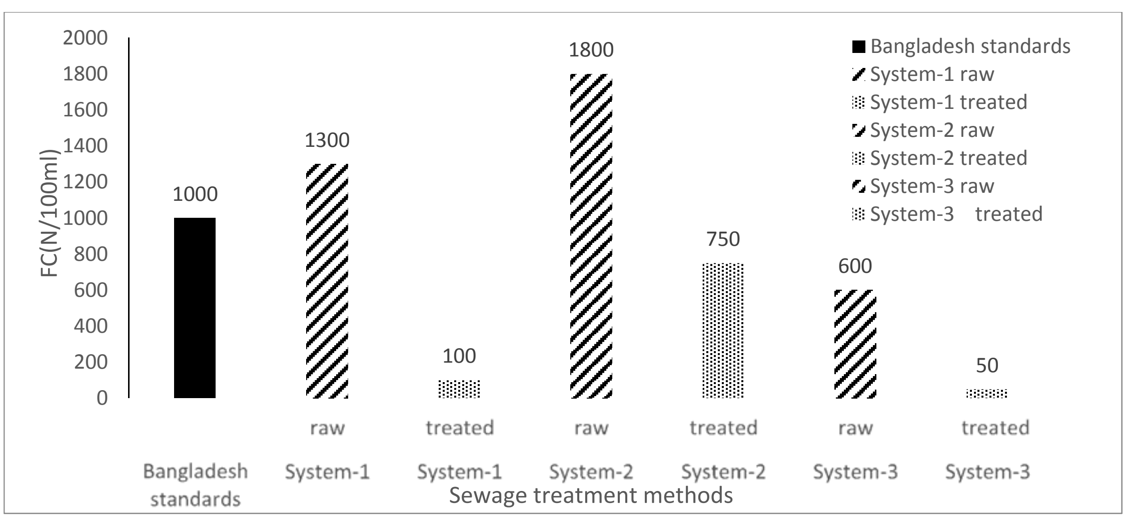


Figure 8: FC values of raw and treated sewage water in different systems

The PO_4 values in treated effluent were found to be varied in the range of 15-39 mg/l while the standard limit for inland disposal is 35 mg/l (Figure 9). The overall reduction of phosphate in the adopted sewage treatment process was observed around 25% from its influent concentration.

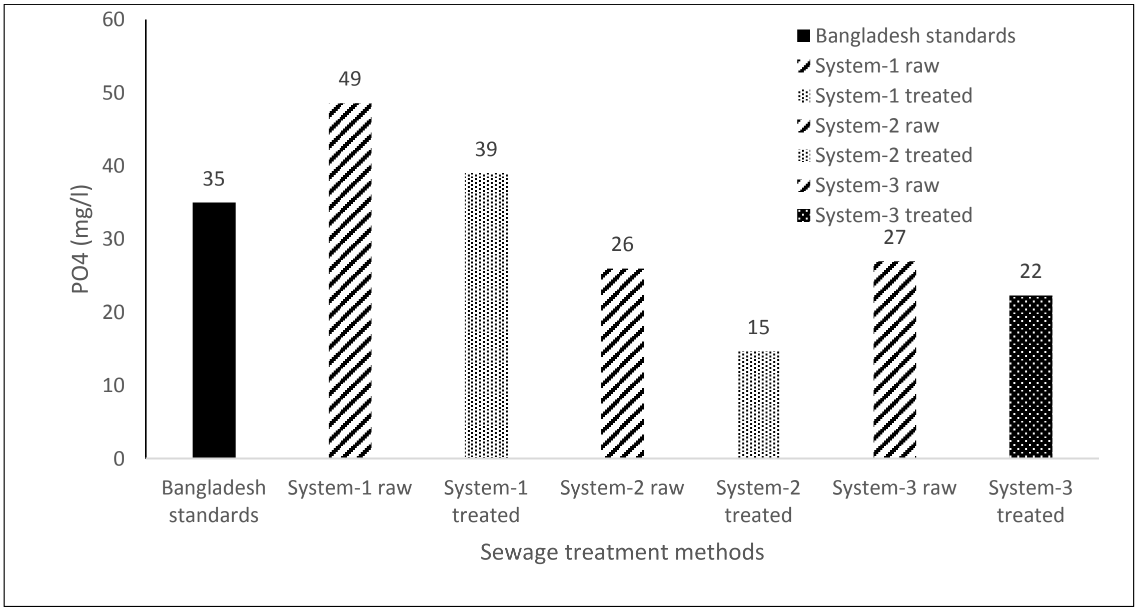


Figure 9: PO_4 values of raw and treated sewage water in different systems

The temperature of sewage water is an important parameter because of its consequences on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses. The temperature in raw sewage waters and in treated effluents was found very close in the range of 30-32°C (Figure 10). Thus, the observed temperature was within the optimum range 25 to 35°C for bacterial activity.

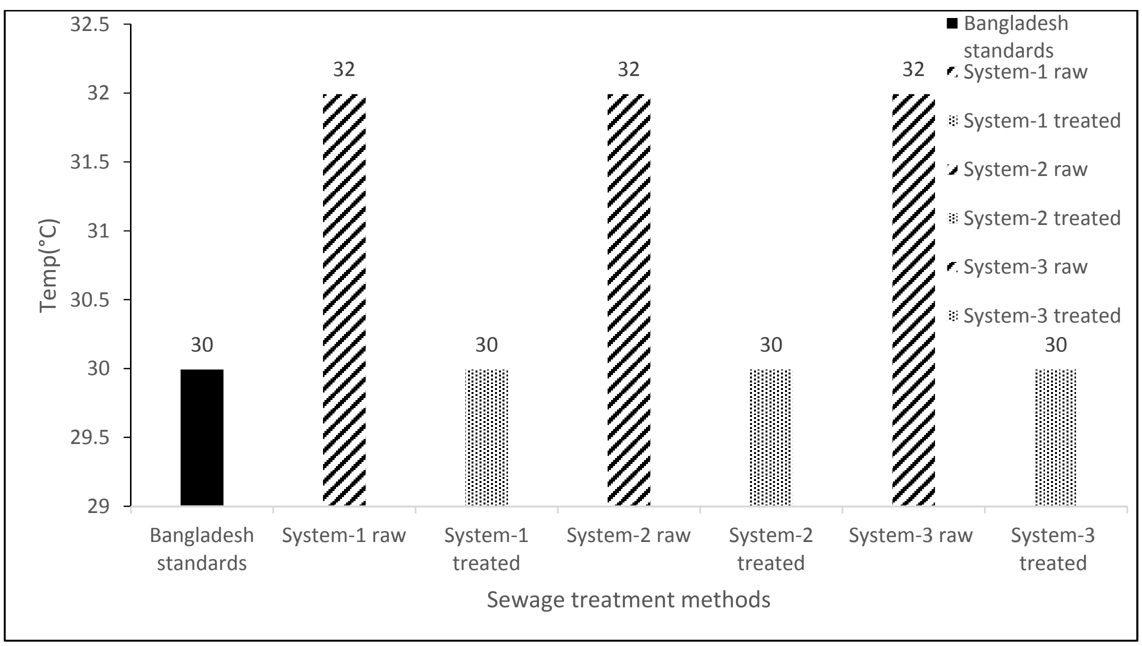


Figure 10: Temperature values of raw and treated sewage water in different systems

CONCLUSIONS

The principal objective of sewage treatment is generally to allow human effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. The design of sewage water treatment systems are usually based on the need to reduce organic and suspended solid loads to limit pollution of the environment. Three sewage treatment systems had been implemented and functioned at Khalishpur ward number 10 through SNV Netherland development organization. The quality of raw sewage samples and treated effluents collected from different locations of sewage treatment facilities were analyzed in laboratory. The experimental results for BOD_5 were found to be 114~282 mg/L (raw sewage) and 66~84 mg/L (treated effluent) having reduction efficiency around 50%. TSS values were observed in the range of 560~6750 mg/L (raw sewage) and 160~243 mg/L (treated effluent) and reduction efficiency around 90%. FC has been found 600~1800 N/100ml for raw sewage and 50~750 N/100ml for (treated effluent) with reduction efficiency around 25%. Though the number of fecal coliform (E.coli) was within the standard limits, but the BOD and TSS values were far beyond the limit of Bangladesh standards for sewage discharge in inland water bodies. As some of the important parameters for sewage samples have gone beyond the limits, the implemented systems are not fully effective in reducing the harmful effect to human and environment.

ACKNOWLEDGEMENT

The authors would like to thank Department of Civil Engineering, KUET for all the funding for research. And also would like to thank SNV and Mr.Saker Ahmed for all the data, information and help.

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ASSESSMENT OF TREATED WASTEWATER TO MEET FIRE FIGHTING WATER DEMAND IN A UNIVERSITY CAMPUS OF BANGLADESH

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ABSTRACT

In the reign of modern earth, everything especially the basic needs are highly consumptive when it comes under the consideration of human consumption. Today's world is a world of more than 700 million people and resources are yet limited. Clean Water is such a basic consumptive which cannot be replaced by any other possible material. The consumption of water is mainly depended on its consumers and waste water demand in fire safety holds importance related to the growth of population. In this study, the population of a university campus has been counted from 2006 to 2018 and by population projection, fire-fighting water demand of KUET in the year of 2020 and 2030 has been extrapolated. The firefighting condition of the residential buildings (halls and dormitory) of KUET has been analyzed to understand the fidelity of the fire safety system and to suggest effective fire safety alternatives for this university campus.

Key words*: *water demand management, wastewater, population, fire water demand, fire hydrants.

INTRODUCTION

Water demand management, ensuring the minimum consumption of water, analysis of resources, planning for fire safety are the common concern of rapidly developed communities and it is much challenging to ensure enough fire safety for the students specially in a university campus with respect to the population growth by year ends' enrollment of students and staffs. The world has witnessed an alarming increase in the frequency and severity of disasters. Globally there was a total of 353 catastrophe events in the whole world in 2015 out of which 198 were natural disasters and 155 man-made (Swiss Re, 2016). Evidences show that most cases of disasters are fire incidences which occur due to anthropogenic factors coupled with a near absence of efficient disaster mitigating approaches like the use of fire hydrants in our cities of world. University campuses are valuable assets as it holds most intellectual future deciders of any country. To ensure safety of them, hazard assessment must be done based on various parameters and incidents. Khulna University of Engineering & Technology, a renowned public engineering university of Bangladesh was selected and hazard sustainability was assessed based on fire accident parameter with wastewater emitted from different communal inhabitants of it. At present almost 6.7 thousands people are living here which includes undergraduates, graduates, school students, teachers, officers, staff and it is planned to be increased to 7700 students, 618 teachers, 216 officers and 728 staff in 2018-2019 (from official website of KUET). The construction of new janata bank office, shaheed minar, URP building, students welfare center cum central cafeteria, extension of Civil and Mechanical building and third floor of Planning & Engineering Building have been completed recently. More the constructional building is being built, more the fire safety is required. In this case, treated wastewater can be reused to reduce fire-fighting water demand. Disasters have catastrophic effects upon the community and community life in the countries exposed to disaster (Okon, Njoku and Itu, 2016). Hydrant water supply is one of the most common water sources used by the fire fighter at the fire scenes. However, the fire departments are often stuck in the trouble of lacking water sources by the damage of water pipelines which worsen the fire-relieving work (Wang and Shih, 2018).

Studies show that from 2006 to 2018 almost 30% new building has been constructed in KUET campus. This study will open a new scope to eradicate the damage amount caused by fire lit in buildings of a university or even for residential areas which are more or less fire susceptive by using the treated wastewater as fire-fighting component.

MATERIALS AND METHODOLOGY

Study Area

Total population of KUET from 2006 to 2018 has been collected from the administration office and population forecast of 2020 and 2030 has been demonstrated by Least Square Parabolic Method. After the population calculation, fire water demand has been estimated by Insurance Service Office Formula (Yadav), National Board of Fire Underwriters' Formula, Freeman Formula and Kuichling's Formula (Khan and Farooq). Figure 1 shows the increase of communal and infrastructure density in KUET from 2006 to 2018.

Figure 1: Campus view of KUET in 2006 & 2018 (Source: Google Earth Pro)

Population Forecast (Least Square Parabolic Method)

Least square parabolic method (Stigler *et al.*, 2015) is a method for extrapolating population in future by using previous data and implementing them on some basic equations listed below,

$$y = a + bx + cx^2 \quad (1)$$
$$\sum y = aN + b\sum x + c\sum x^2 \quad (2)$$
$$\sum xy = a\sum x + b\sum x^2 + c\sum x^3 \quad (3)$$
$$\sum x^2 y = a\sum x^2 + b\sum x^3 + c\sum x^4 \quad (4)$$

Where,
x = Assumed value
y = Population in thousands
N = Number of observations on year
a, b, c = Constant values for population forecast

Estimation of Fire Water Demand

Fire water demand has been estimated by Insurance Service Office Formula (ISO), National Board of Fire Underwriters' Formula (NBUF), Freeman Formula (FF) and Kuichling's Formula (KF).

Insurance Services Office (ISO) Method

One of the most comprehensive and widely recommended methods for estimating fire flow requirements is found in the Insurance Services Office's *Fire Suppression Rating Schedule3*. It provides guidance for estimating fire flow requirements for specific structures and was designed for insurance rating purposes. The flows determined by this method are generally considered a good estimate, and, as a result, the ISO method has received wide spread use(Wang and Shih, 2018). In this schedule the basic formula is,

$$\mathrm{NFF_i} = (\mathrm{C_i})\,(\mathrm{O_i})\,(\mathrm{X+P})_\mathrm{i} \qquad (5)$$

Where
$\mathrm{NFF_i}$ = needed fire flow (NFF) in gal per min
$\mathrm{C_i}$ = a construction factor that depends on the construction of the structure under consideration
$\mathrm{O_i}$ = an occupancy factor that depends on the combustibility of the occupancy
$(\mathrm{X+P})_\mathrm{i}$ = an exposure factor that depends on the extent of exposure from and to adjacent structures.

Construction factor (C_i):

$$\mathrm{C_i} = 18\mathrm{F}\sqrt{\mathrm{A_i}} \qquad (6)$$

Where,
F = coefficient related to the class of construction
= 1.5 for frame structure
= 1.0 for joisted masonry structure
= 0.8 for noncombustible structure
= 0.6 for modified fire resistant structure
$\mathrm{A_i}$= effective building area (m^2)

Table 1: Occupancy Factor (O_i)

Type of Building	Occupancy Factor (O_i)
Noncombustible	0.75
Limited Combustible	0.85
Combustible	1
Free Burning	1.15
Rapid Burning	1.25

Exposure and Communication Factor [$(X+P)_i$]:
The equation for exposure and communication factor is,

$$(\mathrm{X+P})_\mathrm{i} = \sum_{\mathrm{i=0}}^{\mathrm{n}} \mathrm{X_i} + \mathrm{P_i} \qquad (7)$$

Where,
n= Number of sides of building
The maximum value of $(X+P)_i$ is 1.75
The exposure factor (X_i) reflects the need for additional water to reduce the exposure to adjacent buildings. The communication factor (P_i) reflects the potential fire spread through open or enclosed communicating passageways between building(Yadav).

National Board of Fire Underwriters' Formula (NBFUF)

National Board of Fire Underwriter's Formula is stated as below,

$$\mathrm{Q} = 4637\sqrt{\mathrm{P}}(1 - 0.01\sqrt{\mathrm{P}}) \qquad (8)$$

Where,
Q= Quantity of water (liter/minute)
P=Population in thousands

Freeman Formula (FF)

Freeman Formula for calculation of firewater demand can be illustrated as below,

$$Q = 1136.5(\frac{P}{5} + 10) \tag{9}$$

Where,
Q= Quantity of water (liter/minute)
P=Population in thousands

Kuichling's Formula (KF)

Kuichling's Formula for calculation of amount of firewater needed can be demonstrated as below,

$$Q = 3182\sqrt{P} \tag{10}$$

Where,
Q= Quantity of water (liter/minute)
P=Population in thousands

RESULT AND DISCUSSION

Water Demand Management

The importance of a proactive maintenance management policy becomes more pronounced when considering vital systems. This importance emanates from the fact that an unexpected failure of a component of one of these complex systems usually creates disruptions, which could have cascading effects leading not only to havoc and its consequences of inconveniencies, but also to major economic effects requiring colossal expenditure to contain the damages incurred from such premature and unexpected failures (Meegoda et al., 2017). Urbanization process is also severely affecting water resources and solid waste management facilities in all growing cities as compare to other requirements. Conservation and sustainable development of water resources and waste disposal and management facilities should be integral part of any urban planning program (Misra *et al.*, 2018). As the structural buildings of KUET is increasing day by day, water demand and waste-water management has become an important factor to ensure good surroundings for all.

Table 2: Water Demand Management Table of KUET Campus (2018)

Consumer	No. of Border	No. of pump	Tank Capacity (L)	Running Time (H) (2 times/day)	Total water needed/ day (L)	Consumed water (liter/capita/ day)	Percentage of water use (%)
BSMRH	960	3	49500	3	99000	103.125	14.78053
KJH	400	2	18000	2	36000	90	5.374739
FHH	400	2	13500	2	27000	67.5	4.031054
Rashid Hall	450	2	17000	2	34000	75.555556	5.076142
LH	400	2	17500	2	35000	87.5	5.22544
AEH	873	3	45000	3	90000	103.09278	13.43685
Rokeya Hall	600	3	26500	3	53000	88.333333	7.91281
Teachers' and stuffs' residential area, Departments	2595	WTP	151400	7	302800	116.68593	45.20752
	Total = 6678		Total = 338400				

Table 2 shows the scenario of consumed water and percentage of water use in residential halls, departments, residential area of stuffs and teachers of KUET campus. From the table, it is evident that water consumption rate per capita in teachers' residential area and the departments is the highest and in Fazlul Haque (FHH) Hall it is the lowest.

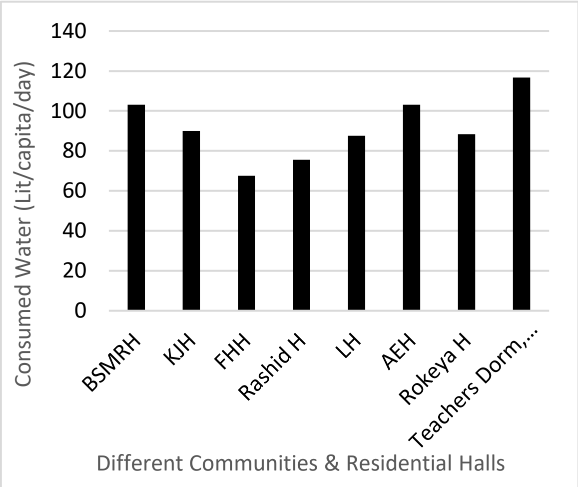

Figure 2: Consumed water (liter/capita/day)

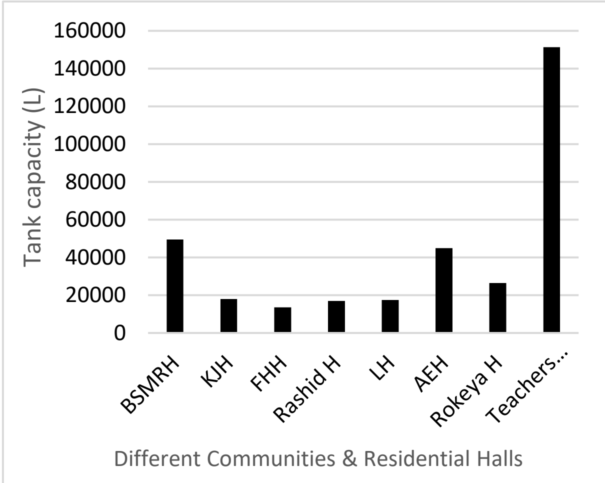

Figure 3: Tank Capacity (L)

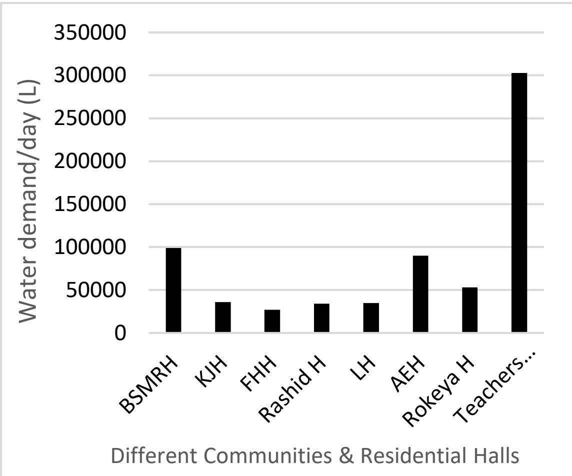

Figure 4: Total water needed/day (L)

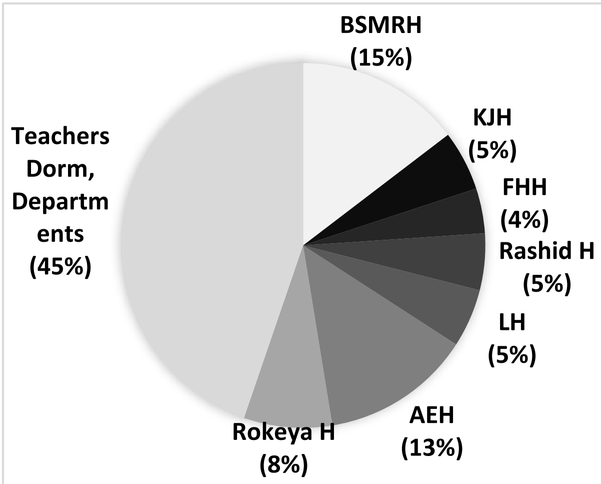

Figure 5: Percentage of water use

Table 3: Population Growth Scenario of KUET from 2008 to 2018
(Source: KUET Administration Office)

Year→	2006	2008	2010	2012	2014	2016	2018
Population↓							
Undergraduates	1838	1896	1944	2516	2580	3132	4834
Graduates	196	276	345	584	642	760	1100
Teachers	182	187	195	201	216	282	320
Officers	73	77	79	89	97	103	132
Stuffs	222	226	230	220	247	284	292
No of Departments	12	12	12	14	16	16	18
Total Population =	2511	2662	2793	3610	3782	4561	6678

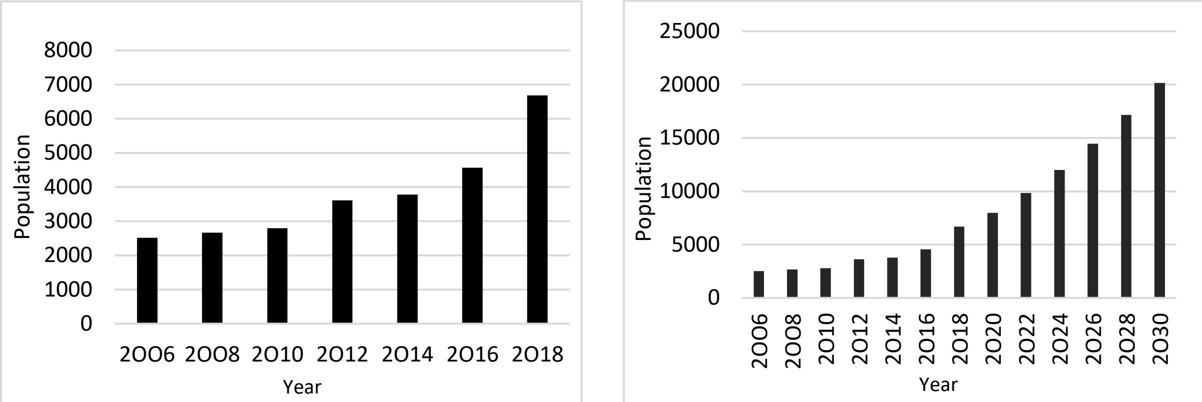

Figure 6: Population Growth till present year and projected population for 2020 and 2030 in KUET

Figure 6 (left) shows the gradual increase of population from 2006 to 2018 in KUET campus. The population in 2018 is more than two times of the population in 2006. The population growth rate in 2018 is higher than the previous years. And the right sided graphical representation of figure 6 shows the projected population for future years up to 2030 with respect to the previous growth rate of population in KUET campus using least square parabolic method in equation (1), (2), (3), (4) and the values of constant a, b and c are 3.25, 0.62 and 0.14 respectively.

The population forecast equation is,
Forecasted population, $y = 3.25 + 0.62x + 0.14x^2$ (11)
Using equation (11), future population estimated in 2020 & 2030 will be 7.97 & 20.17 thousands.

So the future population of KUET for the year of 2020 and 2030 will be 7970 and 20170 inhabitants respectively which means the water demand required for mitigating fire-hazards will commensurate according to this increasing population in near future. In those two specific year of 2020 and 2030, findings of fire-water demand by different formulas have been tabulated in Table 4 afterwards.

Fire water demand with respect to population

Table 4: Water needed for fire safety according to population calculation

		Fire Water Demand(Liter/min)		
Year	Population(Thousands)	NBFUF (Q=4637√P(1-0.01√P))	FF (Q=1136.5(P/5+10))	KF (Q=3182√P)
2020	7.97	12721	13177	8983
2030	20.17	19890	15950	14291

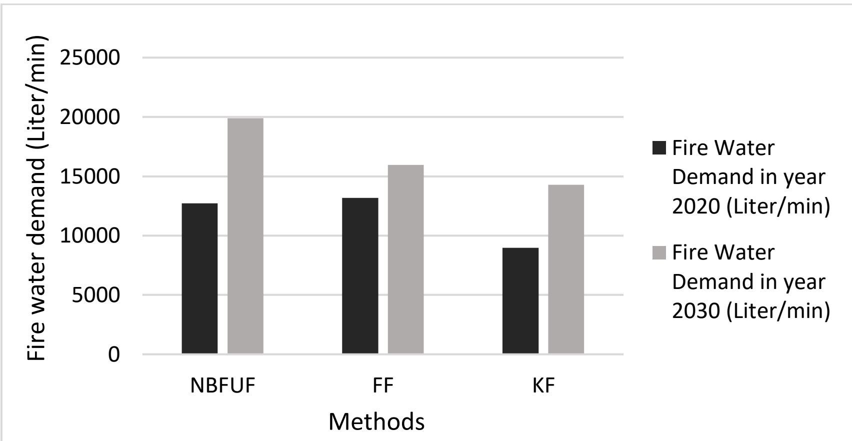

Figure 7: Comparison of different formulas in firewater demand calculation in year of 2020 and 2030

From Figure 7 histogram, fire water demand (Liter/min) in the year of 2020 according to National Board of Fire Underwriter's Formula, Freeman Formula and Kuichling's Formula are 12721, 13177 and 8983 respectively. And fire water demand (Liter/min) in the year of 2030 according to National Board of Fire Underwriter's Formula, Freeman Formula and Kuichling's Formula are 19890, 15950 and 14291 respectively. Thus fire water demand both for the 2020 and 2030, Kuichling's Formula is the most convenient method as it suggests the least water demand required for mitigating same amount of fire hazard that might possibly occur in this university campus.

Fire water demand with respect to building area

ISO Method:

For the academic buildings of KUET,
Area, $\mathrm{A_i}$ = 5500m^2, F = 1.5, $\mathrm{O_i}$ = 0.85 and $(\mathrm{X+P})_\mathrm{i}$ = 1.75
Using equation (6), the value $\mathrm{C_i}$ = 2002.37
Now using equation (5) needed fire flow, $\mathrm{NFF_i}$ = 2979 gal/min = 11261 liter/min

Needed Fire Flow (NFF). The needed fire flow is calculated from the formula given previously and from the foregoing factors .The NFF calculated from the formula should be rounded to the nearest 250 gal/min (946 L/min) for flows under 2500 gal/min (9463 L/min) and to the nearest 500 gal/min (1893 L/min) for larger flows and then adjusted by the following:
• For buildings with a wood roof, add 500 gal/min (1893 L/min).
• The needed flow should not exceed 12,000 gal/min (45,420 L/min) nor be less than 500 gal/min (1893 L/min). The practical reason for these figures is that manual fire-fighting methods using hose streams and heavy stream appliances are not likely to need a larger supply, considering the general arrangement of buildings and the availability of hydrants.
• For habitation buildings, use the calculated NFF up to 3500 gal/min (13,248 L/min) maximum.
• For groupings of one-family and small two-family dwellings not more than two stories high(Yadav).

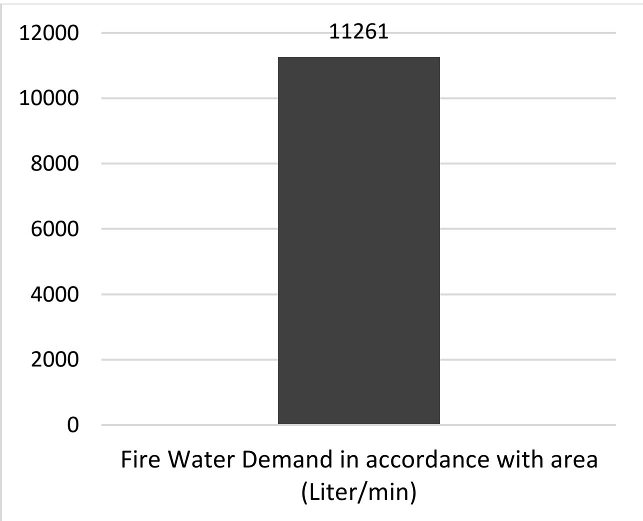

Figure 8: Firewater demand according to ISO method.

CONCLUSION

This research study focused on the water demand management, future population projection, fire water demand and inadequacy of fire hydrants and effective use of fire hydrants consistent with the global best practice for KUET campus. Water demand management table shows that the water consumption in Teachers' Dorm and Departments (117 liter/capita/day) are greater than Students Hall. According to Least Square Parabolic Method, the predicted population for 2020 and 2030 are 7.97 and 20.17 thousands respectively which indicates that fire safety has become an essential factor. At the time of any fire occurrence, huge amount of water is required. Thus use of treated wastewater can minimize the additional water demand. For the estimation of fire water demand with respect to population, Kuichling's Formula (KF) requires less water for KUET campus. Fire hydrants are important municipal installations, placed at strategic positions to assist in putting out fires during an outbreak. There are above-ground connections that provide access to water supply primarily for the purpose of fighting fire and alternatively for some other municipal activities such as construction works and other outdoor water needs. Water is the most cost effective fire suppressant and importance of fire hydrants have been increased a lot with respect to population growth in KUET campus. Thus, installation of fire hydrants in KUET campus can ensure the safety both for its inhabitants and departmental buildings at the time of any kind of fire occurrence and exigency related to fire harm.

ACKNOWLEDGEMENT

We are thankful to the hall assistants and the administrative officers of KUET for providing data and information regarding to the water demand and population of various years. We gladly wish to express our gratitude to Professor Dr. Md. Saiful Islam sir for giving ideas and inspiration with continuous technological support behind this research.

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PRESENET SCENARIO OF HOSPITAL AND CLININCAL WASTE MANAGEMENT IN KHULNA CITY

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ABSTRACT

With the rapid urbanization and increased facility with improved day to day life, the health facility of people has also been emphasized. That is why the number of hospitals is increasing with a higher pace that causing huge amount of medical waste generation every day. The study shows the existing clinical waste management in Khulna city, classification of clinical waste, waste generation rate, contribution of public organization (KCC) and private organization involved waste management. The study is consisted of face to face interview with the proper related authorities, questionnaire survey and representing them thorough graph and images with some recommendation at last. There are about 175 health facilities in Khulna City Corporation. The total waste generation is about 580 ton/day and the amount of clinical waste generation is 3.0 ton/day. The study focuses on the contribution of KCC, NGOs and other private organization for management of this huge waste generated.

Keywords: *clinical waste, clinical waste management, disposal of waste, health facilities and waste generation.*

INTRODUCTION

The study of solid waste has become a matter of major concern in recent days because of the socio-economic development, urbanization and growth of population in most cities of developing countries. One of the important components of solid waste, waste generation from health centers, is a serious problem in the developed as well as developing countries. Medical effluents are infectious and dangerous too. Hassan et al (2008) reported, wastes of medical centers are serious threat to environment and needs specific treatment and management prior to its final disposal. Clinical waste as a whole is being disposed with the municipal garbage (Pathak; (1998)).But clinical waste management in developing countries is still poor and disposed without adequate experience and supervision. In some other countries, hospital effluents have not been legally declared (Dutta, 1998; Kwok-Kuen, 1998). Often medical staffs was found to generate revenue through sale of medical waste due lack of knowledge and interest in safe waste disposal and absence of a budget to effectively implement safe waste disposal (Akter, 2000). At present, Bangladesh has no rigorous laws or regulation which is enforced in various cities of the country. Khulna, the largest metropolitan city of Bangladesh, stands on the banks of the Rupsha and the Bhairav rivers. Establishment of various health care centers, clinics and hospitals has made difficult for management of different waste (A. U. Jabbar, 2009). Waste products from these are not treated or destroyed properly, rather thrown into the dustbins thereby creating health hazards (A. A. Talukdar, 2009). The present practice of improper handling of generated clinical wastes in Khulna city is playing a contributing rule in spreading out various diseases such as diarrhea, tuberculosis, heamorrtetanus, AIDS, STD, meningitis, infection of the liver, stomach, breathing infection, infection of the reproductive organs, various skin diseases, etc. Khulna is currently facing the impacts of improper management of hospital wastes. Realizing the intensity of the problem, some NGOs have already extended their helping hand to KCC for the management of clinical waste, yet the existing management system is a threat to environment and human health (Khandaker, 1999).The problem of hospital waste disposal and other toxic hazardous wastes is growing rapidly throughout the world as a direct result of rapid urbanization and population growth. Hospital waste or clinical waste, which poses serious threats to environmental health, requires specialized treatment and management prior to its final disposal. Simply disposing it into dustbins, drains, and canals or finally dumping it to the outskirts of the city poses a serious public health hazard. Such disregard for protecting public health occurs due to lack of awareness, skill of the people and institutions engaged in hospital waste generation and disposal as well as due to lack of treatment facilities and system in the city. The problem is getting worse with the increasing number of hospitals, clinics, and diagnostic laboratories in the city. The rapid increase of hospitals, clinics, diagnostic laboratories etc in Khulna city exerts a tremendous impact on human health ecology. More than 250 clinics and hospitals exist in the KCC. These facilities generate an estimated 100 tons of waste a day (Lawson, 2003). Only a few have the necessary means to dispose the waste safely. It is reported that even body parts are dumped on the streets by these HCE. The present practice of improper handling of generated hospital wastes in Khulna city is playing a contributing role in spreading out the Hepatitis and HIV diseases. The liquid and solid wastes containing hazardous materials are simply dumped into the nearest drain or garbage heap respectively where they are prone to contaminate the ragpickers that sift through the garbage dumps. The chances of infection are very high to the cleaners, concerned people in the HCE and to the general population. The improvement of waste management for the HCE in Bangladesh will have significant long-term impact on keeping the spread of infectious diseases to a minimum and result in a cleaner and healthy environment. Unlike the ordinary household waste, medical wastes are highly infectious and hazardous. They may carry germs of dreadful diseases like hepatitis B, C and HIV/AIDS. Mixing with the household wastes, they make the entire pile a great public health hazard. To make the matter worse, poor scavengers (tokai) rummage through the pile, earnestly searching for saleable items like syringes. These are collected, washed, repacked and resold to the public. Thus, the vicious cycle of transmission continues. The prevalence of diseases that may be transmitted by hospital wastes is alarming in Bangladesh. There is evidence of hepatitis B infection among 10 percent of children (5-10 age group) and 30 percent adults. About 5 per cent of the total population in Bangladesh is thought to suffer from chronic hepatitis B infection. Although cases of HIV/AIDS is low in Bangladesh (about 13,000 cases estimated in 2001) in comparison to neighboring countries, nevertheless the numbers are rising (Waste Concern, 2003). It is noted here that much of the clinical wastes (e.g. syringes, needles, saline drips, discarded food, gauze, vials, and ampoules) are collected by women and children who re-sell it despite of the deadly health risks. It is estimated that hospital wastes account for a very small fraction, notably, only about 1 percent of the total solid wastes generated in Bangladesh. In a report from the World Bank (2003), only 10-25 percent of the hospital wastes are infectious or hazardous. The amount of such hazardous waste is quite small in figure and until recently this is not handled properly (WHO, 2001). Mixing with the domestic solid wastes, the total waste steam becomes potentially hazardous.

The main objectives of the study are as follows:

(1) to quantify the amount of clinical waste generated from various health center of Khulna city

(2) to investigate the present clinical waste management and dumping systems in Khulna city

(3) to qualitative study on the level of knowledge and increase the level of awareness of the people about the health hazards happening due to this uneven management.

STUDY AREA

Khulna lies between 22.04°7´16´´ to 22.05°2´00´´ north latitude and 89.03°1´36´´ to 89.03°4´35´´ east longitude. The city is 4 meter above the mean sea level (MSL). The city covers an area of 45.65 square kilometers (17.62 square miles) with a population of near about 1.5 million. The city, for administrative purposes, is divided into 31 wards: each ward consists of different masalas, the total number of which is 143 (Population Census, 2001).

LITERATURE REVIEW

With the recent rapid growth of private health sector, the need of safe and proper medical waste disposal is become important. Hospital waste is frequently described to be an environmental pollutant as well as a serious health concern. The problem arises if the unsafe disposal of hospital wastes resulting in hepatitis B and C (jaundice), and HIV/AIDS. Generally, hospital waste is defined as the discarded or unwanted material solid waste which is generated from the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biological (Lee, 1989). These have the potential to cause disease and are a health risk. It is a by-product of health care that includes sharps, non-sharps, blood, body parts, chemicals, pharmaceuticals, medical devices and radioactive materials (WHO, 2002). The HCEs are one of the major producers of solid wastes which are hazardous in nature. Poor management of clinical wastes exposes health workers, waste handlers and the community to infections, toxic effects and injuries (Ecoaccess, 2004). Medical wastes are mainly categorized into non-hazardous and hazardous wastes (Figure 2.1). The non-hazardous waste includes wool, kitchen wastes, etc. that do not pose any special handling problem, hazard to health or the environment and is generated in the patients' ward areas, out-patient-department (OPD), kitchens, offices, etc (Mato and Kaseva, 1999). The hazardous waste includes pathological, infectious, sharps and chemical wastes and are normally produced in labour wards, operation theatres, laboratories, etc (Mato and Kaseva, 1999; Or and Akgill, 1994). Some definitions of hazardous wastes are (Henry and Heinke, 1996; Mato and Kaseva, 1999):

(a) **Pathological wastes** consist mainly of tissues, organs, placentas, blood, etc.

(b) **Infectious wastes** contain pathogens in sufficient concentrations or quantity that, when exposed to it, can result in diseases. Examples are, waste from surgeries with infectious diseases, contaminated plastic items, etc.

(c) **Sharps** include needles, syringes, broken glass, blades and any other items that could cause a cut or puncture.

(d) **Chemical wastes** comprise of expired medicine, discarded chemicals - usually from cleaning and disinfecting activities.

Alamgir et al (2003) reported that all the hospitals, clinics and pathological centers generate all most similar waste in nature; however, amount depends on the infrastructural facilities of hospitals or clinics to handles the number of patients and the types of diseases. Considering the safety of the community, the wastes can be categorized as Kitchen wastes (all types of vegetables and food wastes, paper, medicine strips, packing materials etc), Non-sharp or Reusable wastes (syringe, saline bags, blood bags, plastics materials etc), General hospital wastes (gauge, cotton, tissue, organs, human fetuses ete) and Sharp wastes. Rahman et al (2003b) reported that 288 tons of solid waste generated in every day within the Sylhet City Corporation area of which 6 tons were healthcare waste. Again among them 24.35% of healthcare waste were hazardous. Rahman et al (2003) reported that 288 tons of solid waste generated in every day within the Sylhet City Corporation area of which 6 tons were healthcare waste. Again among them 24.35% of healthcare waste were hazardous (neddle, broken glass etc). Rahman (2000) reported that 3700 metric tons of wastes were generated per thy in Dhaka City among them about 200 tons were medical waste and 40 tons were infectious waste. Nurunnabi (1997) conducted a study at the Mymensingh Medical College Hospital and Thana Health Complexes, in 1992, to compare the existing systems of disposal of hospital wastes. This study reported that the existing waste-disposal systems were not satisfactory in all the places. Alamgir et al (2003) reported the treatment system of 44 hospital I clinic I healthcare establishment of Khulna City. He stated that the wastes were separated by the users at the source in different categories such as needle and sharp parts, reusable wastes, surgical wastes and food and vegetables wastes by depositing them separately in four bins marked different colors'. Food and vegetables wastes were dumped with other municipal solid wastes in the same site of KCC. The UNEP (2003) formulates some technical guidelines on the environmentally sound management of bio-medical and health-care waste. solid waste in Khulna City (JICA, 2004). BRAC (2004) conducted a pilot project work between January 2004 and August 2004 on medical waste management. They mainly focused on the Khulna Shishu Hospital, Institute of Child Health, and one upgraded BRAC SUSHASTO KENDRA (a medical centre). They are now trying to replicate their activities regarding to this issue. A study, conducted by the Directorate General of Health Services (DGHS) in 2000, reported that the supervisory persons agreed that they have the responsibility toward waste management, but there was no provision of quantifying and record-keeping of wastes in the hospital (Rahman.2000). There was a lack of awareness and knowledge among the staff about the consequences of the wastes and environmental impact. Recycling of waste materials started from the point of generation, and a number of hospital staff were familiar with recycling. The Bangladesh University of Engineering and Technology (BUET) conducted a study in some hospitals in Dhaka city in 1999 (Rahman.et.al.1999). The total study was limited to the generation of solid wastes per bed per day. It has been found that an average rate of solid waste generation was 1.00 kg/bed. day. It has been found that the rate of waste generation was about 1.16 kg/bed. day, and the hazardous waste was 0.169 kg/bed. day. The contribution of infectious, sharps, and pathological wastes was about 10.5%, 3.5%, and 1.5% respectively compared to solid waste of 3,000 tons/day in Dhaka city. The Bangladesh Rural Advancement Committee (BRAC) conducted a study, in 1998, in different government and non-government hospitals, clinics, and diagnostic laboratories in Dhaka city (BRAC, 1998). According to this Most hospitals, clinics, and laboratories do not have any waste management system in place. All wastes are collected together and are dumped in a common place, such as roadside, hospital surroundings, and dustbin of the Dhaka City Corporation. The Environment and Development Associates (Prodipan) conducted a study, in 2000, in different clinics and hospitals of Khulna city aiming at formulating and demonstrating replicable models for hospital waste management (WHO, 2000). Results of the study showed that the method of waste disposal was improper and inadequate in most clinics and hospitals. The current 15 practice of waste disposal was to dump all types of wastes in the nearest Khulna City Corporation (KCC) bins or adjacent low-lying areas. Hazardous wastes are openly burnt in some hospitals without any air emission and temperature control. Most management people were not concerned with the disposal system, and they believe that placing of wastes in the municipal bins or discharging it into the drains is enough. There was no environmental awareness programme in any hospital in the city.

METHODOLOGY

The methodology includes observation in field and data collection at field level through inventory, questionnaire survey and interviews in formal and informal ways. Data were collected from primary data sources and secondary data sources. Primary data includes collecting data through questionnaire survey in the field. A number of formal and informal approaches were adopted in order to gather data. Face to face Interviews were conducted with the association of the hospital authority, ward master and office staff of KCC and NGO's. Questionnaire was conducted with people involved in providing waste handling and pretreatment of hospital waste before final disposal. After collection of data it was interpreted and expressed through graphical representation.

RESULS AND FINDINGS

According to the KCC and NGO's report, there are 10 governmental hospitals, 20 private hospitals, 60 clinics, and 70 diagnostic centers at Khulna City.

Table 1: Number of Existing facilities in Khulna City according to KCC

Type of facility	Number of facility	Percentage
Govt. hospital	10	5.71
Private Hospital	25	14.29
Clinic	60	34.29
Diagnostic Centre	80	45.72

Clinical Waste

Clinical waste is defined as the waste generated by hospitals, clinics, pathological laboratories, diagnostic centers, doctor's offices and other hospital and research facilities. Clinical waste includes syringes, live vaccines, laboratory samples, body parts, bodily fluids and waste, sharp needles etc. Though WHO (1999) classified clinical wastes in nine categories, but it is extremely difficult to conduct such survey in the context of the Khulna City hospitals. So it is classified in four categories. They are:

i. Infectious Waste: This includes wastes from infectious wards and materials or equipment contaminated with blood and its derivatives, other body fluids or excreta. Blood soaked bandages, dressings, surgical gloves, laboratory culture, swabs from laboratories, contaminated blood clots and glassware material generated in the medical analysis laboratories.

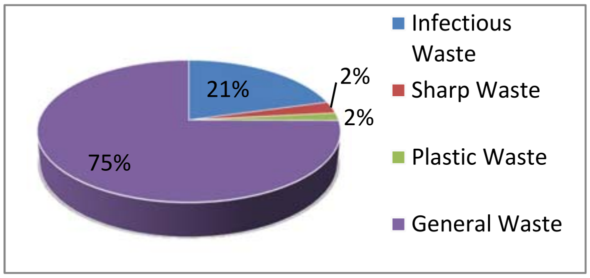
ii. Sharp Waste: This comprises all hypodermic needles and syringes, intravenous needles, ampoules, sharp blades, lancelets, broken glassware, broken glassware and vials without content.

iii. Plastic Type Waste: This includes saline bags, syringe, tubes, ampoule vial, etc.

iv. General Waste: This includes food waste, office paper, packaging, plastics, cardboard, non-contaminated plastic or metal, cans or glass.

Table 2: Waste generated from various hospitals and clinics

Name of Waste	Color division	Pot/Drum	Amount of Waste (Kg/Day)	Percentage
Infectious Waste	Yellow	Plastic pot/drum (no hole)	622	20.69
Sharp Waste	Black	Plastic pot/drum (no hole)	80	2.66
Plastic Waste	Red	Heavy plastic box/pot (no hole)	53	1.77
General Waste	Green	Plastic pot/drum (no hole)	2250	74.88
Total Waste			3005	100



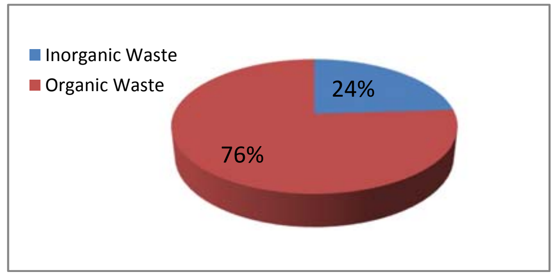


Figure 1: Waste generation pie chart

Figure 2: Amount of organic and inorganic waste

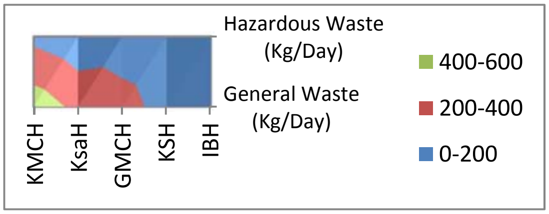
Table 2 shows the collection system of waste has some different ways. For example the infectious waste are collected in Yellow, Sharp in black, Plastic in red and General waste in green pot/drum having no hole at the bottom (Prodipan). Figure 1 shows the percentage amount of waste generated in pie diagram. Prodipan (2012) has confirmed that 76% of organic waste and 24% of inorganic waste is generated in Khulna city corporation area (figure 2). The following data were collected by questionnaire survey in the field from KCC, NGO's and different hospitals. There are various health centers such as large, medium and small in size. Among them the data of clinical waste of some popular hospitals and clinics is given below in Table 3.

Table 3: Waste generated from various hospitals and clinics

Name of Hospitals	Number of bed	General Waste (kg/day)	Hazardous Waste (kg/day)	Total waste (Kg/day)	Waste generation rate (Kg/bed/day)
KMCH	500	512	150	662	1.324
KsaH	250	351	54	405	1.62
GMCH	250	279	84	363	1.452
KSH	200	120	27	147	0.735
IBH	100	69	17	86	0.86
NMH	100	44	8	52	0.52
SMH	100	15	12	27	0.27
KPH	100	46	4	50	0.50
NCH	100	45	6	51	0.51
PGH	50	25	3	28	0.56
SSANSH	50	38	4	42	0.84
BH	50	65	5	70	1.40
KH	50	26	2	28	0.56
NMSC	20	32	4	36	1.80
SHC	20	30	3	33	1.65
MSC	20	52	19	71	3.55
RMH	20	45	6	51	2.55
SMC	20	52	31	83	4.15
GNC	20	34	13	47	2.35
AAMCH	20	43	17	60	3

Source: Field survey, 2012; (KMCH=Khulna Medical College Hospital, KSaH=Khulna Sadar Hospital, GMCH=Gazi Medical College Hospital, KSH=Khulna Sishu Hospital, IBH=Islami Bank Hospital, NMH=Nargis Memorial Hospital, SMH=Santa Maria Hospital, KPH=Khulna Police Hospital, NCH=Navy Camp Hospital, PGH=Pongu and Gyne Hospital, SSANSH=Shahid Sheikh Abu Naser Specialized Hospital, BH=Bokkhobadhi Hospital, KH=Kara Hospital, NMSC=Nagar MatriSadan Clinic, SHC=SurjerHasi Clinic, MSC=Meri Stops Clinic, RMH=Rashida Memorial Hospital, SMC= Shamela Memorial Clinic, GNC=GaribNewaz Clinic, AAMCH=Ad-din Akij Medical College Hospital).

Table 3 shows the most amount of medical waste are generated in Khulna Medical College Hospital because it is the biggest hospital in Khulna city in terms of area and number of patients. Although it is called "250 bed Hospital", it has more than 500 beds. In terms of per bed waste generation per day Surjer Hasi Clinic and Meri stops clinic have higher values. But in consideration of number of bed available the Khulna Sadar Hospital has more number of patients with waste generation rate of 1.62 Kg/bed/day.



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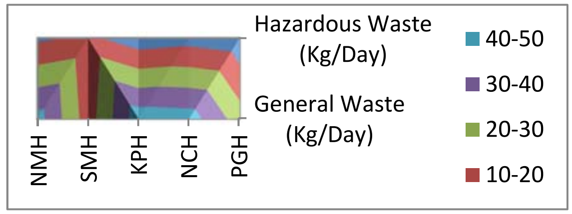

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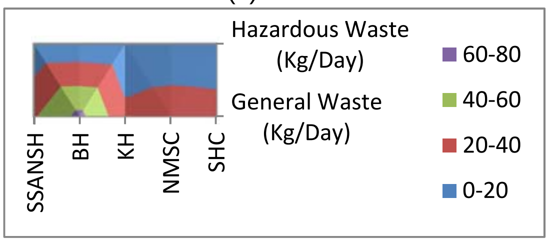

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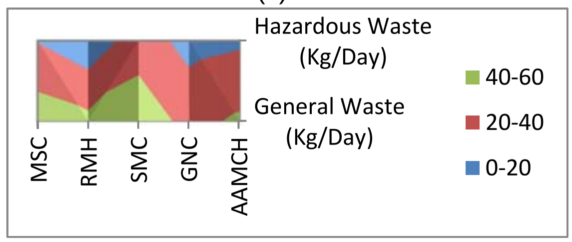


2(d)

Figure 2 (a,b,c,d): Different Waste Contour on the volume of waste generating hospitals

Figure 2 shows the waste contour on the volume of waste generated in various hospitals. From the figure it is evident that the amount of generation waste production is much higher than that of hazardous waste.

Table 4: Different types of Waste generated from public, private and diagnostic centers in Khulna city

Type of HCEs	Non Hazardous waste (kg/Day)	Infectious Waste (kg/Day)	Pathological Waste (kg/Day)	Chemical Waste (kg/Day)	Plastic Waste (kg/Day)	Sharp Waste (kg/Day)	Total
Public	793	86	47	8	41	23	998
Private	1399	135	83	11	56	32	1716
DC	96	14	7	5	19	14	155
Grand Total	2288	235	137	24	116	69	2869

(Hasan, 2018)

This figure was calculated only from 120 registered HCEs (Total number of beds: 3000). It can be mentioned that there were more than 50 nonregistered HCEs existing in Khulna city. These HCFs produced relatively small portion of the overall amount of waste in the studied area.

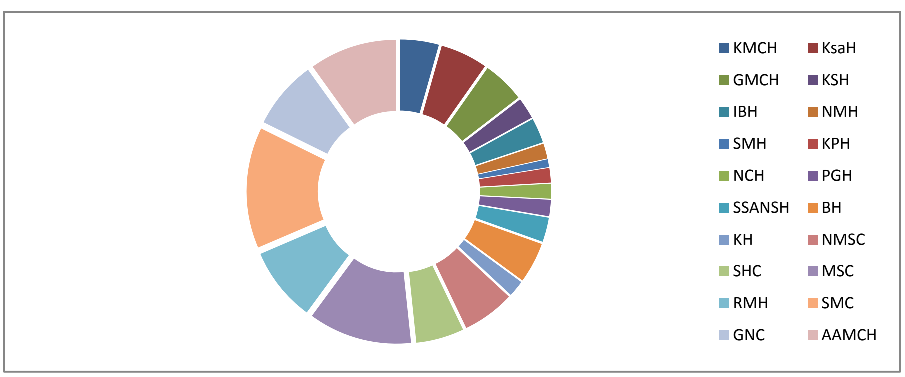


Figure 3: Waste Generation per kg per bed of hospitals

Clinical Waste Management

A suitable and proper waste management procedure of clinical waste includes the following-
- Waste segregation
- Storage of waste
- Waste handling
- Collection of waste

• Transportation
• Treatment and final disposal

i. Collection, Transportation and Disposal: KCC are the authority to collect all kinds of waste from dustbins twice a day. KCC has 20 trucks and about 200 wheel carts, only 16 trucks go for the collection of wastes at a time. But the clinical waste dumped together with all other waste without taking any safety dumping procedure. The trucks are used for collecting wastes only from primary dustbins. On the other hand, the wheel carts bring wastes from the secondary dustbins to the primary dustbins.

Figure 4: Waste collection in different drums

Figure 5: Different types of clinical waste

ii. Dumping Site: The common dumping side**,** Rajbandh, close to Dumuria, about eight kilometers south of Khulna city. As all types of waste are dumped there as shown in figure 6, huge odor pollution occurs that enhances the chances of health risk. For land filling purpose, KCC uses different open location to dump waste which increases the risk of health hazard of the local community.

Figure 6: Waste being dumped in open location in Rajbandh

iii. Private Organization Involved in Clinical Waste Management: Prodipan an NGO is playing an important role in managing Khulna city clinical waste. Staring in in May, 2000, their clinical waste management service with funding from Swiss development cooperation (SDC), UNDP and World Bank. Prodipan felt it when it was developing a community based solid waste management in the city. The vision of Prodipan is the developing a sustainable society for ensured standard of living and improved quality of life for the underprivileged. At the beginning, Prodipan had no waste treatment process. But now they have taken initiative to treat some waste before dumping. Now Prodipan has covered about 70% of all clinical waste management in Khulna City Corporation.

iv. Segregation, collection and transportation: Prodipan generally collects different types of waste in different drums colored in different color as mentioned in figure 4. The four drums are marked with four different colors for easy identification. The number of set of drums differs according to the capacity of the hospital. But actually it has been found that many of the hospitals are provided with less than four colored drums. An auto van carrying 1.5 ton waste is used for transportation of clinical waste from the various health facilities in KCC area.

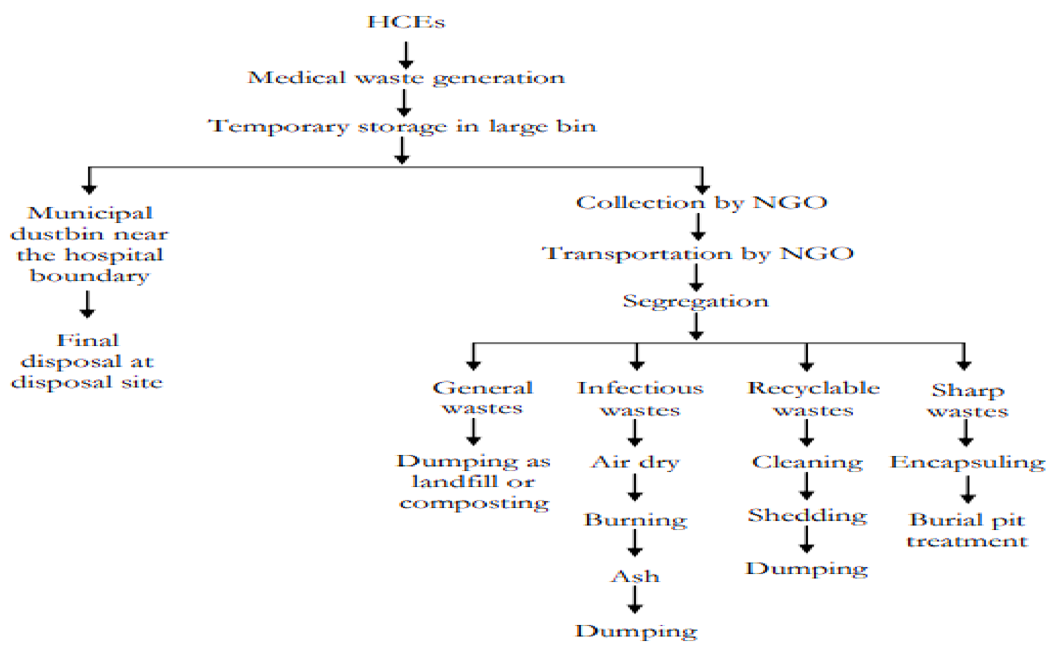
v. Final disposal method: In case of clinical waste management, disposal system is one of the major parts. Prodipan generally burns the gauge, bandages, human organs etc. by developed a simple burning chamber. The rests are disposed of by open dumping and also needle, blade, broken and unbroken glasses and all other sharp type materials are disposed in a concrete pit to check them from spreading germs. The syringes, saline bags, vial and tubes are sliced in small pieces and then dumped in another concrete pit. Prodipan disposes the clinical waste in the following way:

I. Infectious wastes such as Gauge, bandage, human organ etc are wet in nature; they are dried with Bleaching powder, washed and then burned in furnace.
II. Sharp wastes such as Needle and all other sharp type material are disposed in a concrete pit.
III. Plastic wastes such as Syringe, vial, ample, saline bags etc are wetted, washed by Bleaching powder, then cut to be unsuitable for using and sold.
IV. General wastes are dumped openly.

Table 5: Service cost for collection and final disposal of clinical waste (Prodipan)

SL No.	Number of Bed	Monthly service cost (Tk)
01	From 01 to 20	= 800/-
02	From 21 to 50	= 1,400/-
03	From 50 to 100	= 3,000/-
04	From 101 to 200	= 4,000/-
05	From 201 to 350	= 8,000/-
06	From 350 <	= 20,000/-

Table 5 shows the monthly service cost for waste collection, transportation and disposal of Prodipan on the basis of generation of waste and number of beds.



(Mokbul, 2014)

Figure 7: Clinical waste management system in Khulna City

CONCLUSION AND RECOMMENDATION

Now a day, the clinical waste management has become one of most crucial issue around the world. This study was mainly carried out to have a clear idea about the clinical waste management practices and amount of waste generation rate in Khulna City Corporation. However the present system of clinical Dumping Site: KCC has fixed a piece of land at Rajbandh to dispose the clinical waste properly. However there is concrete blocked box to dispose the needle and sharps and a locally made incinerator to burn the infectious waste. waste management of Khulna City Corporation is neither satisfactory nor adequate. About 0.6 ton of hazardous waste is generated every day in Khulna City Corporation (Arifuzzaman, 2013). There is no existing law and regulation of clinical waste management in Bangladesh and there is no penal action against improper disposal of hazardous waste. National legislation is the basis for improving Health care waste practices in any country. Therefore, a national management plan will be required which will permit healthcare waste management options to be optimized on a national scale. The law should be complemented by a policy document and technical guidelines developed for implementation. This legal document should specify regulations on treatment for different waste categories, segregation, collection, storage, handling, disposal, transportation, responsibilities, and training requirements. Training of healthcare personnel as well as general people regarding hygiene and healthcare waste management is needed to create awareness and foster responsibility among them which will prevent exposure to related health hazards. So it is necessary to formulate appropriate laws for the management of clinical waste. As KCC does not give proper attention for the collection and disposal of clinical wastes, so it should involve more Non- Governmental Organizations to upgrade the waste disposal system. However the participation of Local NGO Prodipan illuminates most of the clinical management system in Khulna City Corporation. The overall clinical management system should be safe. Hygienic and cost effective measures have to be taken for the final disposal and treatment of the hazardous waste. Sometimes some cleaners are engaged to mishandle the generated wastes. They do not segregate infectious wastes from non-infectious wastes and dispose the wastes to the open dumping site. The authority of the clinical waste management system should follow WHO guideline properly. Also there is an urgent need for planning and implementation of clinical waste management systems. Public awareness and training are the most important factors for proper management of clinical waste. Therefore it is necessary to be much careful about dumping waste in a proper and manageable way. Overall the government and more NGOs should come forward to maintain the clinical waste management according to WHO guidelines to have a safe and healthy environment for future generation.

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CHARACTERISTICS OF DOMESTIC WASTEWATER AND ITS TREATMENT IN KUET CAMPUS

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ABSTRACT

The focus of this study was to investigate the characteristics of domestic wastewater as a resource and to develop a low cost domestic wastewater treatment system which satisfies the normal water standards for secondary uses such as toilet flushing, gardening, the influent and effluent water quality. Parameters were investigated to determine the performance of the domestic wastewater treatment system for the potential recycling of water for selected reuse purpose. Using treatment process the removal efficiency of BOD, Color, Turbidity, COD were found 5%, 75%,78% and 89% respectfully using sand filter. The microbiological water quality in terms of Total coliform and E. coli was also improved satisfactorily with average removal efficiency about 55%. The treated water was very clear with Turbidity value roughly 2.5-3 NTU. The recycling and reuse of treated wastewater would have promising application in household and agricultural uses after treatment without any hazard to human health and environment.

Keywords: *Domestic waste, Reuse, Recycle, Treatment unit, reclamation, grey water, black water*

INTRODUCTION

The world's population is projected to increase dramatically between now and the near future and with this growth will come an amplified need for water to meet various needs, as well as an increased production of wastewater. Many communities throughout the world are impending, or have already reached, the limits of their available water supplies.

Bangladesh is a south Asian country having more than 160 million people. During wet season water is available in almost everywhere. But during the dry season water is scarce in most of the areas in Bangladesh. Sometimes cultivation is hampered due to scarcity of water. Moreover the groundwater table is undergoing day by day due to very frequent use of groundwater. To remove the consequences of water scarcity, the concept of wastewater reuse might be thought of a solution besides Rainwater harvesting and other conservation methods. Reuse of wastewater through treatment yields major results economically and in small time frame. That is why water reclamation and reuse have almost become necessary for conserving and extending available water supplies.Water demand management is matter to get the most from limited supplies by using water efficiently and promoting conservation as a response to scarcity as opposed to looking for new sources of supply from already overtaxed water resources. Among the avenues being pursued is the use of wastewater to counterbalance the demand for fresh supplies.

It has been estimated that water savings in the range of 19%-30% for an average household could be achieved by reusing domestic water (Lechte, 1992). Domestic water represents a precious renewable resource that can permit significant household water reserves and reduces demand for potable water. Reusing wastewater brings with it risks largely related with the high levels of nutrients and the existence of pathogens (Ghawi & Kris, 2011).

The main objectives of this study are:

- To investigate the characteristics of domestic water.
- To develop a low cost treatment process for domestic water reuse or recycling

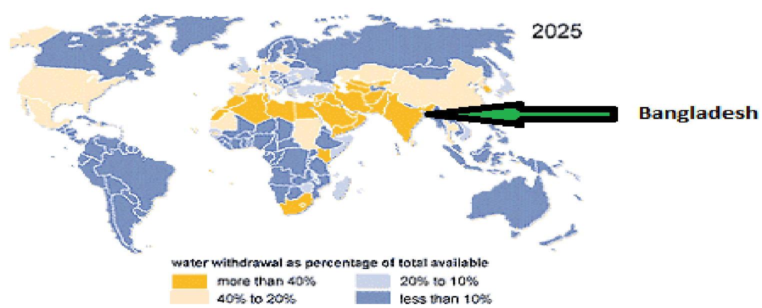
- To find out the operation and maintenance problems of the developed domestic water treatment unit.

STUDY AREA

Six hall (Amar Ekhushey hall, lalon shah hall, Dr. M.A.Rashid hall, khan jahan ali hall Bongobondhu sheikh Mujibor Rahman hall, rokeya hall) of Khulna university of Engineering & Technology were selected to collect waste water in different sources. Different bathtubs, basin waste kitchen waste were selected for this study. Two option of treatment unit were made for reusing waste water.

LITERATURE REVIEW

Global population has more than doubled since 1950 and reached six billion in 1999. The present world population is estimated that slight greater than seven billion. The most recent population forecasts from the United Nations indicate that, under a medium-fertility scenario, global population is likely to peak at about 9.5 billion in 2060.
Given that many natural resources (such as water, soil, forests and fish stocks) are already being exploited beyond their limits in some regions, significant effort will be required to meet the needs of an additional two billion people in the next 40 years.
Rapid population growth, combined with industrialization, urbanization, agricultural intensification and water-intensive lifestyles is resulting in a global water crisis. About 20 per cent of the population currently lacks access to safe drinking water, while 50 per cent lacks access to a safe sanitation system. Falling water tables are widespread and cause serious problems, both because they lead to water shortages and, in coastal areas, to salt intrusion. Both contamination of drinking water and nitrate and heavy metal pollution of rivers, lakes and reservoirs are common problems throughout the world. The world supply of freshwater cannot be increased.
The water withdrawal as percentage of total available is shown in the figure. It is seen that some major part of the world have already withdrawal more than 40 percent of their available water. Some other portions of the world have already withdrawal around 20 to 40 percent of their available water. Water scarcity is severe in this area or will be severe in near future.



By the year 2025, two thirds of the world population may be subject to water scarcity.

Figure 1: Water withdrawal as percentage of total available

Bangladesh is a developing country in the world Bangladesh will face lot of water crisis within next 20 years due to random contamination of surface and ground water, absence of comprehensive water sharing with neighboring countries and mismanagement in preserving rain water. Water crisis of Bangladesh affects both rural and urban areas, and is a matter of both water scarcity and water quality. The size of the urban population is increasing at alarming rates. The poor from the rural areas continue to migrate to the urban areas with the hope of being able to earn larger wages to support their families. Many of these people find shelter in Dhaka's slum communities, overcrowding, poor housing, and unhealthy disposal of waste all play major roles in the water and sanitation crisis in the urban areas of Bangladesh.
Dhaka experiences a hot, wet and humid tropical climate. The city is within the monsoon climate zone, with an annual average temperature of 25 °C. Nearly 80% of the annual average rainfall of 1,854 mm (73 in) occurs between May and September. The aquifer of this city is basically recharged

by direct rainfall, river water, and floods through direct infiltration and percolation. But due to unplanned urbanization, the recharge area of the city is decreasing significantly with time. In summer, scarcity of water is acute at many places of Dhaka city. It is becoming worsened due to frequent load shedding and fall in groundwater level. During dry season ground water table moves downward from -45 to -54 m depth from the sea level due to continuous extraction of ground water (Akther et al. 2009).

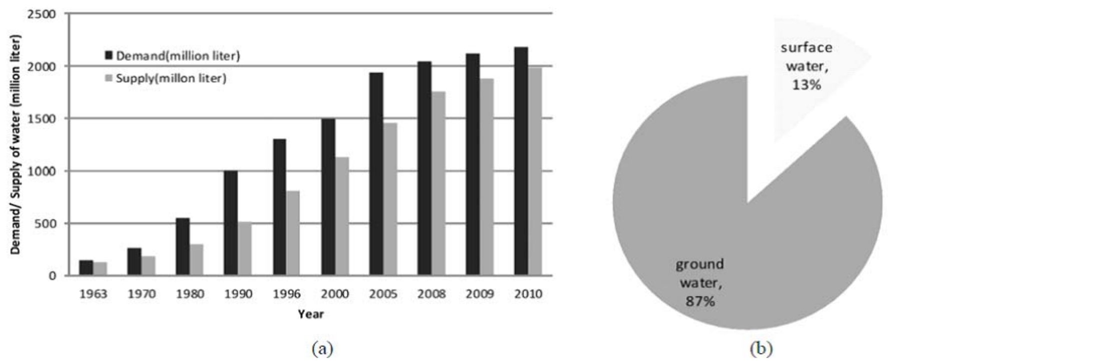


Figure 2.3: (a) Demand, supply and deficit of water, (b) Percentage of contribution of water sources in daily water supply in Dhaka.

The Dhaka Water Supply and Sewerage Authority (DWASA) is the only public utility to cater for potable water and sanitation services to about 90% of the urban people of Dhaka metropolitan area and Narayanganj district. Remaining 10% people get water from private deep tube wells.

Table1: Water-quality characteristics of selected domestic wastewater

Water Source	Characteristics
Bath tub and shower	Bacteria, Hair, Hot water, Odor, Oil and grease, Oxygen demand, Soaps, Suspended solids, and Turbidity
Evaporative Cooler	Salinity
Sinks, including kitchen	Bacteria, Food particles, Hot water, Odor, Oil and grease, Organic matter, Oxygen demand, Soaps, Suspended solids, and Turbidity
Swimming Pool	Chlorine, and Salinity

In developed countries, In terms of basic water quality parameters (TSS, BOD, turbidity), it is considered to be comparable to a low-or medium grade wastewater. However, there are several key differences in the composition of domestic waste water that need to be considered in order to narrow in on the specific challenges involved in its reuse. Jefferson et al. (2004) found that, though similar in organics content to full domestic wastewater, drainage water tends to contain fewer solids and is less turbid than full domestic wastewater, suggesting that more of its contaminants are dissolved. Domestic waste water position varies widely from household to household, depending on the personal habits of residents and the products used in the home. For example, a household that uses phosphate-free laundry detergent will produce domestic wastewater that is much lower in phosphate-P than one that does not. Eriksson et al. (2002) found that Danish domestic water samples could contain up to 900 different xenobiotic organic compounds (XOCs), depending on the cleaning and personal care products used in the home. Family makeup also plays a role- studies have found higher counts of total and fecal coliforms in domestic waste water produced in homes occupied by adults with small children than those occupied by adults only (Rose et al. 1991, Casanova et al. 2001).

METHODOLOGY

First of all simple Domestic water treatment unit was developed. The Domestic water sample was collected from the selected site (six halls in KUET campus). Then the water quality parameters of raw water and reclaimed water at three different stages were analyzed in the laboratory to observe the performance of the developed treatment unit and also to study the suitability of the reclaimed water for its potential and extending reuse. The operational and maintenance problem of the developed treatment unit was also studied. Finally a recommendation was given for the successful reuse of reclaimed drainage water in the household premises.

Development of Simple Domestic Water Treatment Unit

For the purpose of the development of low cost domestic water treatment unit a simple filtration unit was developed. The schematic diagram of the filtration unit is shown in figure 2 and figure 3 . The filtration unit consists of three major components. These components are storage tank, roughing filter, sand filter char coal filter.

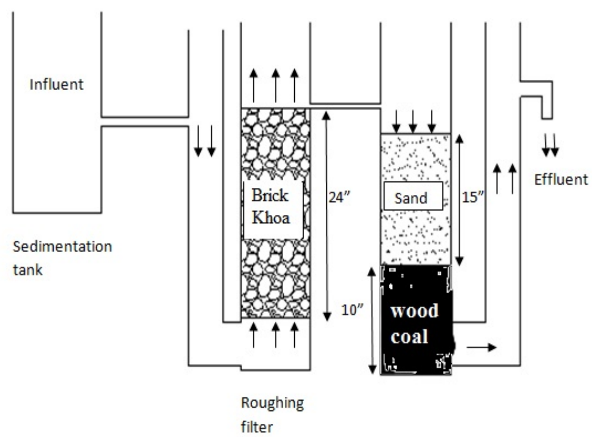


Figure 2: Schematic diagram of developed domestic water treatment unit (Option 01)

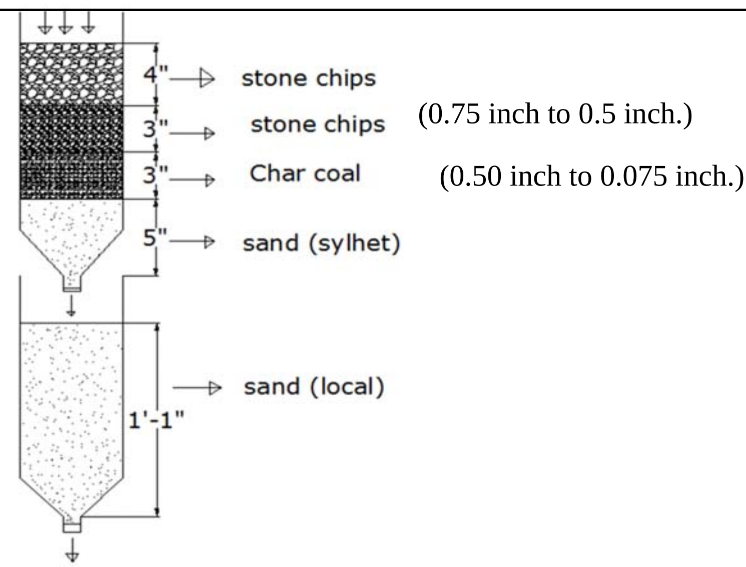


Figure 3: Schematic diagram of developed domestic water treatment unit (Option 02)

Roughing filter consists of stone chips in three different layers of two different sizes. At the top of the roughing filter 4 in. thick stone chips layer of size 0.5 in. to 0.75 in. was placed. and then the roughing filter 3 in. thick stone chips layer of size 0.075 in. to 0.5 inch was placed. So the total thickness of the filter material in the roughing filter was become 7 inches. The sand filter consists of sylhet sand and local as a filter material. The thickness of the sand layer was 18 inches. Char coal was used over sand filter. Thickness of char coal filter is 3 in. The thickness of the filter material in the filter is shown in the table

Table2: Thickness of aggregate layers

Aggregates	Aggregate size	Thickness of layers
Stone chips	0.75 in. to 0.5 in.	4in.
	0.50 in. to 0.075 in.	3 in.
Sand (sylhet)	-	5 in.
Sand (local)		13 in
char coal	-	3 in.

LABORATORY ANALYSES

For the laboratory analysis of the fifty different water quality parameters, the raw water collected and then it was filtered in the developed filtration unit. The raw water and the filtered water at two different stages were tested. The selected water quality parameters are pH, TDS, TSS, BOD_5, COD, turbidity, total coliform, E. coli, color. The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) was followed for the analyses of all the physical parameters. DO bottle is required for laboratory analysis of BOD_5 and DO meter is needed for measurement of BOD_5, it is measured in mg/l. For determination of COD, $K_2Cr_2O_7$ is taken in the pipette and ferrion indicator is used as reagent and titrates until the radish color formed. pH meter is used for determination of pH. Turbidity was measured with a Partech model DRT 100B Turbidimeter. Color was measured by the color comparator. For TDS and TSS test the sample is placed into oven at 105^0C.

(a) (b)

` (c) (d)

Figure 4: Laboratory test of samples (a) weight Machine, (b) Oven, (c) waste water filtering with filter paper, (d) Turbidimeter and p H meter

RESULS AND FINDINGS

The collection of raw water was done and brought to laboratory. The raw water was treated by the developed simple domestic waste water treatment unit. The water quality parameters of the raw water and the treated water were tested to study the performance of the treatment unit and to judge the suitability of the treated domestic waste water for further reuse. The sample was not reserved but tested as soon as possible to get better results.

Physical domestic water quality

The performance of the developed domestic waste water treatment unit was studied in the laboratory with regards to different physical water quality parameters (e.g., pH, color, turbidity, TDS, TSS).

Biological domestic water quality

The performance of the developed domestic water treatment unit was studied in the laboratory with regards to different biological water quality parameters (e.g., BOD_5, COD, Total coliform, E. coli).

The value of the pH was more or less same before and after the filtration. The pH slightly increased after filtering in the sand filter. But this increment is so small to say. The cause behind this phenomenon may be the sand filter contained some alkaline substance that dissolved in the water and lead to slight increase in the pH value. The pH value of raw water was around 8.5. The standard value of pH for the portable water lies within 6.5 to 8.5.

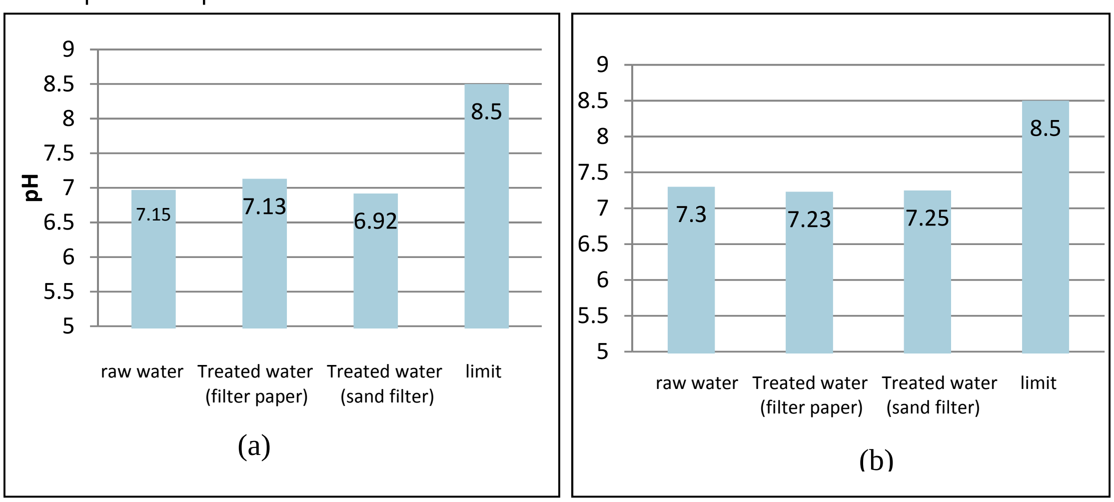


Figure 5: Variation of pH in the treatment unit (c) amar ekhushey hall kitchen waste (d) fazlul hall kitchen wastewater.

The color was removed significantly by the developed treatment unit. The average color removal efficiency was near about 70% .In Amar Ekushey hall basin, the color removal efficiency in normal filter Paper was 68% and sand filter it was 78%. But in basin waste water it was 56% in normal filter papaer and 62% in sand filter when choose in option 01, but when select option 2 the color removal efficiency was about less then 55% which is less than 70% so finally select option 01.

The color was removed mostly on the roughing filter. There are several causes behind the color removal. These are the adsorption in the stone chips, reduction of the organic matter, reduction of dissolved solids and mechanical staining that remove colloidal particles and removed color.

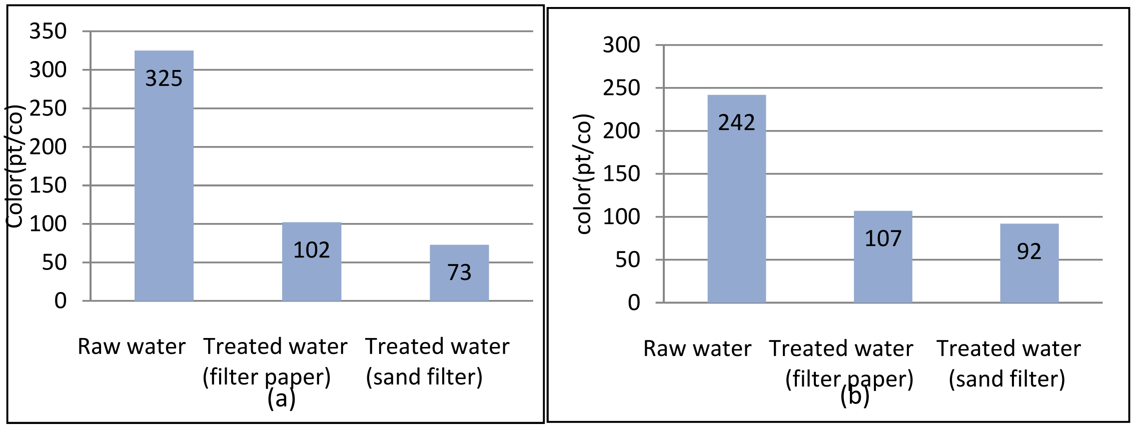


Figure 6: Removal of color in the treatment unit.. (a) B.S.M.R hall basin waste. b) Rashid hall bath waste

For Fazlul haque hall basin waste (for option 01)
For filter paper, efficiency= (325-102)/325=68.61%
And for sand filter efficiency=(325-73)/325=77.53% ,
When using option 02 the value of color in raw water was 325 (pt,co) and the values of treated water were 129 and 97 pt/co)respectively, here the efficiencies were 60% and 70%.

The removal efficiency of turbidity was about 85% for filter paper and 89% for sand filter. The sand filter is intended for the reduction of turbidity and TSS in the raw water. Most of the turbidity is reduced by the sand filter. When the waste water pass through the pore of the filter media, particles caused turbidity stacked and results significant reduction in the turbidity.

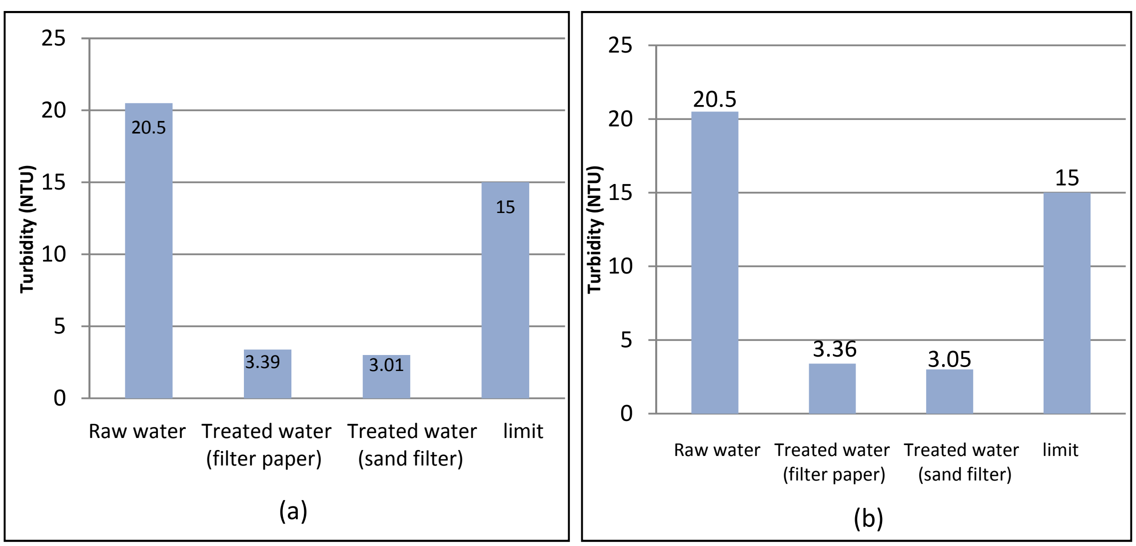


Figure 7: Removal of turbidity in the treatment unit. (a) Lalon shah basin waste. (b) A.E.H kitchen waste

The BOD removal efficiency was 6% for normal filter and 5% for sand filter. BOD removed in sand filter significantly, because the large chain of the organic matter cannot pass through the small pore of the aggregate and also adsorbed in the filter media. BOD values of different hall near about same. Sand filter result more accurate than normal filter paper. From the result it is clear that this waste water will be use any purposes excepting drinking such as gardening toilet flashing irrigation etc.

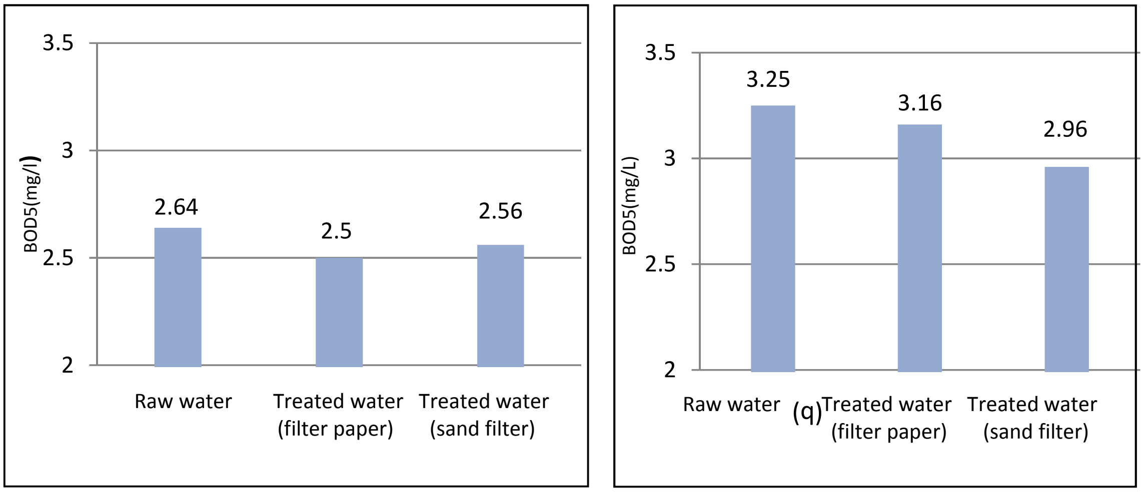


Figure 8: Removal of BOD5 in the treatment unit. (a) K.J Ali .hall basin waste. (b) A.E.H bathtub waste

The average COD removal efficiency was near about 60% for normal filter and 75% for sand filter. COD mostly removed in sand filter significantly, because the large chain of the organic matter cannot pass through the small pore of the aggregate and also adsorbed in the filter media.

The average TC removal efficiency was near about 60% for normal filter and 75% for sand filter. There are three general actions behind this phenomenon. These are sedimentation and adsorption, microbial action and electrostatic attraction. The sedimentation and adsorption action was previously discussed in the TDS part.

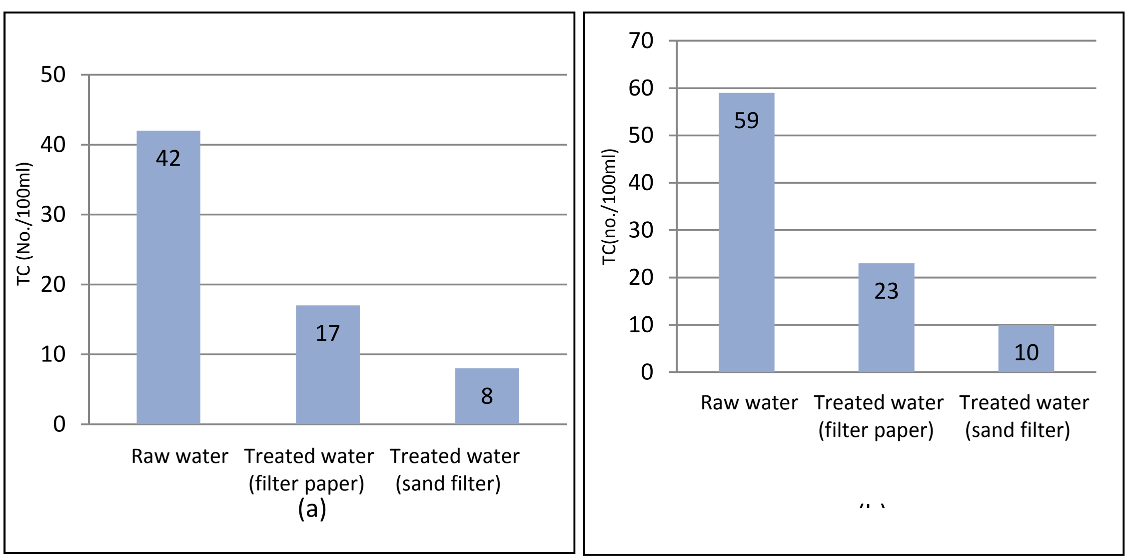


Figure 9: Removal of TC in the treatment unit. (a) fazlul haque hall basin waste. (b) A.E.H bathtub waste water

OVERALL TREATED WATER QUALITY

Salinity and turbidity are the single most important parameter in determining the suitability of the water to be used for irrigation. Salinity is determined by measuring the electrical conductivity (TC) and / or total dissolve solid (TDS) in the water. From this study the obtained removal efficiency of TC and TDS after reclamation was found 60% and 70% , respectively for seven inch thick sand layer. By using eight inch sand layer the removal efficiency can be increased up to around 75%. These two values satisfied the permissible limit for wastewater reuse . The salinity tolerance of plants varies widely. Crops must be chosen carefully to ensure that they can tolerate the salinity of the irrigation water, and even then the soil must be properly drained and adequately leached to prevent salt increase. Leaching is the purposeful over application of irrigation water in excess of crop needs to create a downward movement of water and salt away from the root zone.

In the filter having seven inch thick sand layer BOD_5 and COD reduced 5% to 6% and 60% to 75%, respectively after filtration. So the removal efficiency of the of the domestic water treatment unit in organic matter removal is about 60%. The color of the raw waste water was 325 Pt. Co. unit where after filtration it became 102 Pt. Co. unit. So the color removal efficiency is 68%. The microbiological water quality in terms of total coliform (TC) and E. coli was also improved satisfactorily with average removal efficiency about 60% for normal filter and 75% for sand. The treated water was very clear with turbidity value roughly 2.5-3 NTU.

CONCLUSIONS

Over the last two decades, the domestic waste management has become one of most crucial issue around the world. Based on the findings of this study the following conclusions have been drawn:

- Different characteristics of the domestic water and also the water quality in terms of different parameters were studied. Physical, and biological water quality parameters were identified.

- The treated (in the filter having seven in thick sand filter followed by a roughing filter) water quality was found to be satisfying the permissible limit for wastewater irrigation. Thus, the reclaimed domestic water could be efficiently used for household gardening and agricultural purposes. Toilet flushing might be another option for this water reuse. The microbiological water quality in terms of total coliform (TC) and E. coli was also improved satisfactorily with average removal efficiency about 60% to 75% and reduced to 10 and 8 cells, respectively. The treated water was very clear with turbidity value roughly 2.5-3 NTU.

- The operational and maintenance problems of the developed low cost domestic water treatment unit were found out. The major problems were negative head in the filter bed due to excessive head loss in the top layer of the sand bed, cracking of the filter bed caused by unequal head loss particularly at the walls, difference in the porosity and permeability of sand gravel beds, consolidation of the sludge and the gelatinous coating of the filter material, etc.

- Finally, an environmental friendly wastewater reclamation technique in the context of the Bangladesh was proposed

RECOMMENDATIONS

The developed domestic water treatment unit would be located at any suitable plain ground around the house premises. The treatment unit would have two chambers containing brick khoa sand and charcoal. A storage tank following the treatment operation could provide storage of the treated water for its potential reuse purposes.

This water will pass through filter and the reclaimed water will be stored in the storage tank. The treated water will be pumped from storage tank. There must have provision for excess water to overflow to sewer. Then the water will be used for different secondary purposes like gardening, car washing, toilet flushing. If the treated water is clear and microbiologically save then it may be used for laundry as well as toilet flashing.

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SCENARIO OF SOLID WASTE MANAGEMENT IN KHULNA CITY IN ACCORDANCE WITH THE ECONOMIC STATUS

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ABSTRACT

One of the most daunting issues facing the world is the increasing quantity of solid wastes due to increase of population, rapid economic growth and rise in community living standard. The purpose of this study is to investigate the present scenario of solid waste management in Khulna City. To achieve this motive, study involves a questionnaire survey and collection of secondary data from the city corporation. From the exploration of survey data, about 22% resident is not satisfied with the present SWM system, Average 58.42% resident use the door to door service but 14.11% resident yet dumps their waste in open place. Low income resident has propensity to dump waste in open place. On the other hand, opposite scenario is observed in medium and high-income community. Thus, the practice of waste management depends mainly on the socio-economic conditions and colonial waste collection system considering the socio-economic status can be adopted.

Keywords: *solid waste, disposal of waste, waste generation, socio-economic condition, flow path*

INTRODUCTION

Solid Waste Management (MSWM) of the municipalities has become a matter of concern worldwide, especially due to environmental problems such as air, soil and water pollution and open dumping sites in developing countries, a major problem is greenhouse gas production. During the last few decades, the problem of municipal solid waste management has acquired an alarming dimension in the world. This problem emerging from the contemporary lifestyle of urban people and becomes an imminent danger for the civilization. The world has now become an urban-dominated living place. Global Waste Management Market Assessment (Key Note Publications Ltd, 2007), reported 2.02 billion tones MSW generation globally and annual increase rate of 8%. The need to manage this increasing waste in an environmentally effective, technologically feasible, economically affordable and socially acceptable manner is a great problem. In a developing country, the problems associated with solid waste management are acute than in a developed country (Zerbock, 2003). Lack of financial resources and infrastructure to deal with solid waste creates a vicious cycle; lack of resources leads to low quality of service provision which leads to fewer people willing to pay for said services, which in turn further erodes the resource base and so on (Kuniyal J., Jain, & Shannigrahi, 1998; Zerbock, 2003). In any developing country, the threats posed by improper handling and disposal of solid wastes (though often ignored) contribute to the high level of mortality and morbidity (Medina, 2002). Human and ecosystem health is also threatened due to improper handling of solid wastes. Another significant factor that contributes to the problem of solid wastes in a developing country scenario is the lack of proper collection and transportation facilities. Improper planning coupled with rapid growth of population and urbanization serves to add congestion in streets, and as a result, the waste collection vehicles cannot reach such places, thus allowing filth to build up over time. Lack of monetary resources, at times, results in improper or no transportation vehicles for waste disposal adding another dimension to the ever rising cycle of problems (Jain R., 1990; Zerbock, 2003). Municipalities have failed to manage solid waste due to financial factors. The huge expenditure needed to provide the service (Sharholy, Ahmad, Vaishya, & Gupta, 2007a) the absence of financial support, limited resources, the unwillingness of the users to pay for the service (Sujauddin, Huda, & Hoque, 2008) and lack of proper use of economic instruments have hampered the delivery of proper waste management services. (Sharholy, Ahmad, Mahmood, & Trivedi, 2008) indicated that the involvement of the private sector is a factor that could improve the efficiency of the system. Bangladesh is currently undergoing a period of rapid economic growth and urbanization. Due to rapid industrialization, urbanization and population explosion the solid waste management in the municipal areas of Bangladesh become so hazardous that is poses a great threat to the city dwellers. All the tires of MSW management at Bangladesh are in the primitive stage and needs modernization through the innovative and appropriate approach in the association with local conditions for its proper management (Alamgir, McDonald, Roehl, & Ahsan, 2005). The want of adequate and proper facilities for waste management, severe lacking in people's awareness about environmental hazards, a serious gap in the process of motivation and participation, ineffective enactment of laws and poor enforcement made the whole system a pandemonium. Municipal solid waste management definitely a complex process because it involves disciplines and stakeholders from local to central government, civil societies and private sectors. Solid waste management is known to be a major environmental issue in developing countries, in particular in urban centers (Scheinberg, Wilson, & Rodic, 2010). Khulna City is situated in the southwestern area of Bangladesh. It is the third largest city in Bangladesh. The city core is about a quarter of the total city area and is densely populated. It has mostly multi-storied residential and commercial buildings. The rest of the city is a mixture of urban and peri-urban areas. Khulna is experiencing huge problems in dealing with the solid waste generated in the city every day. A fast growing population, coupled with an increase in industrial activities and uncontrolled urbanization, has lead to rapidly increasing quantities of waste being generated. The solid waste management services comprise of the collection of waste from approximately 1,200 masonry bins, constructed by the City Corporation, located on roadsides throughout the city. Households are expected to dispose of their waste in the door to door system. The waste is then transported to its final disposal site (approximately 6 km from the city) by the City Corporation trucks. The main objective of the paper is to depict the scenario of solid waste management in Khulna city. And to investigate the waste management synopsis with the socio economic status of the city resident.

STUDY AREA

Khulna is the third largest city in Bangladesh. It is the divisional headquarters of Khulna Division and a major industrial and commercial center. The encompassing Khulna metro area had an estimated population of 1.022 million as of 2014 (population census, 2011). Khulna is located in between 24°45' and 24°54' north latitudes and in between 89°28' and 89°35' east longitudes, on the banks of the Rupsha and Bhairab River. It covers a total area of 59.57 km^2, while the district itself is about 4394.46 km^2.

LITERATURE REVIEW

Waste management is one of the major concerns of environmental policies in the developed Community. The European Union's approach to waste management is based on three principles: prevention, recycling and reuse and improving final disposal and monitoring. The landfill is viewed as the last resort for those wastes that cannot be recycled or reused. Municipal waste makes up approximately 14% of the total waste produced each year that is around 415 kg per capita (EEA, 2004). Household waste makes up around two thirds of municipal solid waste, while the rest is composed of wastage of a similar nature to household waste produced by commercial and institutional activities. The content of municipal solid waste is of residual waste, bulky waste, secondary materials from the separate collection (paper and glass), household hazardous waste, street sweepings and litter collections. The waste is made up of materials like paper, cardboard, metals, textiles, wood and organics. Bangladesh is currently undergoing a period of unprecedented rapid economic growth and urbanization. Most cities of Bangladesh face environmental problems caused by inadequate provision of sanitation and waste management facilities. Recently solid wastes problems draw noticeable attention to the concerned stakeholders since it creates nuisance in the daily urban life as well as other problems such as drainage clogging resulting water logging in some parts of the cities (Alamgir, 2009). With over 3.3% annual growth in urban population in Bangladesh during 1991-2001 census years, solid waste generation has also increased proportionately with the growth of urban population. In 1951, the percentage of urban population was 4.33% of the total population. Since then due to rapid urbanization, it reaches 24% by the year 2001. In a study by JICA

(2004) it has been found that during the wet season the waste generation rate increases by 46%. In another study by Ahmed (1991) this variation was found to be within 15% to 50%. As such to estimate the waste generation rates in the wet season an increase of 46% is considered. Finally, average of dry and wet season is considered to arrive at the average waste generation rate, taking into account the seasonal variation. The composition of solid waste depends upon a number of factors, such as food habit, cultural tradition, socio-economic and climatic condition. The composition of solid waste varies not only from city to city but even within the same city itself and also seasonally (Enayetullah, Sinha, & Khan, 2005). In Bangladesh a significant portion of the population does not have access to waste collection services and only a fraction of the generated wastes are actually collected by the door to door collection systems. Solid wastes are collected from generation sources by NGOs, CBOs and city authority by door to door collection systems, and most of the cases, owner by himself disposes it to the nearest community bins/SDS/open land/roadsides/drains. City authorities collect these waste and transfer to the UDS. City corporations‟ motorized vehicles collect the wastes from SDS and transfer to UDS. City authority does not have the resources to provide door to door collection system because it requires more human resources, physical facility, more responsibility to collect the waste daily directly from generation sources and require proper planning and tight schedule (Ahsan et. al, 2005).

METHODOLOGY

The methodology includes the physical composition survey and the collection of primary and secondary data through questionnaire survey. The sample size of the survey was determined by using Solvin’s formula shown in below

$$n = \frac{N}{1 + Ne^2}$$

P = Degree of variability = 0.50 (assumed maximum variability)

And, let Degree of Variability is maximum that is 50%.

So, P = 0.5

As, q = 1 - P

So, q = 0.5

We will use 95 % confidence level.

e = Desired level of precision or sampling error = 5% = 0.05

The sample size therefore n= $\frac{770498}{1+(770498*0.05^2)}$ = 404 nos.

In every ward 18 surveys are made to fulfill the requirement. The sample was taken randomly by using random table for getting unbiased result. After the collection of primary data raw data were processed to meet up the objective of the study and for this task Statistical Package Software Spreadsheets (SPSS) is used.

After collecting survey data the present situation of solid waste management is analyzed. From the analysis, a flow path of present solid waste management in Khulna City Corporation is depict. From the analysis, the problems and limitations with economic status are found out.

RESULS AND DISCUSSIONS

The amount of solid waste generation in the Khulna city has no reliable estimation. Generation of solid waste may vary with the economic status of people, household size, season of the year etc. It has been estimated that municipal solid waste generation in KCC is 450 ton per day. On this basis the quantity of solid waste generated per capita/day is 0.5 kg. The main source of waste is households and highest quantity of solid waste is generated in winter season and lowest in wet season. About 70 to 80 percent of the generated waste in city is organic in nature and rest 20 percent is inorganic in nature. (Debasish Adhikary, Md. Shahidul Islam-2015)

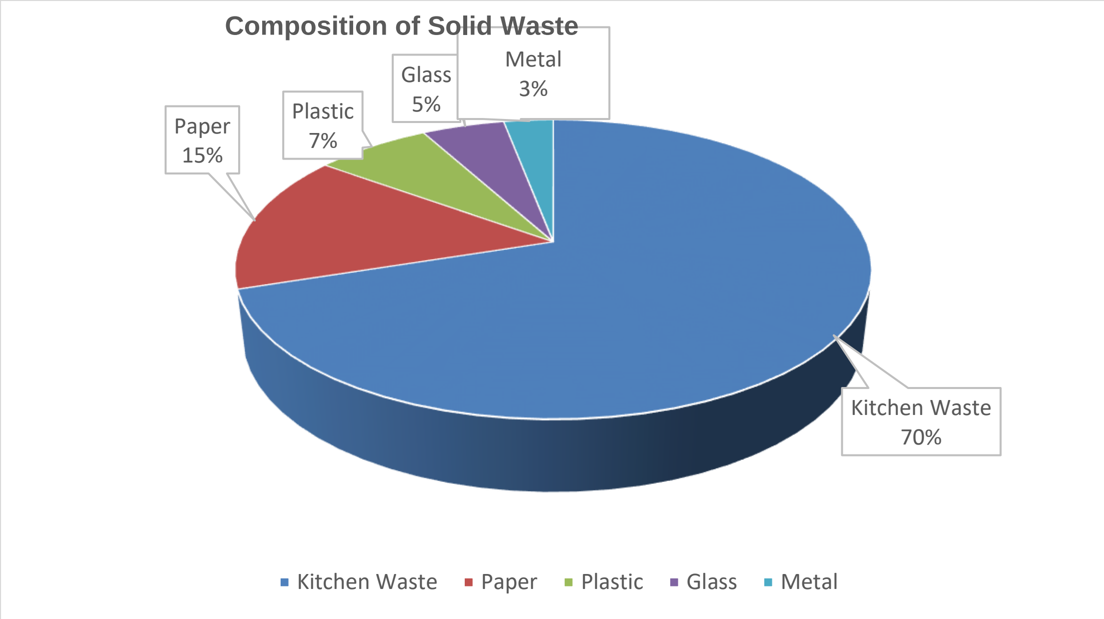


Figure 1: Physical Composition of Solid Waste in Khulna City

Waste Collection

Presently Khulna City Corporation is collecting MSW through the following processes,

- Door to door collection from households.
- Collection of waste by street sweeping.
- Collection of Drain sludge and SW by drain cleaning.

I. **Door to Door Collection:** Khulna City Corporation collects SW by the door to door garbage vans. It has 80 garbage vans, 80 workers (drivers) work on the garbage vans. The collection workers are not paid by the Khulna City Corporation authority. They collect money directly from the household owners. About 30 to 50 takas per month is paid by the users.

II. **Collection of Waste by Street Sweeping:** According to the survey of Khulna City Corporation, there is about 356.64 km of road inside the City Corporation area. The conservancy department of Khulna City Corporation maintain street sweeping. Each sweeper is assigned to a certain length of road for which he/she is responsible.

III. **Collection of Drain Sludge and SW by Drain Cleansing:** The total length of the drain of Khulna City is near about 642.18 km. Khulna municipality on the supervision of the conservancy department cleans the drain at regular intervals by its sweepers.

Waste Transportation and Disposal

After the primary collection of household waste by the garbage vans the wastes are transported in the SDS or ramps and then to the final disposal site (FDS). To this process of transportation and disposal can be divided into two parts-

- Disposal of Collected Waste to SDS/Ramps
- Disposal of Waste to the FDS

KCC has total number of conservancy staff about 358 and 1200 dustbins. There are minimum 10 to 20 dustbins in each ward. Some of the dustbins are open at the top and some are covered. On realizing the present situation, it handed over some responsibilities of taking solid wastes from house to house collection of some wards to the several NGO (mainly Prodipan). The secondary collection means, after primary collection, the primary collection blocks are served by transport points and taken to the final disposal points by a large truck. KCC estimates about 450 ton of wastes are generated daily in the city area and only 120 to 125 ton are collected by it workers and the remaining are dumped irregularly. KCC has 65 secondary disposal sites and some disposal sites are placed with demountable container, from where workers collect wastes with recommended KCC vehicles to the final disposal site in a regulated timetable. It has regular 22 to 25 trips to the final disposal site daily. Rajbandh is the main dumping station of the KCC.

Recycling / Composting

There are four types of NGO had taken initiative on composting in different time. Those are listed below:

RUSTIC started its composting initiative during 2002-2003 in funding support of BEMP/CIDA. It continues the initiative at small scale. At present only RUSTIC is producing about 30 tons compost fertilizer per month on its own 0.47 acre land.

Samadhan had organic compost fertilizer preparation plant under the funding support of Waste Safe/EU during 2007-2010. It has stopped composting before 2 years for not getting certificate from the Ministry of Agriculture.

SPS had a small organic solid waste recycling and compost fertilizer preparation plant under the funding support of PRISM Bangladesh/SEMP during 2002-2004.

Prodipan first time initiated composting in Khulna City under the funding support of World Bank during 1997-2002. It also supported some small NGOs and CBOs on composting during the period. Prodipan compost fertilizer had great demand in Khulna area. At present it does not have any production and marketing.

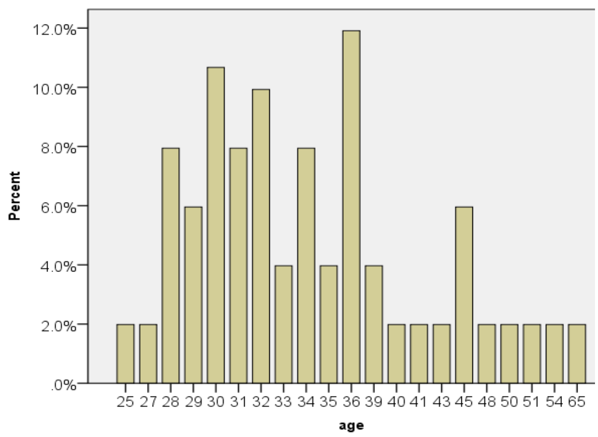
Source: (Tusar Kanti Roy, Saima Rahman, Papon Kumar Dev-2013)

Evaluation of Questionnaire Survey

From the questionnaire survey different respondent characteristics are identified and a comparative relationship are evaluated.

Respondent Characteristics

- Age and sex of the Respondent



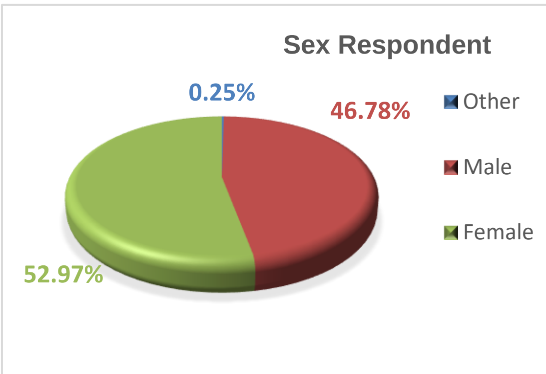


Figure 2: Categories of Surveyed residents by Age and Sex

A questionnaire survey in 31 wards of Khulna municipality was conducted through direct interviews of the residents in all possible levels in terms of age, income level, education, profession with a view to explore the people's perception on SWM.
Among the surveyed people, 46.78% were male and 52.97% were female respondent

➢ Education, Income and Profession of the Respondent

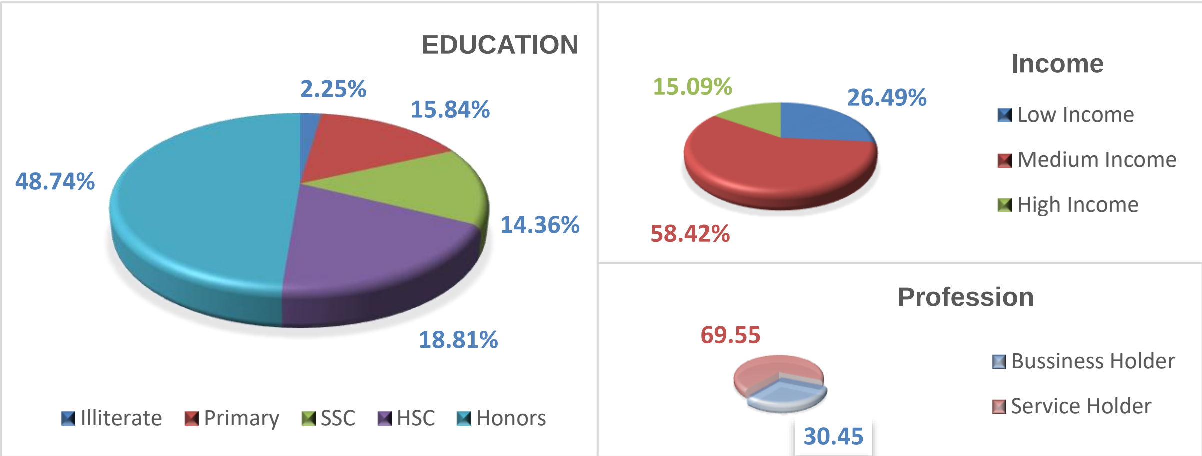


Figure 3: Categories of Surveyed residents by Education, Income and Profession

Most of the city dwellers are educated and 48.32% of people have completed their graduation. The total population have been grouped according to their economic status. Low income community is considered the population who has the capability of monthly income below 20 thousand, medium income from 20 to 50 thousand and high income above 50 thousand.

Table 1: Crosstabs analysis of various component of solid waste management with the economic status.

Income	Average Daily Generated Solid Waste				Respondent
	Below 2kg	2-3kg	3-5kg	Mention others	
Low Income	36	69	2	-	107
Medium Income	43	136	49	8	236
High Income	12	23	19	7	61
Total	91	228	70	15	404
	Storage of Household Waste				
	Dustbin	Polythene	Open Space	Do not Store	
Low Income	22	46	34	5	107
Medium Income	174	51	8	3	236
High Income	47	14	-	-	61
Total	243	111	42	8	404
	Disposal of Plastic Bottle and Battery				
	With Kitchen Waste	Reuse	Sell	Mention others	
Low Income	43	37	27	-	107
Medium Income	68	54	114	-	236
High Income	39	5	17	-	61
Total	150	96	158	-	404
	Where Do You Dispose Your House Hold Waste				
	Door to Door	Open Space	Dustbin	Haphazardly	
Low Income	19	21	53	14	107
Medium Income	166	11	48	11	236
High Income	51	-	10	-	61
Total	236	32	111	25	404

Income	What Type of Disposal System You Like			Respondent
	Door to Door	Dustbin	Mention others	
Low Income	13	94	-	107
Medium Income	187	49	-	236
High Income	58	3	-	61
Total	258	146		404
	Agree To Pay for Door to Door Collection			
	Yes		No	
Low Income	27		80	107
Medium Income	202		34	236
High Income	59		2	61
Total	288		116	404

From the crosstabs analysis, it has been found that the different component of solid waste management varies with economic status and living standard of the city dweller. Thus a colonial waste management system can be adopted considering the social status of the city dweller.

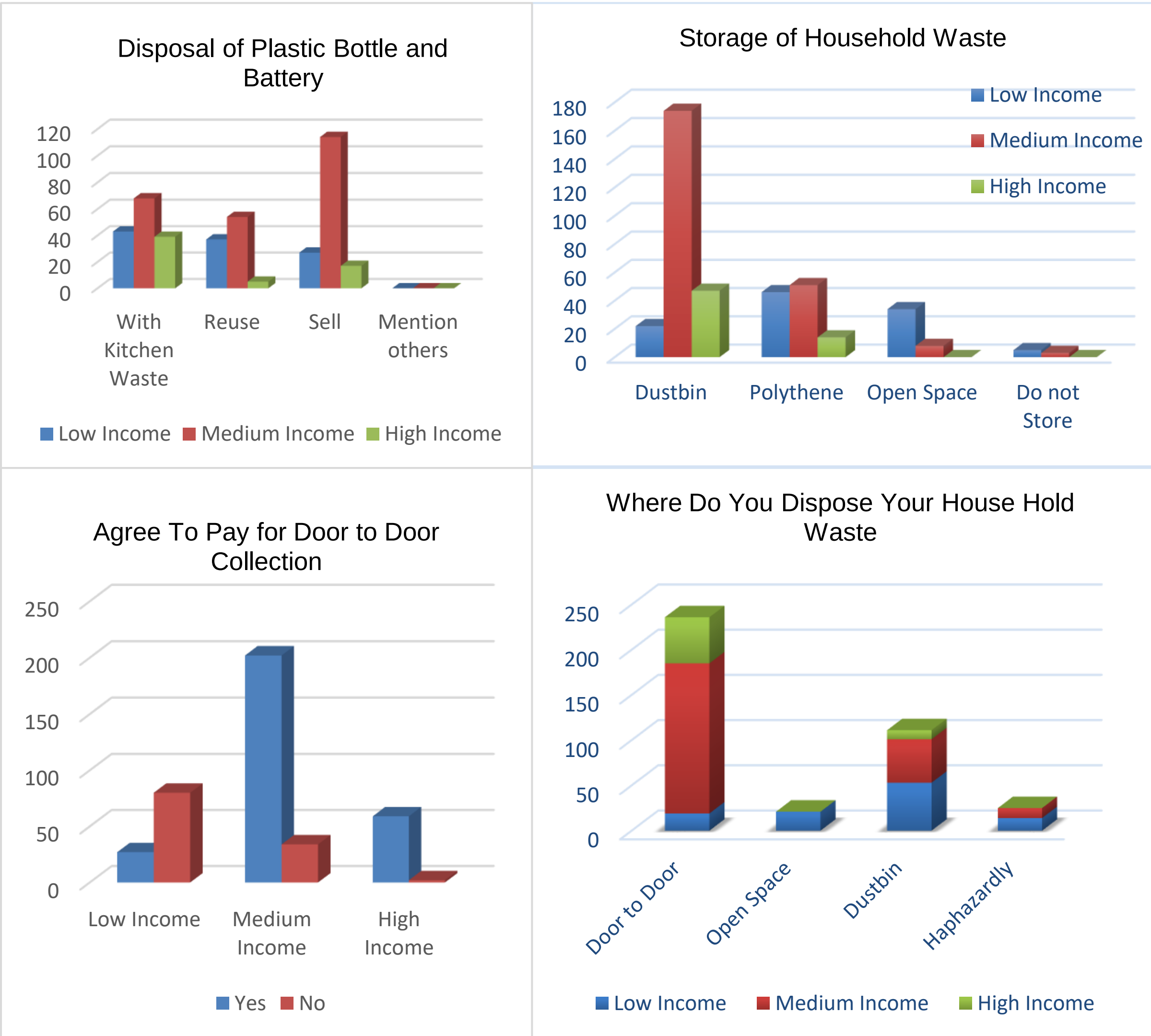


Figure 4: Relationship of different component of Waste Disposal System with Respect to Socioeconomic Status

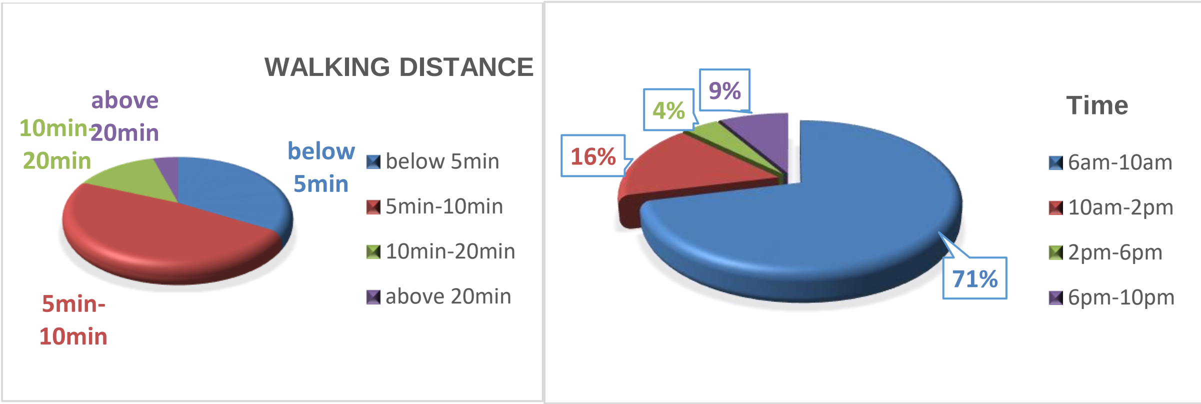


Figure 5: Preferable walking distance of dustbin and the waste collection time.

About 71% people feel comfort to dispose their solid waste in between 6am to 8pm.The preferable walking distance of dustbin from home 5min to 10 min. Low income community prefer dustbin in their locality because they don't want to pay for door to door collection. On the other hand High income community less prefer dustbin due the unpleasant odor comes from the organic solid waste.

From the field survey and secondary data, a flow path of the present SWM system in Khulna city is generated.

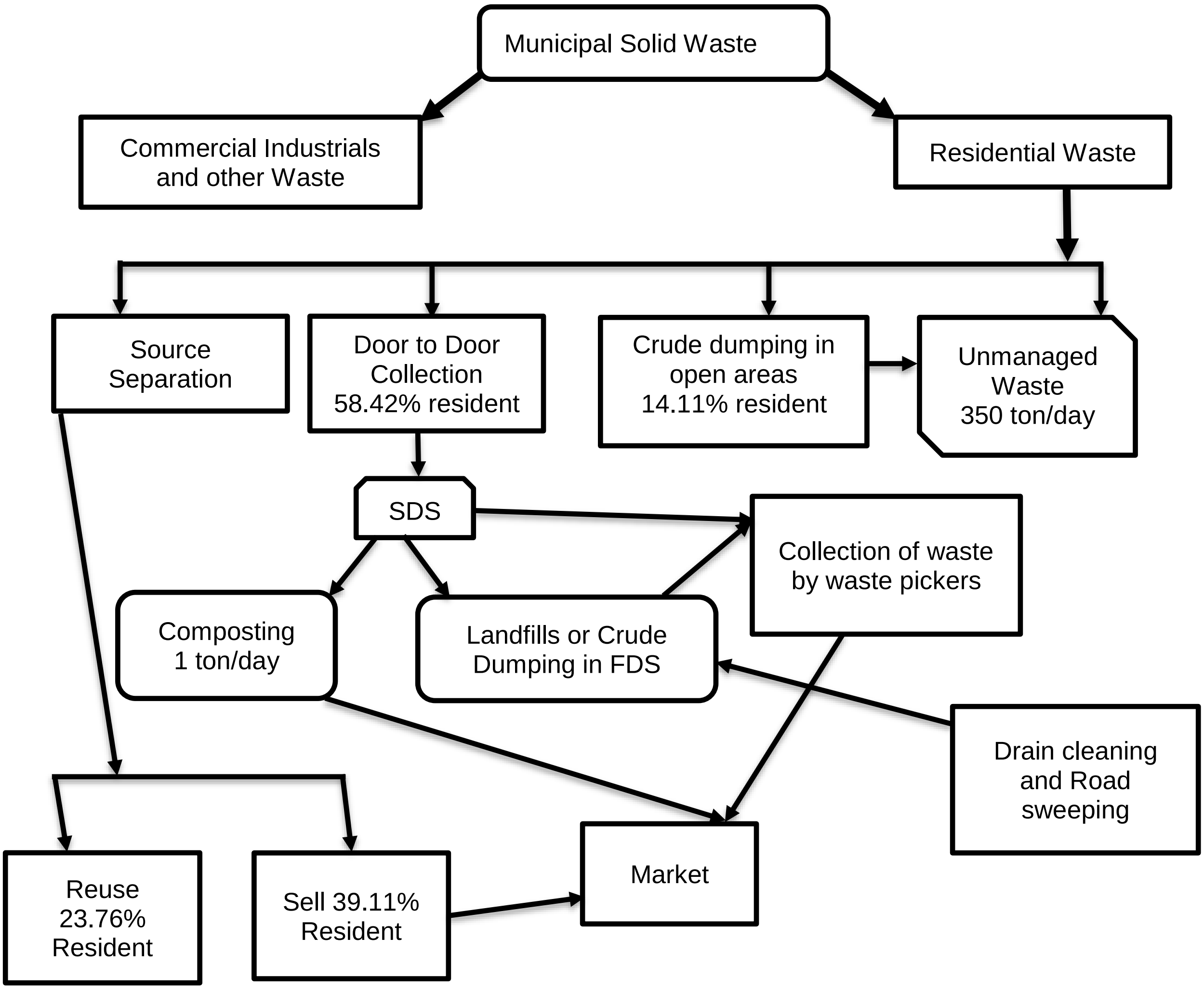


Figure 6: Solid waste management system in Khulna City

CONCLUSION

Solid waste management is a complex process because it involves many disciplines and stakeholders. Khulna city is facing problem in solid waste management with its limited resources. The study aims to depict the scenario of solid waste management in Khulna city. Khulna City Corporation is trying to improve its SWM system by adopting new policies such as door to door collection, compost plant etc. But they are not fully capable of handling the total generated solid waste. About 350 ton/day solid waste is remain unmanaged. Because 14.11% resident dispose their waste in open places. In low income community, about 49.53% resident use dustbin to dispose their waste where only 19.87% of high income community use dustbin. On the other hand 17.76% resident of low income community use door to door collection system. It is also found that most of the low income community wants dustbin as waste disposal system but the scenario is opposite for the middle and high income community. The tendency of use door to door collection system is more desirable in high income community because they do not want dustbin around their house as it creates an unhygienic condition. But in low income community the use of door to door collection system is less preferable because of their unwillingness to pay. A large number of resident nearly 37.12% dispose battery and plastic bottle with their kitchen waste and 23.76% and 39.1% of resident reuse and sell it respectively. It is also found that hazardous waste (such as battery, bottles of spray) 7.92% are separated. A compost plant which can produce 1ton of compost per day using organic waste and fecal sludge. About 22% people are not satisfied with the present solid waste management system. A flow path has been created to describe the present scenario of solid waste management. From the flow path it is clear that there is adequate practice of recycling and reuse.

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REINVENT THE TOILET CHALLENGE AND TECHNOLOGIES FOR ENERGY AND TREATMENT OF WASTE WATER

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ABSTRACT

The study is concerned about the recent reinvention of toilet system and the technology of energy recovery and waste water treatment. To develop a new biotoilet system a community toilet was made at Unmesh Govt. Primary School at KUET campus which is now in under construction. For time contraction we adopt a community toilet for biogas measurement at Shiromoni Hafijia Madrasha, Fultala, Khulna where a special type tank (Biotank) was taken up in which an anaerobic consortium of bacteria completely digests human waste at high efficiency. A filtration bed of five layers consisting of very fine sand, fine sand, coarse sand, large sand and broken sand from top to bottom was made in the laboratory as a prototype to treat wastewater for irrigation purpose. Gas was measured by a Flow Meter and the flow was measured as 0.03111 m^3 /s (after the biotoilet is used by 150 students). Treated water was also collected using a pump. And our study reveals that it is possible to generate energy (biogas) from human excreta and treated waste water can used in irrigation purpose in an eco-friendly way.

Keywords: *reinvention, waste water treatment, biotoilet, biogas, Biotank*

INTRODUCTION

Energy is the prerequisite and fundamental element of national development of Bangladesh. And energy production concurrently eco-friendly treatment of human excreta is obviously a great challenge for Bangladesh as one of the most affected third world countries. Disposal of human faecal leads to the aesthetic nuisance, organic pollution & spread of infectious diseases due to contamination of ground water. To develop a new biotoilet system a community toilet was made at Unmesh Govt. Primary School at KUET campus which is now in under construction. For time contraction we adopt a community toilet for biogas mearure at Shiromoni Hafijia Madrasha, Fultala, Khulna where a special type tank (Biotank) was taken up in which an anaerobic consortium of bacteria completely digests human waste at high efficiency. To conduct the work a special type of tank (Biotank) was designed where an anaerobic consortium of bacteria completely digests human excreta at a high efficiency. Very fine sand, fine sand, coarse sand, large sand and broken sand was used to make a bed of five layers that treated the waste water. After a few days of defecation on the toilet, gas was collected which is used as energy (Biogas). And to get pathogen free water various laboratory tests were done including TC, BOD, COD, TDS, pH measurement, turbidity. The results were satisfied with the ideal values and our paper thus aims to reinvent a toilet system to generate energy (Biogas) from human excreta and get treated water for irrigation purpose in an ecofriendly way. The proposed work is carried out with a view to attaining the following main objectives:

- ✓ To study on present sanitation practices in Bangladesh
- ✓ To create eco-friendly and cost effective sanitation system
- ✓ Generation of energy(Biogas)

✓ Treatment of wastewater using sadimentation bed.

STUDY AREA

Shiromoni Hafijia Madrasha, Fultala, Khulna is location at 22.9750°N 89.4583°E. The city is 4 meter above the mean sea level (MSL). It has 12867 households and total area 56.83 km². To develop a new biotoilet system a community toilet was made at Unmesh Govt. Primary School at KUET campus which is now in under construction. For time contraction we adopt a community toilet for biogas mearure at Shiromoni Hafijia Madrasha, Fultala, Khulna where a special type tank (Biotank) was taken up in which an anaerobic consortium of bacteria completely digests human waste at high efficiency.

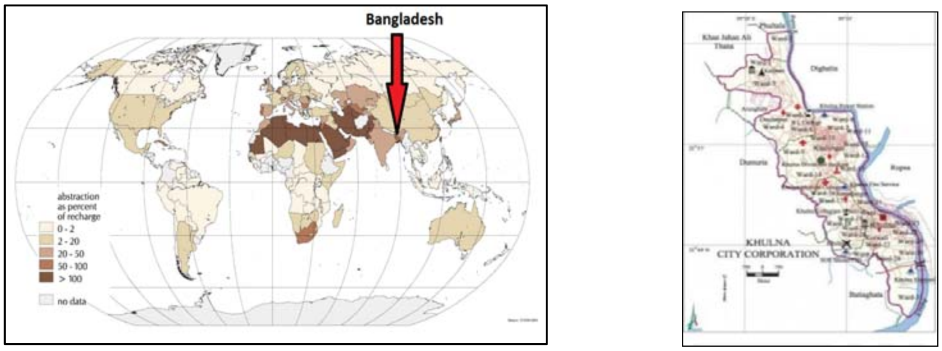

Fig 1: Location of the study area (Fultala, Khunla,Bangladesh)

LITERATURE REVIEW

Water scarcity ,water pollution and energy scarcity are crucial issues in today's world. One of the ways to reduce the impact of water scarcity and pollution is to expand water, wastewater reuse and generation of energy. The increasing scarcity of water in the world along with rapid population increase in urban areas gives rise to concern about appropriate water management practices. In the context of trends in urban development, waste water treatment deserves greater emphasis. Currently, there is a growing awareness of the impact of sewage contamination on rivers and lakes. Accordingly, wastewater treatment is now receiving greater attention from the World Bank and government regulatory bodies. Urban wastewater treatment has received less attention compared to 'water supply & treatment.' Water scarcity coupled with the bursting seams of our cities and towns have taken a toll on our health and environment. The sewage contamination of our lakes, rivers, and domestic water bodies has reached dangerous levels and is being recognized by leading organizations like the World Bank. The current urban wastewater management system is a linear treatment system that is based on disposal. The traditional system needs to be transformed into a sustainable, closed-loop urban wastewater management system that is based on the conservation of water and nutrient resources. A huge loss of life-supporting resources is the result of failed organic wastewater recovery. A wastewater management team is well equipped to create a wastewater management strategy that will result in the reduction of pathogens in surface and groundwater to improve public health.

In order to achieve ecological wastewater treatment, a "closed-loop treatment system" is recommended. Many present day systems use a "disposal-based linear system." The traditional linear treatment systems must be transformed into the cyclical treatment to promote the conservation of water and nutrient resources. Using organic waste nutrient cycles, from "point-of-generation" to "point-of production," closes the resource loop and provides a better approach for the management of valuable wastewater resources. Failing to recover organic wastewater from urban areas means a huge loss of life-supporting resources that, instead of being used in agriculture for food production, fill rivers with polluted water. The development of ecological wastewater management strategies will contribute to the reduction of pathogens in surface and groundwater to improve public health. The goal of ecological engineering, in this particular context, is to attain:

- High environmental quality,
- High yields in food and fiber
- Good quality/high efficiency production, and
- Full utilization of wastes.

In the growing number of conflicts between agricultural and domestic use of scarce water resources, an increased use of treated wastewater for irrigation purposes is vital. Worldwide energy crisis directed the attention to the alternative sources of energy instead of underground fossil fuel. Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions .Biogas has globally remained a renewable energy source derived from .sanitary wasteBiogas is a colorless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane ((%70-50, carbon dioxide (%40-20and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapor etc. A biogas plant or latrine when successful is an appropriate and sustainable method to deal with human or animal waste. This system produces two extremely useful products from the waste: biogas and slurry. Using biogas for cooking and lighting reduces the strain on the environment by decreasing the use of biomass and the production of greenhouse gases (as methane that is produced normally from manure is now captured and used). The biogas system also provides a barrier protecting ground water from contamination from untreated waste .To save the environment from further deterioration and also supplement the energy needs of the rural populace, a strategy incorporating local resources and new technology as biogas technology can be effectively utilized. According to WHO, UNICEF and WSSCC (2000) the improved sanitation options are connection to public sewer, connection to septic tank/soak well, pour-flush latrine, ventilated improved pit latrine and simple pit latrine. In Bangladesh, pour-flush water-sealed direct pit latrines are being promoted for rural areas, while pour-flush twin off-set pit latrines and septic tanks with soak well are the preferred options in urban and peri-urban areas.

METHODOLOGY

Biogas is produced by the process of anaerobic digestion of organic materials. It can be produced either from biodegradable waste materials or by the use of energy crop fed into anaerobic digesters to supplement gas yields (Faulstich et al. 2007). The solid byproduct, digested, can be used as a biofuel or a fertilizer. Biogas in contrast with other renewable primary products, can replace all forms of energy (Heat, Electricity, and Fuels). Biogas can be stored easily, energy can be provided when and where needed. In this study biogas is generated from human faecal from a toilet in a sanitary way and also wastewater is treated for irrigation purpose. Based on anaerobic biodegradation, we developed has an eco-friendly appropriate and affordable sanitation technology for human waste disposal for different climates and situations. The technology of a specially designed tank (Biotank) in which the humen waste is completely digested at a high efficient by an anaerobic consortium of bacteria. After biodegradation, effluent water is further filtered through a sedimentation bed that improves effluent quality by totally reducing turbidity, suspended/ dissolved solids and pathogenic coliforms. The digestion process involves conversion of organic waste into carbon dioxide, water and methane, and the effluent generated is free from obnoxious smell & most of pathogens. The system can be constructed by any local mason resources (like bricks/ cement) for any residential community area. Methodology mainly includes construction of biotank, biogas generation, Sample Preparation, Gas Collection and Measurement System, Filtration Bed Preparation**.** We take a community at Shiromoni,Fultala, Khulna which is a residential building of 150 students.

EXPERIMENTAL SETUP

Figure 3: Super structure of the biotoilet (under construction)

Figure 4: Prototype biotank (under construction)

Figure 5: Measurement of biogas using flow meter

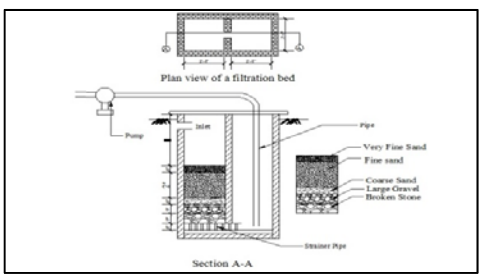

Figure 6: Sedimentation bed

Figure 7: Prototype Sedimentation bed filter

Figure 8: Model of Sedimentation bed at laboratory

RESULS AND FINDINGS

Water Quality Analysis for the Treated Sanitary Water

The collection of raw water was done and brought to laboratory. The raw water was treated by the developed simple domestic waste water treatment unit. The water quality parameters of the raw water and the treated water were tested to study the performance of the treatment unit and to judge the suitability of the treated domestic waste water for further reuse. The sample was not reserved but tested as soon as possible to get better results.

Physical drainage water quality

The performance of the developed domestic waste water treatment unit was studied in the laboratory with regards to different physical water quality parameters (e.g., pH, color, turbidity, TDS, TSS).

Biological drainage water quality

The performance of the developed sanitary water treatment unit was studied in the laboratory with regards to different biological water quality parameters (e.g., BOD_5, COD, Total coliform, E. coli). Raw and filtrated water quality (sedimentation bed filter) was tested. Then the obtained water quality was compared with the WHO wastewater irrigation standards for possible utilization in toilet flushing, gardening, agriculture, car washing and laundry.

pH:

The value of the pH was more or less same before and after the filtration. The pH slightly increased after filtering in the sand filter. But this increment is so small to say. The cause behind this phenomenon may be the sand filter contained some alkaline substance that dissolved in the water and lead to slight increase in the pH value. The pH value of raw water was around 7.03. The standard value of pH for the portable water lies within 6.5 to 8.5. The pH value of filtrated water was around 7.77

Dissolved oxygen:

The raw water dissolved oxygen was found 1.99 mg/l where the treated water conductivity is 5.48 mg/l. To use the treated water as irrigation purpose dissolved oxygen must be lies between 4.5-8 mg/l. So the treated water can be used as irrigation purpose.

BOD

The BOD removal efficiency was 64%. BOD removed in sand filter significantly, because the large chain of the organic matter cannot pass through the small pore of the aggregate and also adsorbed in the filter media. The curved flow paths around grains bring the organic matter in contact with sand surfaces, where they adhere because of physical attraction and presence of gelatinous coating. The BOD also reduced for the lessening of the amount of the bacteria. BOD in the reclaimed water was within the permissible limit for irrigation

COD

The COD removal efficiency was 50%. COD mostly removed in filter significantly, because the large chain of the organic matter cannot pass through the small pore of the aggregate and also adsorbed in the filter media. The curved flow paths around grains bring the organic matter in contact with sand surfaces, where they adhere because of physical attraction and presence of gelatinous coating. The COD also reduced for the lessening of the amount of the bacteria.

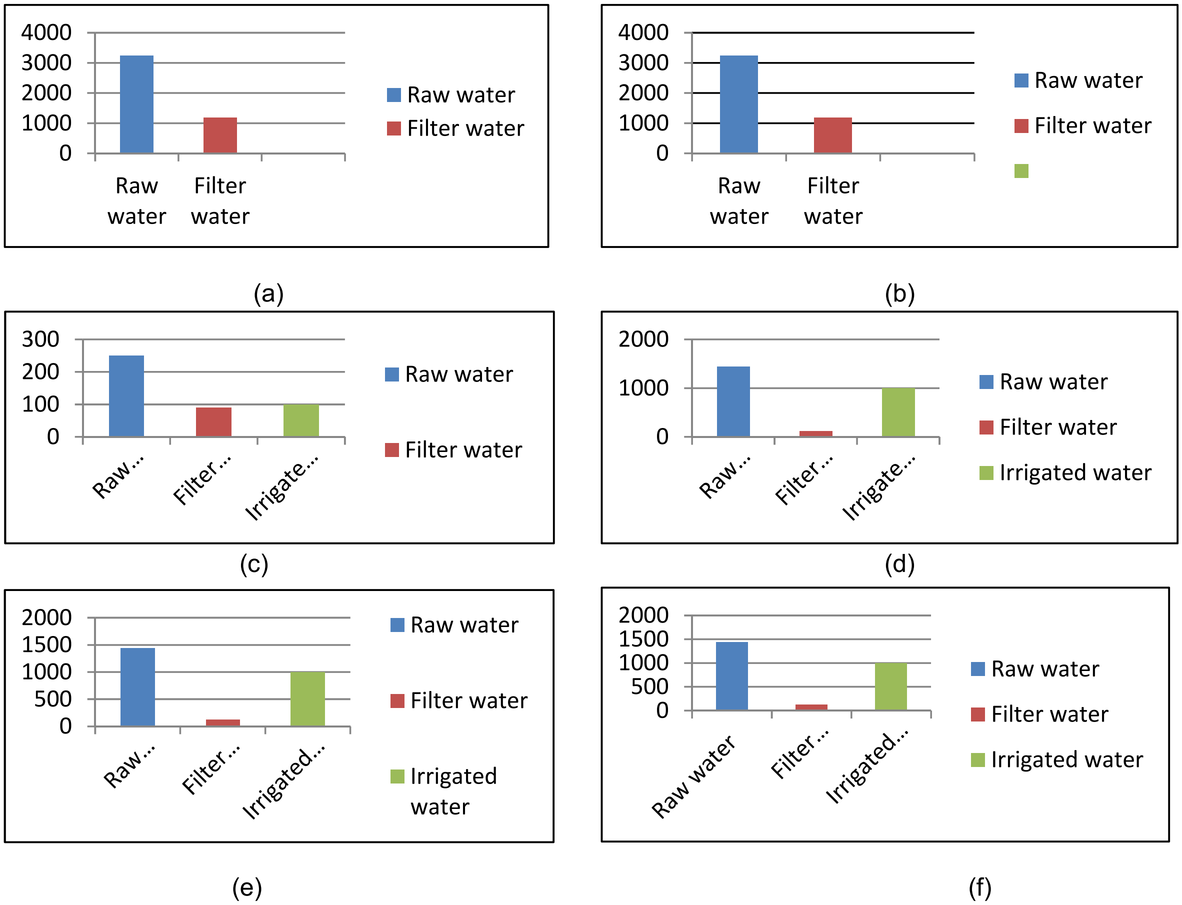

Figure a,b,c,d,e,f: Variation of pH, DO, BOD, COD, TC and FC with raw water, filter water and irrigated water

Total coliform (TC)

The TC removal efficiency was 63.7%. There are three general actions behind this phenomenon. These are sedimentation and adsorption, microbial action and electrostatic attraction. During the process of filtration, a coating of micro-organisms is formed around the sand grains. This is primarily responsible for the removal of organic matters and bacteria present in the raw water. A part of the organic material present in raw water is oxidized for energy requirements and another part is transformed into cell materials for microbial growth. Since the amount of organic matter in water is small, it can support limited microbial growth in the filter bed. The layer of microbial film around the sand grains is called '*Schmutzdecke*', and is very prominent in the top layer of the sand filter. Electrostatic attraction is most effective between particles having opposite electrical charges. The sand particles having negative surface charges are not likely to attract negatively charged bacteria and colloids during the initial ripening period of the filter. However, with the adsorption positively charged particles and ions, the sand surfaces become over saturated and charged reversal occurs. The overall charge of filter grain coatings becomes positive and negative charged particles are attached and retained. The filter bed, after the ripening period, will exhibit continuously varying negative and positive charged grain coatings that are able to absorb most impurities present in water.

E. coli

The E. coli removal efficiency was 68%. The E. coli was reduced significantly in the sand filter. There are three general actions behind this phenomenon.

Table 1: Tested result of waste water and irrigation water standards.

Sl No	Parameter	Raw water	Filter water	Irrigated land
01	pH	7.03	7.77	6-9
02	Turbidity	37.8 NTU	4.86 NTU	1-30 NTU
03	Conductivity (µS/cm)	1564 µS/cm (at 29^{o}c)	1475 µS/cm (at 28.5^{o}c)	≤3000 µS/cm
04	DO	1.99	5.48	4.5-8
05	BOD_5	250	90	100
06	COD	640 mg/l	320 mg/l	400 mg/l
07	Total Dissolved Solid	1410 mg/l	1130 mg/l	2100 mg/l
08	Suspended Solids	3240 mg/l	1190 mg/l	200 mg/l
09	Total Coliform	1930 MPN/100ml	700 MPN/100ml	10000 MPN/100ml
10	Faecal Coliform	1440 MPN/100ml	125 MPN/100ml	1000 MPN/100ml

Measurement of Biogas:

The generation rate of biogas from the biotank (after the biotoilet is used by 150 students) is 0.03111 m^3 /s.

CONCLUSIONS

This study revealed that it is possible to produce biogas from human excreta and waste water can be used in irrigation purpose after treating it through sedimentation filter bed. This biotoilet sanitation system is eco-friendly & cost effective and generation rate of biogas was found from the biotank is 0.03111 m^3/s. The tested result shows that the treated water can be used in irrigation and a five layer sedimentation bed was added with biotank to treat the effluent water for using it in irrigation purpose.

RECOMMENDATIONS

The following recommendations are recommended for further study

- Generation of biogas from public toilet system
- Production of electricity from biogas
- Measurement of biogas composition by gas analyzer
- Effect of carbon-nitrogen ratio on gas generation
- Refine of biogas from biotoilet for undesirable odour and nuisance
- Treatment of wastewater using different physical, chemical and biochemical process.

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ROLE OF INFORMAL SECTOR RECYCLING IN WASTE MANAGEMENT IN KHULNA CITY

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ABSTRACT

Informal waste recycling sectors contribute significantly to waste management and resource efficiency by collecting, sorting, trading and processing waste materials to recycle and reuse. This study investigates the role of informal waste recycling sector and waste management in Khulna City. About 1250 Tokais, 650 Feriwalas involved in the chain of recycling network. They purchase bottles, broken glasses, magazines, aluminum, iron items in exchange of money or different sweets .The Tokais and Feriwalas approach 270 small recyclable dealers who accept all type of waste . The SRD then approaches 159 medium recyclable dealers to sell particular kinds of waste. The MRD usually deals with more than two kinds of specific wastes and passes these recyclable wastes to the 48 large recyclable dealers who essentially specialize in specific waste. After processing, the recyclable materials are transported to Dhaka, Chittagong , Jessore , Barisal as raw materials for new products.

Key Words: *Informal sector, recycling, waste management, Khulna City*

INTRODUCTION

The informal sector is characterized by small-scale, labor-intensive, largely unregulated and unregistered, low-technology manufacturing or provision of services. Informal sector entrepreneurs or enterprises do not pay taxes, have no trading license and are not included in social welfare or Government insurance schemes. The informal recycling sector refers to the waste recycling activities of scavengers and waste pickers. Recycling is the process through which solid waste can be used again. The situation in developing countries is different from developed world where several government had greatly initiated increased recycling of the domestic solid wastes by the end of the last millennium. Specific socio-economic conditions prevail in many economically developing countries, including rapid population growth, migration to urban areas, lack of sufficient funds and affordable services and generally a low-skilled labor force. Solid waste management systems are often poorly run and operate to low standards. They can be unreliable, provide inadequate coverage and may conflict with other urban services. Developing country cities often collect only between 50% and 80% of waste generated, with open dumping the only disposal method available. Insufficient collection, uncontrolled street collection points and improper disposal in open dumps allow refuse to be readily available for informal waste recycling through scavenging/waste picking. (S.M.Moniruzzaman, 2007). This paper reviews the role of informal waste recycling in achieving more sustainable waste management in developing countries. It identifies both the benefits the informal recycling sector provides to the local economy and its characteristics of concern. Public policy changes required to integrate informal recycling with the formal waste management sector are discussed. This paper reviews the role of informal waste recycling in achieving more sustainable waste management in Khulna City. It identifies both the benefits the informal recycling sector provides to the local economy and its characteristics of concern. Public policy changes required to integrate informal recycling with the formal waste management sector are discussed. To achieve the desired goals, the main objectives of this study are as follows:

I. To get a clear scenario of informal recycling sectors and recycling patterns in Khulna City.
II. To Estimate number of waste collectors, dealers, recyclable industries and their income generation
III. To Estimate of quantity of collected recyclable materials of informal sectors
IV. To suggest for sustainable recycling process of informal sectors.

LITERATURE REVIEW

In many developing and transitional countries, the infrastructure and organizational system of waste management is insufficient. Municipalities and formal service providers can thus neither provide collection service to all households, nor guarantee an effective recycling and an environmentally sound treatment or disposal of wastes. These activities not only provide an income opportunity for as much as 1% of the urban population in many countries, but also serve the protection of natural resources and the environment by recovering up to 20% of municipal wastes in a self-financing system (Ellen, 2009). Informal collectors are the tricyclists, street scavengers, pick-up traders, collection crews, and landfill scavengers. For the former four parties, play the role in collecting recyclables directly from various sources around the city. The latter is the last party who sorts the recyclables out of wastes before dumped in the landfill. (Suchanda p, 2003). The international literature on the role of the informal sector has recently been reviewed identifis at least four different categories of informal waste recycling, depending on where and how materials separation takes place. (Wilson, 2006)

(a)Itinerant waste buyers (Fariwala): Waste collectors who go from door to door, collecting sorted dry recyclable materials like newspapers, glass, metals, tin cans and plastics.

(b) Street waste pickers (Tokai): Collectors who recover raw materials from mixed wastes discarded on the streets and communal dumps within neighborhoods of households, commercial establishments and industries before collection (Jak A. Fazakerley, 2013)

(c) Waste pickers from dumps: Waste pickers and scavengers who sort through wastes that are dumped at major dumpsites at the neighborhood and the urban periphery.

(e) Direct waste collectors: It provides waste collection service in several areas especially in commercial areas and residences where there is no normal municipal system in place. While playing traditionally important role in collection and recycling activities, informal sector activities are associated with a lot of problems. Recycling offers opportunities for incorporating resource recovery into solid waste management schemes. It provides a source of income to the poorest segments of the population as well as reduces the need for highly sophisticated and costly recovery systems and reliance on disposal (Joy, 2012)

Methodology

To achieve the objectives firstly the study area was selected after a reconnaissance survey. Then data was collected on primary and secondary basis. Primary data includes collecting data from field survey and formal and informal questionnaire survey. The secondary data was collected from various journals, publications, study reports etc. Then the data was analyzed on the basis of recycling patterns of informal sectors, number of waste collectors, dealers, recyclable industries and their income generation, quantity of collected recyclable materials of informal sectors and concluding with Proposals and suggestion for sustainable recycling process and building recycling rate.

Study Area

The study areas are Fulbarigate, Dowlatpur, Khalispur, Sonadanga, Sheikhpara, Moylapota, Dakbalngla.

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RESULTS AND DISCUSSION

Interview Results on Different Groups Involved in Recycling

Different groups of people were interviewed in this research. The interviews were conducted from June 2016 to May 2017.

Waste Collectors

The waste collectors are the first link in the long Chain of recycling This group comprises of men, women and children. The waste collection was observed under two broad categories:

l. According to the mode of waste collection: House to house waste collectors (usually men and women; local name Feriwala) and Waste bin collectors (usually children; both Sexes, age below 14 years; local name Tokai) .
2. According to the mode of waste transportation: manual, or using a tricycle. The role of the waste collector is to collect and classify various materials that have a recycling value and can be sold to a recyclable dealer.

Estimation of number of waste collectors

The number of waste collectors in Khulna was estimated by conducting surveys on waste recyclable dealers, and some slum areas in Khulna.

Table 1: Estimation of number of people involved in informal recycling sectors in Khulna City

Study Area	Waste Collectors			Dealers			Industries	Total
	Feriwala		Tokai	SRD	MRD	LRD		
	Men	Women	Children	No of Employee	No of Employee	No of Employee	No of Employee	
Fulbarigate	24	3	25	10	15	45	65	187
Dowlatpur	40	4	94	40	80	145	175	578
Khalispur	95	10	85	50	90	215	235	780
Sonadangha	65	3	75	40	60	190	125	558
Sheikhpara	250	25	750	65	125	245	325	1785
Moylapota	80	9	45	95	85	165	165	644
Dakbangla	46	6	46	45	55	85	65	348
Total	600	60	1120	345	510	1090	1155	4880

Table 2: Average daily collection of waste in weight by various categories of collectors

Category	Mode of transportation	Average Quantity of Recyclable Materials (Kg/day)					
		Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
Tokai (Children)	Manual	1	7	1.5	0.5	1	11
Feriwala (Men)	Manual	2	8	3	2	2	17
	Tricycle	10	15	8	3	3	39
Feriwala(Women)	Manual	2	6	3	2	2	15

Table 1 Shows number of Feriwala, Toaki, SRD, MRD and LRD in different area of Khulna city. From Table 1 there are mainly two types of waste collectors and three types of dealers working in this sector. A total number of 4880 number of employees are working currently in this sector. It is matter of threat for the social value that about 1120 children are working as Tokai in Khulna city. Besides most of them in Feriwala section are men and some of them are women. Table 2 shown the mode of transportation of Tokai and Feriwala. Most of them do this work manually and others use tricycle as mode of transportation of waste. Table 2 also shows the amount of metal, paper, plastic, glass waste collected per day by the feriwala and Tokai. It shows Tokai colelcts about 11 kg, Feriwala about 17 kg and women feriwala collects about 39 kg of different types of waste per day from different location of Khulna city.

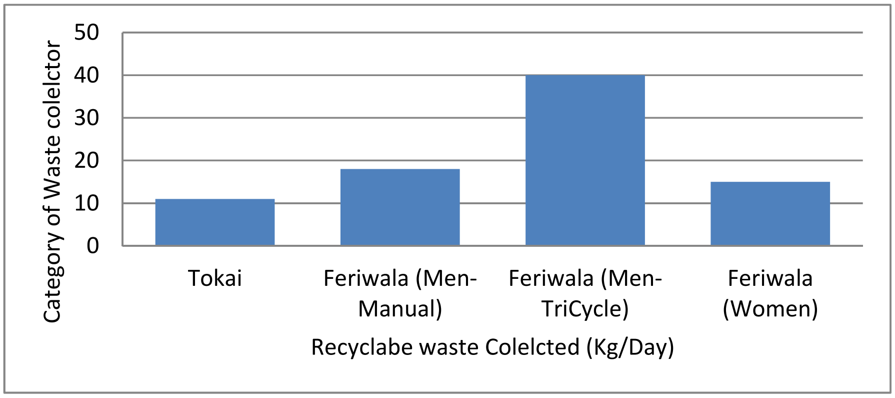


Figure 4: Average daily collection of waste in weight by various categories of collectors

Table 3: Quantity of Recyclable waste collected by Feriwala

SL No of Feriawala	Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
1	20	15	11	3	2	51
2	15	12	8	2	1	38
3	12	15	7	2	1	37
4	14	16	8	4	2	44
5	15	20	12	2	1	50
6	12	15	10	0	1	38
7	8	12	10	2	2	34

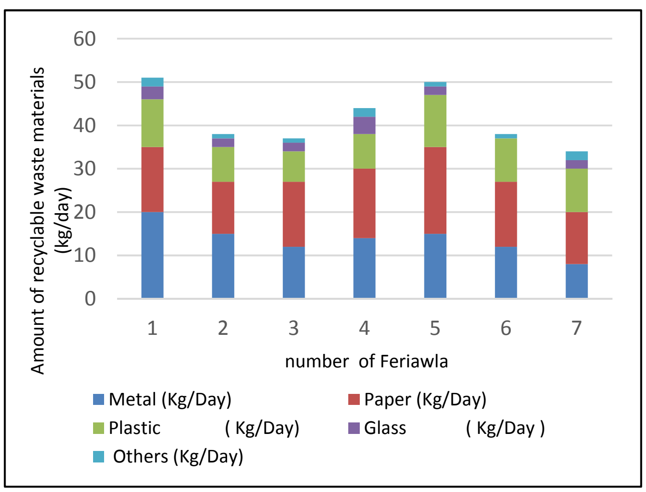


Figure 5: Quantity of Recyclable waste collected by Feriwala

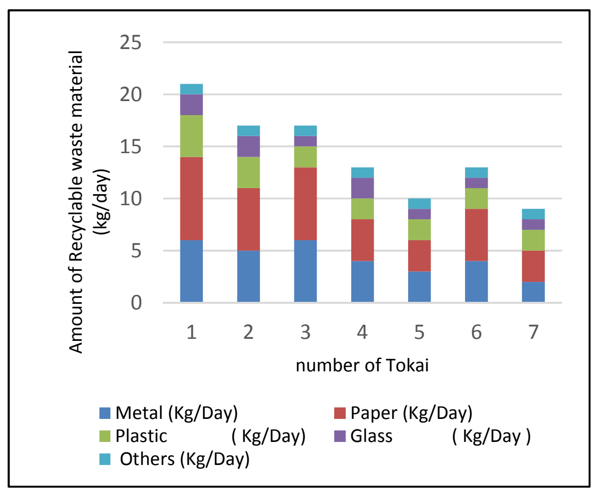


Figure 6: Quantity of Recyclable waste collected by Tokai

Figure 4 shows the average daily collection of waste in weight by various categories of collectors (data tabulated in Table 2). Table 3 show the amount of recyclable waste collected by Feriwala. This data have been presents in a bar diagram in Figure 5. It shows a Feriwala collects about 14 kg of metal, 15 kg of paper, 10 kg of plastic, 3 kg of glass and 2 kg of other waste per day. Where the figure 6 shows the collection of waste by tokai section per day. It show an individual Tokai collects about 6 kg of metal, 14 kg of paper, 18 kg of plastic waste per day in Khulna city.

Figure 7: Collection of recyclable waste by Feriwala

Figure 8: Collection of recyclable waste by Tokai

Table 4: Education, Living Condition and Daily Income of Feriwala

SL No f Waste Collector	Age	Education Level	No of People sharing living	Rent (TK/day)	Daily Income
1	28	Primary	4	40	220
2	32	Primary	3	50	250
3	18	Illiterate	3	30	200
4	45	Illiterate	4	40	250
5	40	Primary	5	45	250
6	16	Primary	3	30	150
7	20	Primary	4	30	200

Table 5: Quantity of Recyclable waste collected by Tokai

SL No of Tokai	Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
1	6	8	4	2	1	21
2	5	6	3	2	1	17
3	6	7	2	1	1	17
4	4	4	2	2	1	13
5	3	3	2	1	1	10
6	4	5	2	1	1	13
7	2	3	2	1	1	9

Table 6: Education, Living Condition and Daily Income of Tokai

SL No of Tokai	Age	Education Level	No of People sharing living	Daily Income
1	12	Illiterate	2	50
2	15	Primary	3	60
3	9	Illiterate	2	30
4	11	Illiterate	4	55
5	10	Illiterate	3	45
6	8	Illiterate	2	40
7	13	Illiterate	3	65

Figure 7 and Figure 8 show the collection procedure of Feriwala and Tokai form different locations. Table 4 shows that the daily income of a Feriwala is about 200 BDT and most of them completed their primary education. They ususally give rent for their van a BDT of 40 average to the van owners. Whereas in case of Tokai, most of them are illiterate and very few completed their primary education. Their daily income is about 50 BDT as shown in Table 6. Table 5 shows the amount of collection of different types of waste per day by the Tokai. It has also been shown in figure 6.

Recyclable Dealers

Recyclable dealers are the second link in the chain of recycling. They are reported under three broad categories according to mode and quantity of collection and type of waste. Figure 4.6 shows the photograph of a typical recycling dealer. The quantity of Recyclable Solid Waste (RSW) collection with different types of dealers and location are summarized in Table 4.7

1. Small Recyclable Dealers (SRD): Each SRD purchase all types of wastes from the collectors and their collection Of RSW is below 300 kg/day on an average.

2. Medium Recyclable Dealers (MRD): Usually they deal in two or three kinds of specific RSW. They purchase RSW from all the SRDs and occasionally from brokers and the amount collected range between 300 kg/day to 600 kg/day.

3. Large Recyclable Dealers (LRD): The LRDs essentially specialize in specific wastes. They collect the waste from MRDs in Khulna and from outside of Khulna. On an average the amount of RSW collection by each LRD is greater than 600 kg/day.

Figure 9 : A typical Recyclable Dealers at Sonadanga,Khulna

Figure 10 : A Small Recyclable Dealer(SRD) at Fulbarigate in Khulna city

Figure 11 : A Medium Recyclable Dealer(MRD) at Sheikhpara in Khulna city

Table 7: Estimation of number of dealers and amount of recyclable material collection in Khulna City

Study Area	Number of Dealers			Total no. of Dealers	Amount of recyclable materials Collection (Kg/day)			Total (Kg/Day)
	SRD	MRD	LRD		SRD	MRD	LRD	
Fulbarigate	10	8	3	21	544	454	544	1542
Dowlatpur	25	5	1	31	1573	1130	1715	4418
Khalispur	32	10	2	44	3285	2300	2695	8280
Sonadangha	15	5	4	24	580	575	875	2030
Sheikhpara	145	115	25	285	19221	23122	23251	65594
Moylapota	25	15	12	52	685	805	832	2322
Dakbangla	15	2	1	18	825	495	859	2179
Total	267	160	48	475	26713	28881	30771	86365

Figure 9 shows the a A typical Recyclable Dealers at Sonadanga,Khulna where Figure 10 shows a Small Recyclable Dealer(SRD) at Fulbarigate in Khulna city and Figure 11 shows a Medium Recyclable Dealer (MRD) at Sheikhpara in Khulna city.

Table 7 shows the number of various dealers in different places in Khulna city. It also shows the amount of recyclable waste collected by dealers in kg/day. It shows a total amount of 267 of SRD, 160 of MRD and 48 number of LRD in Khulna city. Here the SRD collects about 26713 kg, MRD collects about 28881 kg and LRD collects about 30771 kg of recyclable waste per day. A total of 86365 kg of recyclable waste is collected by deals every day.

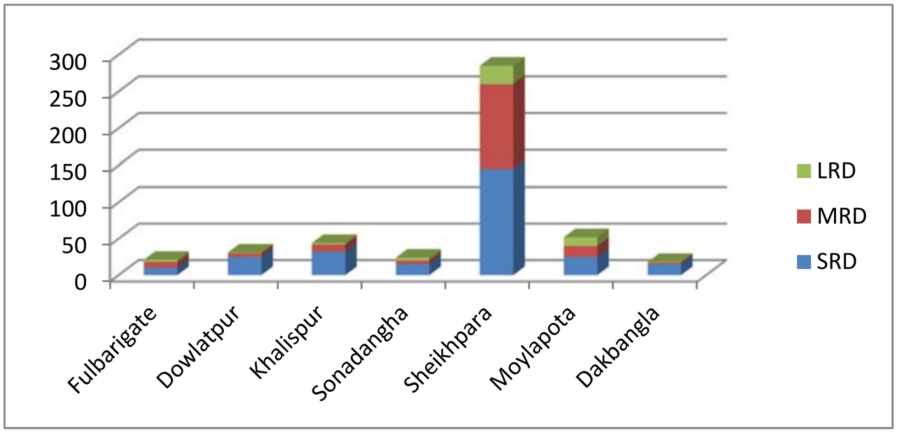


Figure 12 : Number of different dealers in Khulna City

From the field survey, it is found that there are 270 SRDs all over Khulna city (Table 5.4).daily quantities of RSW collected by SRDs are shown in Table 8 . Each and every SRD is dependent on tokais and feriwalas to supply them with RSW. Tokais and feriwalas sell their mixed RSW to SRD on cash delivery basis. It is important for them to have as large a number of suppliers as possible, in order to be assured of a good turnover to support them. Providing loans is the most important means of SRDs to tie the tokais and to them. On an average they have 5 to 6 number of tokais and feriwalas attached to them. Medium Recyclable Dealer (MRD) are 159 MRDs in Khulna city (Table 9). Average quantity of RSW collected by each is shown in Table 9.They employ 5 to 7 people to segregate the waste. Table10 shows two specific type of waste collected by a MRD. It was found that there are 47 LRDs in Khulna city. The average quantities of recyclable solid (RSW) Collected by each LRD are shown in Table 10. Most of the LRDs employ 6 to 10 people to sort, clean the wastes. They sell the recovered materials to industries both in the private sectors.

Table 8: Amount of recyclable material collection by SRD in Khulna City

Study Area	No of Dealers	Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
Fulbarigate	15	250	345	145	75	10	825
Dowlatpur	25	650	535	215	158	15	1573
Khalispur	35	1250	995	550	445	45	3285
Sonadangha	15	220	150	120	65	25	580
Sheikhpara	145	6500	8756	2359	1556	50	19221
Moylapota	25	285	215	85	75	25	685
Dakbangla	10	215	195	60	50	24	544
Total	270	9370	11191	3534	2424	194	26713

Table 9: Amount of recyclable material collected by MRD in Khulna City

Study Area	No of Dealers	Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
Fulbarigate	2	135	225	75	45	15	495
Dowlatpur	5	335	415	235	125	20	1130
Khalispur	10	995	575	450	235	45	2300
Sonadangha	5	225	125	115	75	35	575
Sheikhpara	115	9850	6452	4450	2245	125	23122
Moylapota	15	245	325	125	56	54	805
Dakbangla	7	125	195	54	56	24	454
Total	159	11910	8312	5504	2837	318	28881

Table 10: Amount of recyclable material collected by MRD in Khulna City

Study Area	No of Dealers	Metal (Kg/Day)	Paper (Kg/Day)	Plastic (Kg/Day)	Glass (Kg/Day)	Others (Kg/Day)	Total Kg/Day
Fulbarigate	1	245	365	154	80	15	859
Dowlatpur	1	775	535	235	125	45	1715
Khalispur	2	845	905	575	325	45	2695
Sonadangha	4	225	325	225	75	25	875
Sheikhpara	25	12505	5756	3359	1556	75	23251
Moylapota	12	345	257	125	70	35	832
Dakbangla	2	215	195	60	50	24	544
Total	47	15155	8338	4733	2281	264	30771

Recycling Industries (RI)

From the field survey it was found that there are 46 recycling industries in Khulna. Almost half of them were interviewed. The major recycled items and the corresponding end user industries are Shown in Table 11. The purpose of having face- to- face interview is to have a more in depth conversation with the final recyclers, and to draw their opinion on the development of the industry. Apart from bone, plastic paper, iron and tyre all recycling industries are located outside Khulna district.Figure 4.15 Iron Recycling Industry at Sheikhpara.

Figure 13: Plastic Recycling Industry at Khalispur

Table 11: Number of Recycling Industries in Khulna City

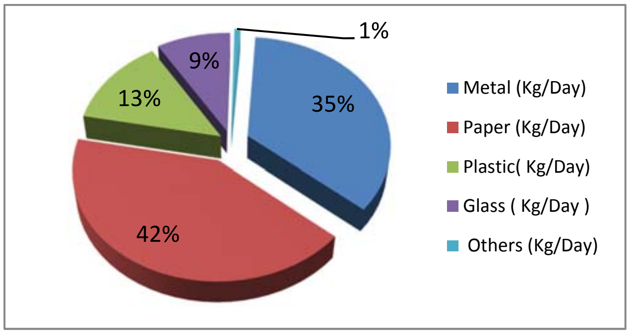
Study Area	Number of Recycling Industries in Khulna City						Total RI
	Plastic RI	Cast Iron RI	Mild Steel RI	Bone RI	Paper RI	Tyre RI	
Fulbarigate	0	1	0	0	0	0	1
Dowlatpur	2	1	1	0	0	1	5
Khalispur	4	2	1	1	1	2	11
Sonadangha	2	1	1	1	0	1	6
Sheikhpara	5	2	2	2	1	1	13
Moylapota	2	2	1	1	0	0	6
Dakbangla	1	1	1	0	1	0	4
Total	16	10	7	5	3	5	46

Variation in Percentages of Recycling

The estimated quantities of RSW recycled by waste collectors in Khulna are 31 tones /day (Table 7). The amounts of RSW collected by SRDs are 26.46 tones per day (Table 7) amount Of RSW Collected by MRDs are 28.23 tones / day (Table 7). The amounts of RSW Collected by LRDs are 30.6 tones/day (Table 7). Finally the amounts of RSW by the RIS are 61.2tones/day.

Recycling Percentage by SRD

The study shows (Figure 14) among the recyclable dealers, Paper (42%), Metal (35%) plastic (13%) are recycled most by the SRDs whereas Glass (9%) and others (1%) are recycled least. It can be explained by the fact that and plastic materials are mostly found at the collection points (house hold, waste bin, dumping site, road sides etc) of Both (tokai). so the waste collectors (feriwala) easily collect these light materials and sell the SRDs. Iron is also separated at the household and industries for sell and can be collected by SRDs.



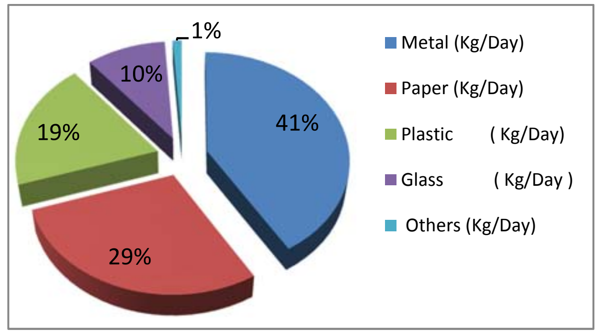


Figure 14: Recycling Percentage by SRD

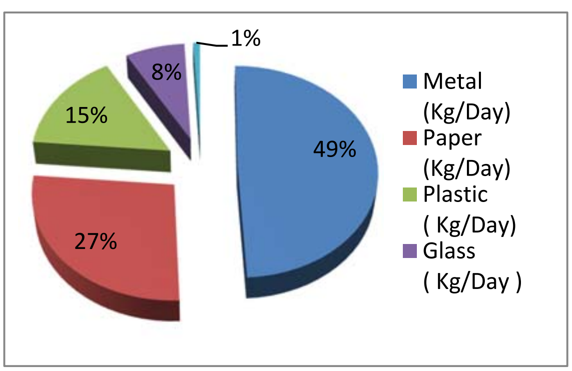
Figure 15: Recycling Percentage by MRD

Recycling Percentage by MRD

The Case is different for MRI)s who collect 41% of metal, the highest percentage of collection. This can be explained by the fact that among the RSW metal especially iron is costly material. Generally people do not through it to the waste bin. Besides that of metal (scrap iron) am industries, construction and maintenance projects .MRDS generally contact directly or through brokers with the owner of scrap iron and trucks. so the waste collectors do not find much iron to supply iron to hand paper reduces to only in MRDs) This can by the fact that a large amount Of paper is recycled by the SRDs by making packets So all the paper collected by the SRDs do not come to MRDs. Plastic (30%), remain almost same like SRDs. (13%).

Recycling Percentage by LRD

In the case of LRD a new RSW (such as scrap tyre) appears by jumping the waste collector, SRDS and MRDs in the Chain of recycling. The fact is that tyre is another valuable material. The owner of car normally carries the tyre to the LRDs for resoling by paying money. Sometimes the LRDs purchase scrap tyres from garages of cars all over the city. In the case of LRDs the percentage of metal increases to 49 % (figure 16). This can be explained by the fact that LRDs import metal (mainly iron) from the MRDS ofKhu1na as well as from outside Khulna. On the other hand the percentage of paper (27%), and glass (8%) reduces because the LRDs sell these materials to Dhaka as raw material. (figure-16)



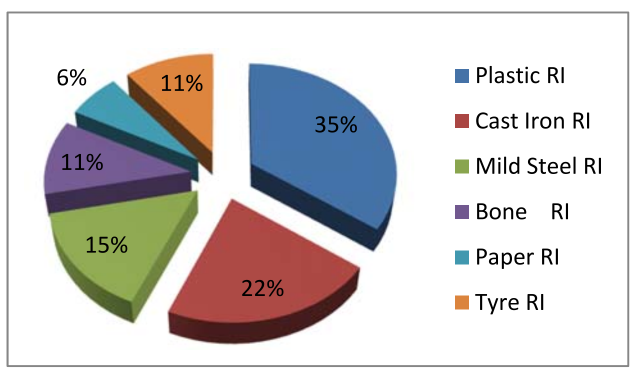


Figure 16: Recycling Percentage by LRD

Figure 17: Recycling Percentage by RI

Recycling Percentage by Recycling Industries

The iron recycling industries purchase iron from LRDs of Khulna and from industries of Chittagong. Glass is transported to Dhaka by LRDs. Tyre Recycling Industries collect scrap tyre from LRDs and also directly from the owner of cars. Sometimes they purchase scrap tyre and sell new tyre. Sometimes the owner of cars comes to the industry and recycle scrap tyre to new tyre by paying money to the industry. Figure 17 shows the percentage of different metals by recycling Industries.

Conclusions

In Khulna, the recycling of solid waste is currently carried out by a private sector comprising waste collectors at the lowest end and a succession of dealers and industries. All the buyers of the recyclable items are the private sector and only a few formal manufacturers are involved in using recyclable substance as raw material. Among the RSW paper, plastic, iron, animal bone, tyre ,rubber, glass, aluminum, tin are processed or recycled by dealers They deal with 39.72 tons/day Of RSW come from all over Khulna city as well as from nearby districts of Khulna. SRDs collect paper (42%), metal (35%) and plastic (13%) are recycled most whereas the case is different for MRDs who collect paper (29%) ,metal 41%, the highest percentage Of their collection. On the other hand paper reduces to only 15% in MRDs. Plastic (19%), glass(8%), other (1%) remain almost same like SRDs. In the case new RSW (such as tyre) appears by jumping the waste collector, SRDs and MRDs in the chain Of recycling. In the case of LRDs the percentage ofmetal increases to 49%. This can be explained by the fact that LRDs import metal (mainly iron) from the MRDs Of Khulna as wen as from outside Khulna. On the other hand the percentage of paper (7%), plastic (13%) and glass (6%) reduces. In the case of RIS percentage of bone (36%) and metal (53%) are higher than those of LRDs. Among the metals only iron is recycled in Khulna. Aluminium, tin etc are transported to Dhaka by LRDs. Tyre Recycling Industries collect scrap tyre from LRDs and also directly from the Owner of cars. The 46 recyclable industries recycle 69.2tons/day which is e about 80% of recyclable waste.

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BEHAVIOR OF CONCRETE PRODUCED BY INCORPORATING WASTE CERAMIC POWDER INTO CEMENT EXPOSED TO FIRE

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ABSTRACT

Now-a-days, use of recycled materials to produced concrete is getting attention to the engineers and stakeholders. However, the effects of fire on the concrete produced by recycled materials need to be considered as the fire incident is occurring frequently in our countries. As concrete is a noncombustible material, the physical and chemical changes may occur due to fire load which causes a decrease in the strength of concrete. Therefore, this study aims to investigate the compressive strength of concrete produced by using recycled material when it is exposed to fire. Ceramic powder from industrial or residential waste was used with cement to produce concrete. The specimens were burnt intofire to investigate the effect on the physical properties of concrete. The compressive strength was reduced by about 14% for 20% replacementof cement by the same amount of waste ceramic powder with cement and further 17% reduced due to burning in fire. The outcome of this research will help the designer to plan the fire-resistant structure and also retrofitting of a structure after a fire incident.

INTRODUCTION

Industrial and residential wastes are increasing day-by-day due to the continued demands of resource use. With increasing restrictions on landfills, industries have to find effective ways of recycling their wastes and by-products. Use of ceramic waste in concrete may be a good solution both in waste management and producing economic concrete for construction. Research showed that ceramic waste powder (upto a certain percent of cement) can be used as a replacement of cement in concrete without significant reduction of strength of concrete.

However, as the fire incidents are frequently occurringat buildings, factories, warehouses in Bangladesh for the last two decades, question raised on post fire incidental recovery actions required for the affected building.Research showed that during a fire, the temperature may reach up to1100°C in buildings and even up to 1350°C in tunnels, leading to severe damage in a concrete structure (Hager, 2013; Fib, 2007). Though we know that the concrete is a non-combustible material, the high temperature my causes physical and chemical changes in the concrete resulting in significant losses of strength of the concrete members. Moreover, use of ceramic waste in concrete may be severe in fire as it is not contributing to the strength of concrete. Therefore, it is necessary to examine the consequence of fire on ceramic based concrete. In this study, the effect of fire on the compressive strength of concrete, produced by ceramic waste powder as a replacement of concrete, has been investigated. The outcome of this study may be beneficial to the engineers, designers, and researchers to take into account the effect of fire during the design period and rehabilitation program after an incident of fire.Furthermore, the use of ceramic waste will reduce the emission of CO_2 due to the replacement of cement by the ceramic waste and resulting contribution to the environment.

EXPERIMENTAL DETAILS

Materials

Four types of materials were used for the preparation of concrete. Ordinary Portland cement (OPC) as a binding materials, Sylhet sand at fine aggregate, black stone as coarse aggregate and ceramic powder as partial replacement of cement. Ceramic white tiles were collected from the locally available ceramic waste. Afterwards, the tiles were grinded into powder and passed through #200 sieve. The material properties are presented in Table 1.

Table 1: Material properties

Materials	Properties	value
OPC	Specific gravity	3.15
Fine aggregate	Specific gravity (SSD)	2.49
	Absorption	4.55%
	Fineness modulus	2.76
	Unit weight	1615 Kg/m^3
Coarse aggregate	Specific gravity (SSD)	2.85
	Unit weight	1570 Kg/m^3
	Maximum size	19 mm

CASTING AND CURING OF CYLINDRICAL SPECIMENS

Mix design was performed according to ACI 211.1. The mix ratio was 1: 2.75: 3.5, giving a water to cement ratio of 0.635 with target strength of 27.5 MPa (4000 psi). However, in case of mixing ceramic powder with concrete, 20% cement was replaced by same amount of ceramic powder. The mixing ratios of concrete are presented in Table 2.

Table 2: Mix ratio of concrete

Sample	Cement	Sand	Stone Chips	Water	Ceramic Powder
Without Ceramic Powder (0% Ceramic Powder)	1	2.75	3.5	0.635	0
With Ceramic Powder (20% Ceramic Powder)	0.8	2.75	3.5	0.635	0.2

Nine cylindrical specimens of size 6×12 in were prepared, three without ceramic powder and six with ceramic powder.Concrete was mixed according to ASTM C192 using a standard concrete mixture.At each time of concrete specimen casting, slump was determined and it was within 50 mm. All of the specimens were cured for 28 days.

BURNING AND COOLING OF THE SPECIMENS

A burning chamber of size 2.5 × 1.0 × 0.75 m was prepared for the burning of the specimens. The chamber was shaped in honeycomb form to facilitate flow of sufficient oxygen inside of it.Locally available wood was used to create fire. The cylinder specimens were kept above the reinforcement bar 2” gape between two specimens. On the surface of the chamber, the wood fiber was placed in row and column by two adjacent layers. The specimens were placed minimum 5” above the surface of the wood fiber. Another, one layer of wood fiber was given above the specimens. The specimens were burnt in fire for duration of 60 mins and the temperature of fire was 950°C with a fluctuation of 50°C. The temperature was measured using a thermocouple. The burning of the specimens in the chamber is shown in Figure 1.After burning the specimens, the specimens were taken to the safe place for natural cooling. In this process, the specimens were cooled about 24 hours in the air.

Figure 1 Burning of test specimens in the fire chamber.

TESTING OF THE SPECIMENS

After burning and cooling, the specimens were capped by gypsum and prepared for testing. The specimens were tested according to ASTM C39/C39M-17a for the determination of compressive strength.The failure load of the specimens were determined by using compressive strength testing machine and finally, the compressive strength was obtained by dividing the load by the cross-sectional area of the specimens.

RESULTS AND DISCUSSION

In this study, nine concrete cylinder specimens of 6×12 in size were prepared; out of which three were controlled specimens (without ceramic powder) and six were with 20% ceramic powder as replacement of 20% cement. Among six specimens with ceramic powder,three were prepared for burning in fire for an hour. The average recorded temperature was 950°C. After burning, the beams were kept in air for cooling. All of the specimens were tested for compressive strength.The compressive strength of the specimens, viz. controlled, burnt and unburnt specimens were determined. The results are summarized in Table 3.

Table 3 Compressive strength of the cylindrical specimens

Type of Specimens & Test Conditions		Sl. No.	Compressive Strength (MPa)	Average Compressive Strength (MPa)	% Reduction of Strength w.r.t. Controlled Specimen
Sample without ceramic powder (SWOCP)	Controlled Specimens	1	25.39	25.94	—
		2	26.19		
		3	26.23		
Sample with ceramic powder (SWCP)	Unburnt	1	24.47	22.37	14%
		2	20.63		
		3	22.00		
	Burnt	1	17.56	17.90	31% (20%)*
		2	17.71		
		3	18.43		

* 20% reduction of strength w.r.t. unburnt sample prepared with ceramic powder.

The average compressive strength from the test was 25.94 MPa for unburnt normal concrete specimens (without ceramic powder), 22.37 MPa for unburnt concrete specimens with ceramic powder, and 17.90 MPa for burnt concrete specimens with ceramic powder. The strength of the specimen was reduced 14% for the replacement of cement by 20% ceramic powder. The strength of the sample with ceramic powder further reduced due to burning in fire. The results are also presented graphically in Figure 3 for comparison of compressive strength of specimens at different test conditions.

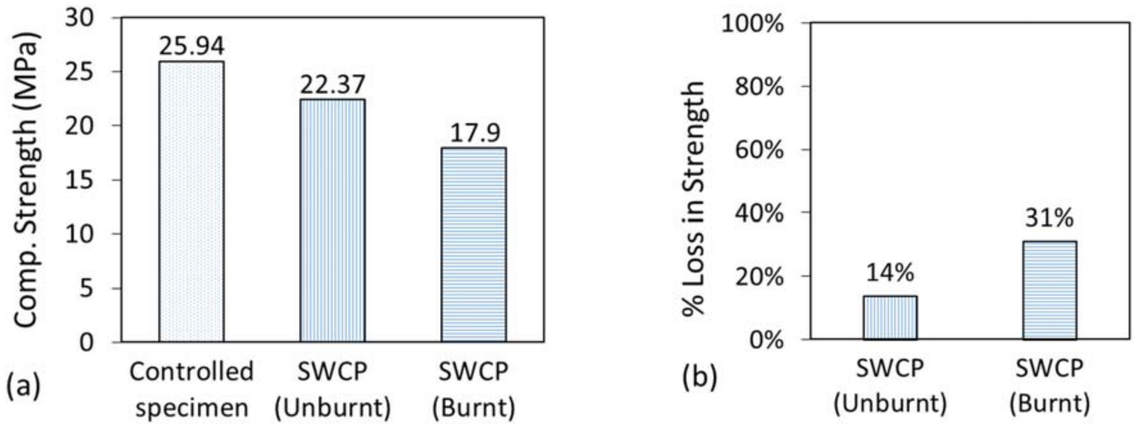

Figure 2: Graphical presentation of test results at different test conditions; (a) Compressive strength of the specimens, (b) % Loss in strength.

The weight of the specimens was also reduced due to burning in fire. This change occurred as a result ofdehydration of the concrete during burning. After burning and cooling, there was 6.7% (avg.) weight loss in the specimens. Table 4represents results on the weight loss of the specimens.

Table 4: Weight loss of specimens due to burning in fire

Sl. No.	Weight Before Burning of the sample (Kg)	Weight Before Burning of the sample (Kg)	% Loss of Weight	Avg. % Loss of Weight
1	12.97	12.18	6.09	
2	13.02	12.1	7.07	6.7
3	12.99	12.09	6.93	

CONCLUSIONS

In this study, the effect of fire on the strength of concrete produced by the partial replacement of cement by ceramic powder has been investigated. Nine cylindrical specimens of size 6×12 in were prepared; out of these nine specimens, three were controlled specimens without any ceramic powder and six were with 20% of ceramic powder as a partial replacement of cement in the concrete. Among six specimens with ceramic powder, three were burnt in fire for duration of an hour and rest three were kept unburnt. After burning, the specimens were kept in air for 24 hoursfor cooling. All specimens were tested for compressive strength. The result shows that the strength of the specimen was 14% reduced due to use of ceramic waste powder as a partial replacement of cement. The strength was further reduced due to burning in fire. The residual compressive strength of the ceramic powder based concrete after burning in fire was 17.9 MPa which is low enough to keep a concrete based frame in service after an incidence of fire.Hence, use of ceramic waste in concrete should be chosen by taking into account the effect of fire in the concrete frame. Furthermore, this effect should be considered in case of repairing/refurbishing a concrete building after an incident of fire.

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A Comprehensive Study on Battery Waste Management Practice in Khulna City

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ABSTRACT

A lead acid battery is widely used as energy storage equipment in motor vehicles such as easy bike etc. Due to an Excessive amount of battery usages, it creates more toxic lead-acid battery waste which has an adverse impact on the environment and mankind. For this reason, in order to ensure the beneficial impact on the environment, battery management practice is necessary. In Khulna, Battery management practices are not quite good and effective. The objectives of this research are to investigate the battery recycling process including its waste disposal practice in Khulna city. This research also reviews its Effluent wastewater quality which measures the suitability of environmental safeguard. Thisstudy was undertaken considering root level of recycling, reuseand disposal practices of battery wastes. The most famousbattery waste recyclers in Khulna city namely Hamko Battery Company Ltd, Boishakhi Super Market, and Ismail market were selected for this study. Approximately 35 secondhand battery shops were identified and 20 shops were surveyed in these selected areas. Outcome of this study shows i) two recycling process were found which are named Direct and Indirect recycling process in this study, ii) batteries used in ships, vehicles, IPS are recycled, iii) recycled batteries costs 35-40% of new battery iv) the flow path forbattery waste recycling process and waste disposal practices in Khulna city, The effectof waste battery recycling process on surrounding water bodies had been evaluated by laboratory tests like pH, TDS, BOD, COD, EC,Pband compared with Standard Limits as per Environmental Conservation Rules (1997)and finally proposal was provided for the improvement of existing battery waste management.

***Keywords**: Lead acid battery, management, recycling, effluent wastewater quality, reusing, disposal,collection,selling amount,environmental suitability.*

INTRODUCTION

Bangladesh is recognized as the fast-growing developing countries in the world which GDP and economic growth is quite significant among the other developing countries. In order to ensure this development, good management practices are always necessary. Battery management practice is one of them.Use of Lead acid battery in Bangladesh has risen with a sharp rise in motor vehicles such as easy bike, IPS etc. To date the number of easy-bike in Khulna city is approximately 25,000, providing more than half (65%) of the total transport demand in Khulna city (Lubna, 2014). For this reason, it creates more lead-acid battery waste which is very toxic and hazardous substances that can easily create potential risk sources. To decrease this negative impact, we have to choose both the alternative solution such as recycle and repair practice of battery waste instead of dumping. The type of this process used depends upon the size of the company, its manufacturing capacity etc. (Dahodwalla & Herat, 2000). For this reason, these management practices are very important. If usable materials can be recovered from used batteries, less raw material needs to be extracted from the limited supplies in the ground (Gaines, 2014). This type of approach does have significant benefit for the environment and the economy since it avoids additional transportation emissions (Bernardes, Espinosa, & Tenório, 2004). It also reduces energy consumption and greenhouse gas emissions. That's why Lead recycling batteries are beneficial to the environment. About 97% lead acid batteries in Bangladesh are manufactured by recycling batteries and scrap metal (Ahmad et al., 2014). Many elements such as a Lead plate, a lead ball can be recycled and reused in the recycling industry. Lead-acid batteries have been used for more than 130 years in many different applications that include automotive, uninterruptible power supply (UPS), telecommunication systems and various traction duties (Zhang, Chen, Zhang, & Liu, 2016).The lead-acid battery consists of both sulphuric acid and a large amount of lead which is not only corrosive substances but also a good carrier for soluble lead and lead particles. That means Lead is very highly toxic metal which causes a wide range of adverse health effect, especially on young children. The most hazardous effects of a lead-acid battery are a human disease such as neurological damage, kidney damage, and cancer. On an average an automobile manufactured contain about 12kg of lead, in which about 96% of lead is used in lead acid battery and remaining 4% is used in other applications like wheel balance weight, protective coating and variation dampers (Chakraborty, 2017). For this reason, it is widely used all over the world. Lead-acid batteries (LABs), an important kind of energy storage equipment, are widely used because they are low-cost, reliable, easily available, and suitable for a wide range of current discharge and temperature conditions (Chen et al., 2017).

In 1990, the Western world had a lead refining capacity of around 5.3 million tonnes per annum (Ramus & Hawkins, 1993). So, Global lead consumption was increasing day by day because of immense growth in the demand for the lead batteries which creates more lead-acid battery waste. If this waste is disposed in landfill or river or illegally dumped the lead as well as heavy metal and sulfuric acid can seep into the soil and sulfuric acid contaminated groundwater, potentially affecting the quality of our drinking water supply. The levels of pollutants in this battery wastewater also vary depending upon the process adopted in battery manufacturing. The heavy metals lead, mercury, copper, cadmium, zinc, nickel, chromium are among the most common pollutants found in industrial effluents (Bahadir, Bakan, Altas, & Buyukgungor, 2007). So, this kind of toxic substances is harmful to human health and the environment.The aim of this research is to review the current status of its management practices such as Collection, Recycling and Disposal practices of battery waste including its full battery recycling process.This research also reviews its Effluent wastewater quality which measures the suitability of environmental safeguard according toEnvironmental conservation rules (1997). Finally, proposal is provided for the improvement of existing battery waste recycling process with proper effluent treatment.Three area are selected for a survey for Battery waste Management practices in Khulna. The survey procedure is completed with proper planning in the Methodology section.

METHODOLOGY

The present study is consists of the selection of the study areas in Khulna city. Preparation of comprehensive questioner form and several survey work to collect selective data as described in the following sections.

Selection of Study Area and Data Collection

The Khulna, the third largest metropolitan city of Bangladesh, stands on the banks of the Rupsha and the Bhairab River, located in the southwest of the country on the middle of the axis of Jessore - Mongla port, and is the second largest seaport of the country. Three area are selected for survey work such as Hamko battery company Ltd, Boishakhi Super Market, and Ismail market. Hamko battery company Ltd is 9.1 km away from Khulna and 1.1 km away from Bhairab River. Broad reconnaissance surveys were done and Data are collected from these survey area. Approximately 35 secondhand battery shops were identified in Khulna city and 20 shops were surveyed in these selected areas. Then effluent wastewater was also collected from the selected study area such as Hamko company adjacent-Drain side and Bhairab River etc.

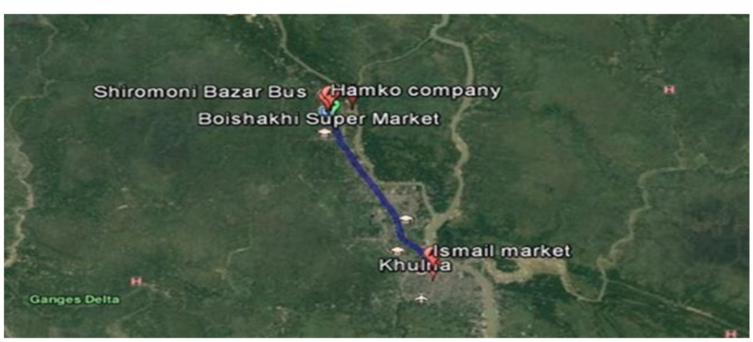

Figure 1: Satellite View of Study Area

Detail Stepwise Observation of Battery Recycling Process

In this studied area, two recycling process is observed in Khulna city. One is direct recycling process and another is Indirect recycling process. Here, the battery waste is collected by a secondary owner shop or to the battery dealers (Ismail market) at a low price. Normally lead-acid battery has more than ten parts such as plates, separator, container, lead, battery cap, cork, connectors, electrolyte, negative plate or anode positive plate or cathode and chemical compound: carbon tetrachloride, lead, Sulfuric acid. By breaking of this battery, battery casing, separator, connector, Lead plate, wasted acid, Battery cover, battery scrap, Polypropylene, plastic, Lead dust, and waste acid etc. are obtained. The battery scrap is a mixture of several substances: metallic lead, lead oxide, lead sulfate and other metals such as calcium, copper, antimony, arsenic, tin and sometimes silver (Chakraborty, 2017). Then, in a smelting plant, it will produce hard or antimonial lead. If this plant intends to produce soft lead, other metals like copper, antimony, and tin have to be removed.

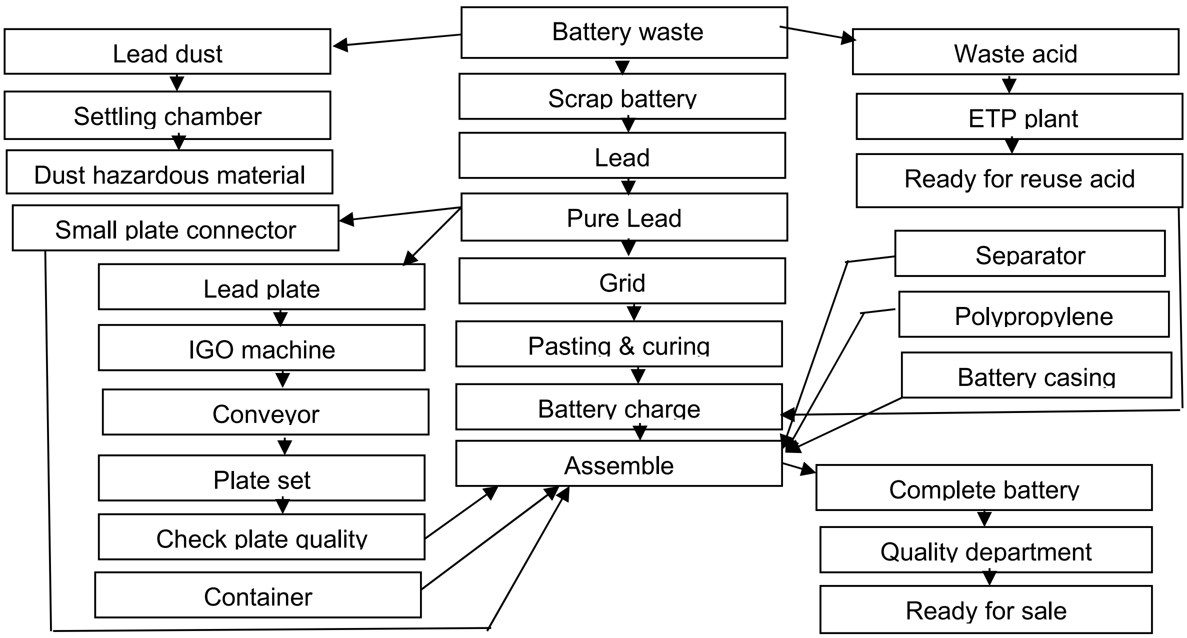

Figure 2 Full Lead Acid Battery Recycling Process

After collection of this battery waste from the sources, next step is recycling of battery. Then, the battery waste is transported to a recycling company by truck. First, the wasted acid is converted into a useful acid by using the ETP (Effluent treatment plant) and lead dust are removed by settling chamber. In this type of old battery waste, each and every part is reusable. Lead from the lead plate can be further reused by melting it and make it a useful shape and plastic parts can also be reused. Then by using a machine, Lead ball and Grid Lead plate are produced from the useful shape lead metal. Then by using pasting and curing process, this grid lead plate is converted to a negative plate and positive plate. Here, in the case of producing the negative plates, this battery plates are covered by a lead dioxide paste and also in the case of producing the positive plates, these battery plates are covered by a porous metallic lead paste. The lead used in the plates may also contain several other chemical elements such as antimony, arsenic, cadmium, copper, calcium, silver, tin and sometimes other elements. Washed and dried polypropylene pieces are sent to a plastic recycler, where the chips are melted at a selected temperature and extruded to produce plastic pellets for use in the manufacture of battery cases. Polyethylene plate separators can be separated from the polypropylene stream and Recycled where the current practice of most secondary plants is to use this stream as a fuel supplement. After being shaped, the battery plates are placed so that the negative and positive plates are alternated. In order to avoid short circuits, Separators of polyethylene, polyvinyl chloride or fibrous paper are used between plates. There are 6 to 20 pairs of negative and positive plates aligned and electrically isolated and these plates of the same polarity are then electrically connected and the plate sandwiches are referred to as battery elements are inserted into battery compartments. These elements are connected in series with a lead-antimony alloy connector in order to provide a higher voltage. Finally, the battery is assembled and filled with electrolyte (sulfuric acid). The lid is then sealed and the product is examined for leaks and after which it will receive its first charge. When the battery is completed, it is sent to a quality department to check the quality of the battery and then it is available for sale.By collection and breaking of this old battery, these two steps are similar in both direct and indirect recycling process. On the other hand, in a direct process, lead is collected from the lead plate and illegally melted in the open air in an unsustainable way. This direct process is done by secondhand shops. Normally the number of sales of this direct recycling process which is usually less than indirect process. Direct melting of lead produce lead oxide (PbO), lead di oxide (PbO2) or different toxic gases; which have adverse impact on environment and human health (Chakraborty, 2017). In the indirect process, the breakage of battery elements is stored into the trucks and sent to the recycling industries.



Figure 2 Breaking to Damaged Battery   Figure 3 Lead Plate   Figure 4 Separator



Figure 5 Heating Wasted Lead Metal to Make Useful Shape Lead Plate   Figure 6 Lead Ball



Figure 7 Lead Plate(Grid Shape)   Figure 8 ETPPlant Figure 9 Complete Battery

Analytical Methods

First, the samples were collected from the selected location and were immediately transferred to the laboratory and were stored in a Refrigerator. The analysis was started without any delay in the lab based on APHA (1994) methods. All the samples like physicochemical parameters were analyzed by APHA (1994) methods. In the case of physicochemical parameters includes pH, Electro-conductivity (EC) were tested by DR2800 Spectrophotometer. The reagent of this instrument is Hellige reagent. Chemical oxygen demand (COD), Biochemical oxygen demand (BOD) and Total dissolved solid (TDS) were determined manually. COD was tested by closed reflux method and was determined COD by calibration equation. The Reagent of this COD test is Standard $K_2Cr_2O_7$, H_2SO_4, Ferion indicator and Standard Ferrous Ammonium Sulphate (FAS).Lead was determined by Flame-AAS (Atomic absorption spectroscopy) method.

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RESULTS AND DISCUSSION

Through a combination of survey results and secondary data sources concerning the recycling and disposal process used and the materials recovered was obtained from a recycling company and also Laboratory analyses and Environmental suitability assessment were shown below::

Collection Practice of Waste Battery

By visiting a renowned lead-acid battery industry like Hamko industry in Khulna, it is come to know that Lead is one of the vital ingredients of the lead-acid batteries. Most of the component of this battery waste is recycled and reused in this industry. When a Local customer (from office, industry, and house mainly IPS battery) and driver (Easy bike, CNG, motorcycle, truck etc.) and feriwalas who are willing to sell their wasted battery to the shopkeeper. Approximately 35 secondhand battery shops were identified in Khulna city and 20 shops were surveyed in these selected areas. Here, Shopkeeper keeps per kilogram of old battery and materials from the sources in an average price of 30-60 taka. Then, secondhand battery shops sell per kilogram of old battery to the Ismail market in 45-75 taka. Then this per kilogram of an old battery is sold by Ismail market to the recycling industry in 80-85 taka. Here, 2 to 3 workers are worked in this medium shop and in the large shop more than 7 workers are worked. The average age of this worker is 30-50 age-old and most of them are not passing the secondary level of education. According to the shopkeeper’s statement, the weight of this battery ranging from 5-60 kg or more. Monthly collection of this battery waste of each secondhand battery shop is approximately 900 kg to 13,000 kg (.9 tons to 13 tons). Approximately 300-15000 kg (.3 tons to 15 tons) of battery waste is sold in each shop per month.This type of battery is damped, damaged and not rechargeable. For this reason, it is not possible to repair this wasted battery. So, Owner can sell it to secondary owner shop or to the battery dealers (Ismail market) in low price. Thus the dealer collects the battery waste by buying the damaged 5 set cell Easy bike Battery which price is 18300 taka only. Finally, recycling companies buy it at costs around 18500 taka.

Figure 10 Collection Practice of Waste Battery

Institutional Setup for Waste Battery Recycling Activity

In Khulna, a Battery waste recycling company such as Hamko Company Ltd which is the top manufacturing company of Lead acid battery. More than 750 Lead acid battery is produced in this company per month. Here, this company collects the battery waste from the Hamko dealer such as Ismail market and then it is transported by truck from Hamko dealer (Ismail market) to this industry and recycle it. Final recycling product is sold by a high price. The price of solar Battery is 7000 taka only and also the price of 5 set cell Easy Bike Battery is 50000 taka. If 25 kg battery is broken, then it is found that 20 kg lead and 5 kg plastic So, there have an intuitional/management setup for waste Battery recycling Activity. The staff number for this recycling company are given below:

Table 1Institutional Setup Practices of Recycling Company (Hamko Company Ltd.)

Designation	Staff Number
HR Admin	6
Project Maintenance	6
Quality Assurance	5
Project Engineer	19
Store & Account	9
Workers	500
Security Guards	7

Waste Disposal in Battery Recycling Process

By irregular dumping, the toxic properties of this batteries are dangerous to the entire ecosystem: land, water, plants, animals, and humans. Each of this toxic element is affected by pollution in different harmful ways. Toxic substances from this batteries may easily enter the environment through leachate that finds its way to the soil as well as the groundwater which pollute the entire ecosystem. This substances may also enter the environment through the gases which mix with and contaminate the atmosphere. Since the toxic chemicals of this battery may easily enter the ecosystem through any of these way dumping batteries into landfills or river does present a hazard to the ecosystem. For this reason, every lead recycling facility should have an effluent treatment system to contain, monitor and treat any water that leaves the recycling facility, including that coming from the electrolyte neutralization, rainwater from battery storage, etc. The recovered emissions can either be reused in the facility or treated before being released to the environment and/or sent to final disposal. For this purposes, Battery recycling company such as Hamko Company has some Battery waste disposal practices such as ETP (Effluent treatment plant), Acid flume neutralization plant and settling camber etc. in Khulna city. For the safely waste disposal in the environment, the application of ETP (Effluent treatment plant) is to treat the waste acid. Finally, this unused waste acid disposes the effluent wastewater into the environment so that the environment cannot be affected by these harmful chemicals.

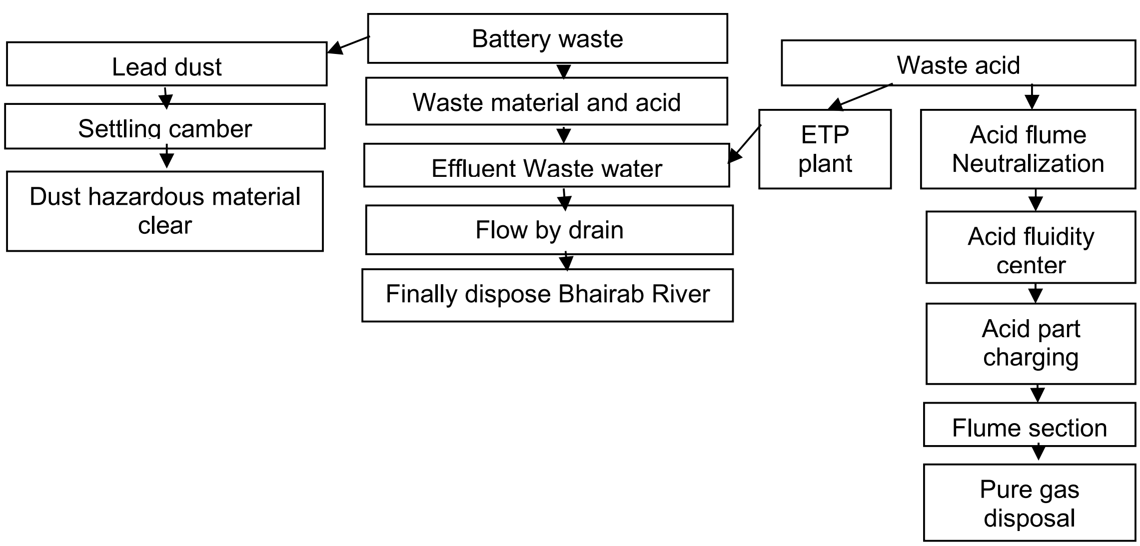

Figure 11 Battery Disposal Practices

On the other hand, In Acid flume neutralization plant, the lead content in the acid electrolyte is recovered in a smelting furnace where the wasted acid is treated first by neutralization with sodium hydroxide and this precipitates the lead as lead hydroxide. The lead hydroxide is then removed by decantation or filtration and finally, wasted acid is converted into a flume which is transported into a flume section where the pure gas is disposed into the environment. Here, lead dust is a hazardous material which is removed by a settling a camber. Thus, the Battery waste disposal practices are completely done in Battery recycling company such as Hamko Company.

Figure 12 Acid Fume Neutralization Plant

Environmental Suitability Assessment

Heavy metal is responsible for toxicological risk than physic-chemical and biological parameters. Heavy metal such as lead which is very toxic and hazardous substance which can easily create potential risk sources. This hazardous effect has a major effect on Environment and Human health. To measure the Environmental suitability safeguard, these parameters are compared with Environmental conservation rules (1997). Two sample was collected from the battery disposal practices in Hamko company such as Hamko Battery Company Effluent (sample 1) and Bhairab river (main disposal point) (sample 2) and its laboratory analyses (pH, TDS, BOD, COD and EC) were also be done. Industrial Effluent Quality Standards and laboratory test results are shown below in table:

Table 2 Industrial Effluent Quality Standards and LaboratoryTest Results

Parameter	Unit	Industrial Effluent Std. (ECR'97)	Sample 1	Sample 2
pH	---------	6-9	7.4	7.52
EC	(μs/cm)	1200	1260	960
TDS	(mg/L)	1344	800	590
BOD	(mg/L)	50	60	120
COD	(mg/L)	200	363	973
Lead(Pb)	(mg/L)	0.1	1.19	0.02

pH represents the concentration of hydrogen ions in the water. In this laboratory test result table, it was found that sample 1 and 2 which all had pH greater than 7 that means it was basic and the amount of sulfuric acid was very low. According to Environmental conservation rule (1997), it prefers a pH range of 6.0-9.0. That means this samples pH value lies in this range. On the other hand, Electric conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, and sulfides. Compounds that dissolve into ions are also known as electrolytes. The more the ions that are present, the higher the conductivity of water. The standard value of electric conductivity for inland surface water for industry effluent is 1200 uS/cm. In the laboratory test, it was found that the electric conductivity value of the two sample water was almost the same as the standard value. So, it will not be critical to the survival of some aquatic plants and animals. Total dissolved solid is a measure of the combined amount of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended soil. The sum of all the chemical ions dissolved in the water is called total dissolved solids (TDS). Generally, the operational definition is that the solids must be small enough to survive filtration through a filter. The electric conductivity of water is directly related to the concentration of dissolved ionized solids in the water. Total dissolved solid above 1000 mg/L could be indicative of a pond that has an existing water quality problems but for a river, it is 1344 mg/L. In the laboratory test, it was found that total dissolved solid value of the two samples water was almost same the standard value. So it will not be critical to the survival of some aquatic plants and animals. Chemical oxygen demand is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water. COD is an important water quality parameter because it provides an index to assess the effect discharged wastewater will have on the receiving environment. The standard value of Chemical oxygen demand for inland surface water for industry effluent is 200 mg/L. In this laboratory test, it was found that two samples water which all had COD value was greater than the standard value. So it creates an adverse effects on the ecosystem. Biochemical oxygen demand is a measurement of the amount of dissolved oxygen (DO) that is used by aerobic microorganisms when decomposing organic matter in water. BOD is an important water quality parameter because it provides an index to assess the effect discharged wastewater will have on the receiving environment.In this laboratory test, it was found that two samples water which all had BOD value was greater than the standard value. So it also creates an adverse effects on the ecosystem.

Lead is a chemical element with symbol Pb and atomic number 82. It is a heavy metal that is denser than most common materials. Lead is soft and malleable, and has a relatively low melting point. In the late 19th century, lead's toxicity was recognized and it is very toxic for the environment and human health.The standard value of lead for surface water for industry effluent is 0.10 mg/L. In the laboratory test it was found that sample 1 which had lead value was greater than the standard value. So, these effluent wastewater is very harmful for the human health and environment. But sample 2which had lead value was smaller than the standard value. So, these effluent wastewater is not harmful for the human health and environment.So, overall these study is found that environment are affected by these Effluent wastewater.

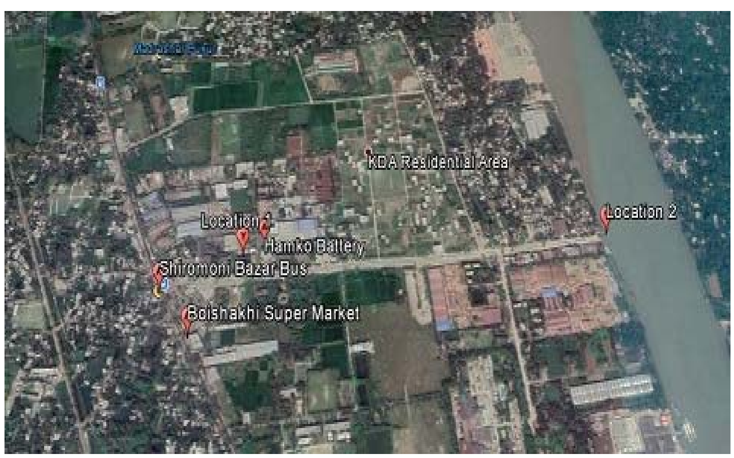

Figure 13Hamko Battery Effluent Disposal Point at Bhairab River

PROPOSALS FOR IMPROVEMENT:

Battery recycling facilities should meet the requisite environmental regulations and guidelines in the jurisdiction at which they are located. Proposals for the improvement of existing battery recycling process are outlined as below:

- The battery recycling plant is needed to be constructed by the best available technologies for improving the recycling rate along with environmental safety.
- Appropriate legislation and regulations are needed to protect worker and public health and the environment.

- The policy framework and infrastructure are needed for improving the rate of battery recycling in an environmentally sound manner. In addition to a regulatory and enforcement framework, countries should have in place a policy framework that facilitates the environmentally sound recycling of battery waste. These following elements are needed to ensure for making an effective lead collection and recycling program:
  a) The Policy is provided to inform the consumers about the importance of lead-acid battery recycling so that they can not only return their battery waste to the retailer or depot but also they store this battery waste in an environmentally sound manner.
  b) Retailers or others who collect and temporarily store the battery waste should be licensed for ensuring appropriate battery waste storage places.
  c) Lead smelters and refineries should be licensed and inspected so that they might adopt the best available technologies to improve their waste recycling rate in order to achieve high standards of environmental protection.
  d) A procedure would be followed for public outreach and for notification of unusual occurrences (e.g., emergencies, spills, leaks that are released to the environment).
  e) The control measures should be carried out at the collection points for battery waste in order to avoid accidents that may produce human and/or environmental damage.
  f) Take-back programs are provided possibly including a “deposit return fee” in order to increase the battery recycling rate.
- Manufacturer-supported Returning System is provided for the effective collection and transportation of this battery waste. This system is the best alternative solution for this battery waste collection and transportation practices in Khulna city because more informal and/or unregulated collecting network is already present here.
- Batteries should be stored in proper places such as an acid-resistant container (e.g., polypropylene pail or tub which is sealed and used as the transport container. This phenomenon minimizes the risk of accidental spillage.
- The storage place should be secured and covered from rain and other water sources, be equipped with an effluent collection system and be located away from heat sources.
- Local authorities should immediately be notified of any disposal practices of battery waste residues to the environment. Transporters should be trained to immediately notify local authorities of any leaks. This site assessment is needed to identify any contamination of land and groundwater and any clean-up that is necessary to ensure that the land and groundwater are suitable for future use.
- Direct recycling process should be banned for reducing adverse impact on the environment.

CONCLUSIONS

The study was undertaken considering root level recycling and reusing and disposal practices of battery wastes in Khulna city. Currently, no proper management practices are followed in the study area. Under this survey, 35 secondhand battery shops were identified and 20 shops had been surveyed. Various functions ofrecycled batteries were observed in these shops such as IPS, Easy Bike Battery, etc. Monthly collection of the battery wastesfor each secondhand battery shop is approximately 900 kg to 13,000 kg (0.9 tons to 13 tons). Approximately, 300-15000 kg (0.3 tons to 15 tons) of recycled battery wasteshad been sold in each shop per month. The price of recycled lead-acid battery is 35-40 percent of the new ones. The price of this old battery waste varies according to batteries quality, function, and the number of lead plates and variation of ampere. Around 552 staffs are employed in recycling company such as Hamko Company Ltd. Both shopkeepers and workers have no idea about the environmental effect of this system. In this study, two different recycling processeshad been observed which are termed as Direct and Indirect recycling process. The direct recycling process had been performed in the secondhand battery shops. Nevertheless, the indirect process of collected battery waste is sent to the battery manufacturing industry and whole recycling process is completed in the industrial periphery. The reuse, recycle and disposal practices of battery waste have combined effect on the environment and human health. In Hamko Company Ltd., the effluent wastewater is treated in ETP using Acid Neutralization Unit, Settling Chamber, etc. so that the environment is not affected by the hazardous chemicals.Thetreated effluent from industrial wastewater was tested in the laboratory. Based on thesurvey findings and laboratory testresults,recommendations are providedto improve the existing battery recycling process with proper effluent treatment for further reducing the overall environmental impacts by Lead-acid battery.

ACKNOWLEDGEMENT

The authors would like to thank Department of Civil Engineering, KUET forresearch funding.The authors would also like to thank the Hamko Battery Recycling Company for kind cooperation in field observation of the complete battery recycling process.

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RESTAURANT FOOD WASTE MANAGEMENT - A CASE STUDY OF DHANMONDI AREA

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ABSTRACT

Food waste occurs at every stage of the value chain. This is the part of food which is being discarded or lost uneaten. This part of waste has a credible share in the municipal waste which is not common only for the developed countries but also familiar for countries like Bangladesh. Management of this extensive amount of waste has become unavoidable as this problem is affecting the city areas specially the capital city Dhaka in a comprehensive manner. Thereupon more attention is being sought to manage this issue by the policy makers, industrialists and consumers to avoid its economic, environmental and social impacts. This Study has focused predominantly on the current restaurant situation is holding on in Dhanmondi area. Structured questionnaire was designed which queried regarding the waste management practice, encouraging policy for reducing waste and their future contemplation in waste management. The study used a mixed-method approach, relying on document analysis and interviews with relevant persons in the restaurant industry. The study begins by exploring issues in the restaurant food system that result in the current levels of food waste. It then identified the current context of restaurants in Dhanmondi area. This study found that substantial regulatory changes are required to achieve substantial reductions in restaurant food waste. Along with the management practices few questions were related to the average number of attendants, the amount of produced waste, the type of waste, the expenditure part for the management practice. Besides questioning there was an attempt taken to prepare compost from the restaurant waste. To do that waste was being carried towards a barrel compost. After waiting for two months the compost fertilizer was ready to use and the amount of compost fertilizer that came out from 3.9 Kg restaurants waste was 326 g. After separating non-biodegradable material like bone, oily tissue and bottle caps, the amount of compost reduced to 180 g. The overall cost was within 3000 BDT (35 US dollar) for preparing the composting barrel.

***Key words**: restaurant waste, questionnaire survey, compost, Dhaka City Corporation*

INTRODUCTION

Waste Management can be defined as a process that goes through several stages, beginning with the generation of municipal solid waste and followed by storage, collection, transference, transportation, processing and ending with final disposal (Ebrahiem, 2015). The most important reason for proper waste management is to protect the environment and human health from certain types of waste which might be hazardous for both the people and the environment. In recent days waste management practice has become unavoidable due to its extensive volume.

In the modern life the municipal solid waste (MSW) is rising throughout the time in its volume, whereas a food scraps consider as part of solid waste stream (NEA, 2009). Food waste is any by-product or waste product from the production, processing, distribution and consumption of food. Food waste is any food that is not consumed by humans and can be generated at any level within the food chain (farms, processing plants, manufacturers, commercial establishments, and households) (Westendorf, 2000).

Food wastes which are being produced from different types of restaurant are contributing credible share in municipal waste which is almost same over the whole world. Primarily the study was done to know the current practices which are being maintained by the restaurant authority regarding their waste management system.

The food waste management system is not same throughout the whole world. It was found that the management depends on the availability of lands, people's behavior towards it, the skilled Labors, sufficient knowledge regarding the handling system and last but not the least the current financial situation of the nation whether it is a developing country or developed country. Like in Singapore the amount of food waste has hit a record high of 703,200 tons in 2012. Due to the limitation of land, Singapore has applied the policy of burning all 'incinerable' solid waste, including food waste (Khoo et al., 2010). India has a large amount of food waste, but their recycling activities are poor, and the dump sites are mostly used to dispose of organic wastes. Currently, there are more than 70 composting facilities in India treating mixed municipal solid waste, which recycles up to 5.9% of a total food waste amount to generate about 4.3 million tonnes of compost each year (Kaushik, 2014). In South Korea the major practices for treating waste are dry feeding (DF), wet feeding (WF), and composting, while anaerobic assimilation and co-digestion with sewage sludge are the minor practices, and land filling of food waste was banned in Korea (Kim et al., 2011).

Dhaka, the capital city of Bangladesh, is expanding rapidly turning it into a mega city within the enormous growth of the population at a rate of around 6 percent a year. The growing number of restaurants in Dhaka city exerts a tremendous impact on public health and the environment. All the restaurants waste considered here as SOLID waste. In Dhaka city solid waste generation is about 200 tons of waste which includes household waste, medical waste, and restaurant (Zahur, 2007). In this study the observed location was within the Dhanmondi area of Dhaka city. Dhanmondi area is the municipal administrative ward (ward number 49) of Dhaka city. Once a quiet residential area was established basically for commercial establishments by the RAJUK (Rajdhani Unnayan Katripakkha, Capital Development Authority) in 1972. This commercial development consequently raised the number of restaurants in Dhanmondi area which became even higher in number since 2008-2009 (Rahman and Al-Muyeed, 2010).

The survey was conducted on the characteristics of restaurant waste and the present practice of restaurant waste management in 20 restaurants within the study area. These were selected as large and small categories as well as the type of services they rendered. This analysis seeks to document the handling practice of waste (e.g. collection, storage, transportation and disposal) along with the types and amount of waste generated by the restaurants. The survey was also conducted for better ways for managing restaurants waste in order to achieve the ultimate purpose of minimizing waste produced by restaurants.

The study in the second part was concern about the feasibility of preparing compost by collecting restaurant waste. This conception came out from the reduction in quantity and reusing the waste after being prepared as compost with a minimal initial investment and the composting system that is being practiced on a regular basis in few developing nearby countries.

METHODOLOGY

Structured questionnaire was designed to collect information addressing the generation of different restaurant wastes according to the amount and sources. The questionnaire was being asked in different categories on the basis of: waste types, waste generation sources, waste collection system, waste storage facility, availability of waste recycling and re-using process, primary treatment process and transportation process (EPA, 2014). The collected data from questionnaire survey were analyzed, mainly with simple descriptive statistics, while the qualitative mode of analysis is mainly in narrative form.

Besides the questionnaire survey, waste was being collected from different restaurants for preparing the compost. To do so a compost barrel was prepared (Moqsud et al., 2011). A plastic barrel was used for preparing compost which had a capacity up to 200 litres (55 gallons). The length and width of the barrel are 35 inch and 23 inch respectively (Figure 1). Its total height and width is 49 inch and 43 inch respectively, including a 1.5 inch schedule #80 PVC pipe. Few other parts for operating the composting barrel was 2X4 treated lumber, nails, circular saw, jigsaw, drill motor, drill paddle bit and drill bits, hole saw, basic hand tools (hammer, measuring tape, flexible metal ruler, framing square), hinges, latches and "L" brackets.

Figure 1 Barrel compost

KEY FINDINGS OF THE QUESTIONNERY SURVEY

The survey was related to the waste management practice scenario by the restaurant authority as well as the attitude of the customer regarding this issue. All the recorded data were then formatted as per the questions and interpreted along with graphical explanation.

Number of Attendants and Amount of Generated Waste

It was found that on an average 500 people visit per restaurant per day in Dhanmondi area. While this situation is not same for all the restaurants. The attendants' number varies as per the popularity of the restaurant

It is obvious to have positive co-relation between the number of attendant person and corresponding generated waste and this was even seen in this survey results. But the phenomenon was different in case of KFC restaurant. The restaurant's average attendants were 1600 person (per day). So it has been expected that their waste generation rate will be as high as their attendants. But their waste generation rate per day is only 5/6 kg. The reason behind this anomaly is the food which is being served in KFC is imported from outside and nothing is prepared within the restaurant kitchen.

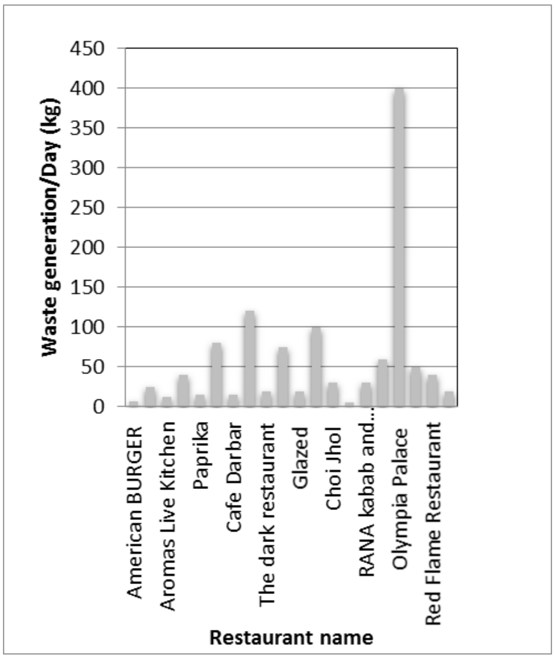

Figure 2 Waste generation of restaurant per day

The average waste being generated from a restaurant is within 200 kg each day, whereas the maximum value was found in case of Olympia Palace, a Chinese food restaurant. Figure 2 shows the quantity of waste being generated by different restaurant in Dhanmondi.

Types of Food Waste Produced

The amount of biodegradable waste is more than non-biodegradable waste that a restaurant generates. An approximate measurement of biodegradable wastes is boiled rice (30%), vegetable (20%), meat, fish and chicken (10%) and other wastes are about 5% (Figure 3).

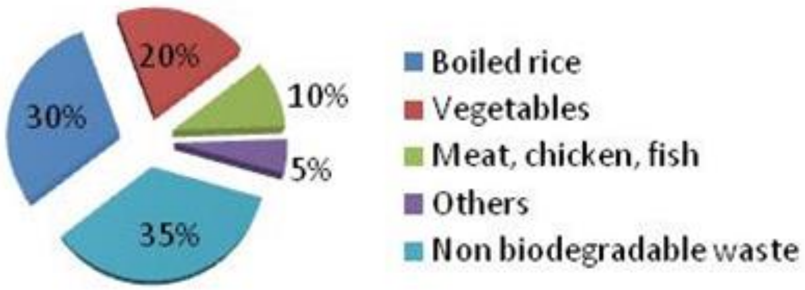

Figure 3 Approximate percentage of biodegradable and non-biodegradable waste

The non-biodegradable (35% of the total restaurant waste includes bone, plastic glass, oily tissue and foil paper (Figure 4).

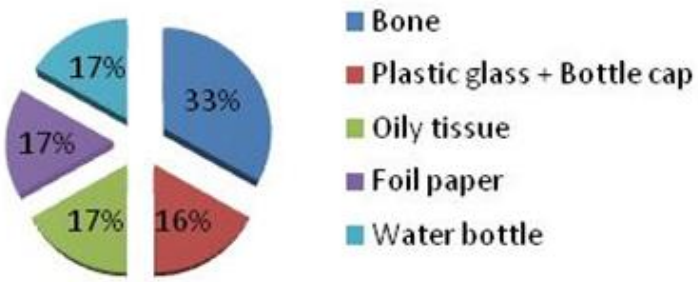

Figure 4 Non-biodegradable waste material percentages

Food waste tracking sheet to record the amount of food waste generated in the kitchen was filled up by the restaurant authority. The record seems maximum amount of restaurant waste is produced by customers (82.73%) and spoilage production is very low (2.08%). Preparation food waste is 15.17%. So if it is possible to reduce customer plate waste that can be effective for food waste reduction.

Sorting Practice

Regarding the sorting practice, it was found maximum restaurant did not perform any kind of sorting practices. After asking questions related to sorting practice it came out that instead of sorting, maximum people are using polybag to dump all the unsorted garbage together

Current Waste Disposal System

Waste disposal system is mostly organized by the Dhaka City Corporation (DCC). DCC gives contractual responsibility to ward by ward organization. Dhanmondi Cleaning Association, a contractual organization carries out Dhanmondi areas waste to the secondary dumping station.

DCC uses covered truck to carry out waste to the final dumping zone. By this treatment process few general treatments have been done like using bleaching powder and dumping the waste to the final disposal zone. Generally, they don't separate various types of waste materials. Around 20% waste disposal management is done by the private organizations.

Figure 5 Waste transportation vehicles

Cost Associated with Waste Disposal

The cost associated with waste disposal is generally spent by restaurants authority. On an average a restaurant spends around 1650 BDT (20 US dollar) per month. Ward basis responsible authority is in charge for waste collection. A chart of cost for waste management by restaurants in a month is shown in Figure 6.

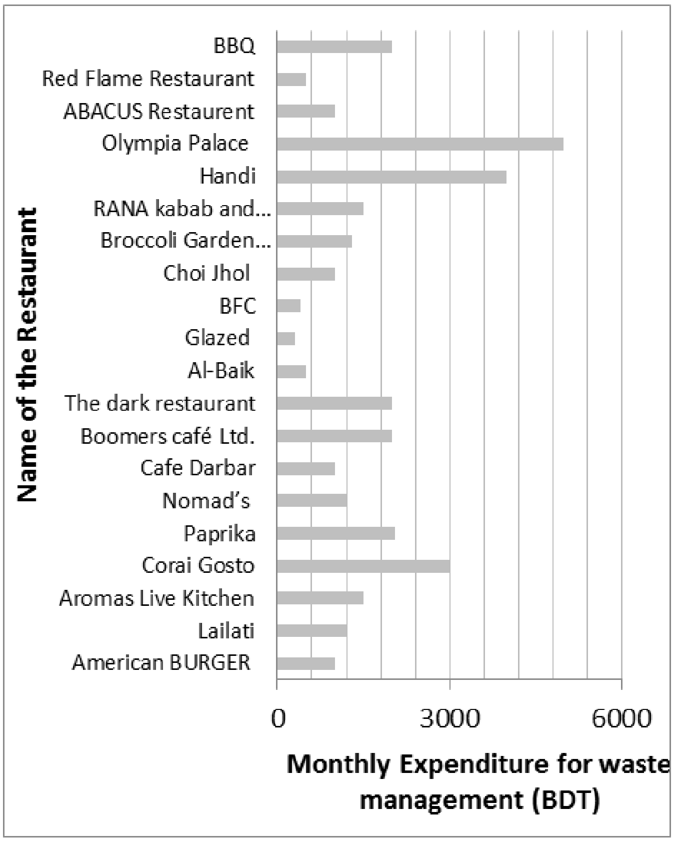

Figure 6 Monthly expenditure for waste management (BDT)

Reuse Practice

In case of reuse and recycling of waste, most of the restaurants have no concern for this issue. Only water bottles are being separated from other waste because of its recycle value. Restaurants worker or waste collection field workers collect the used bottle to sell them. Whereas all the other waste material goes from the restaurant directly to the final dumping/disposal zone. A chart of reuse practice scenario is shown in Figure 7.

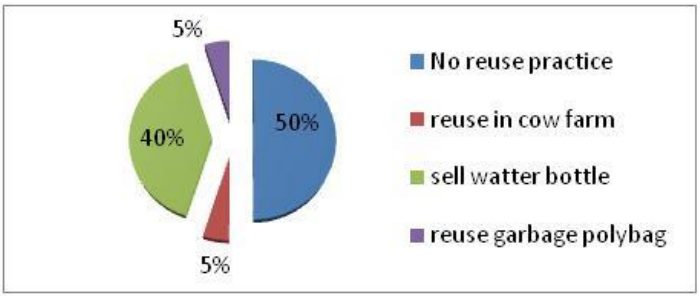

Figure 7 Reuse practices by restaurants

BARREL COMPOSTING SYSTEM

Roughly restaurants of Dhanmondi area produce daily 320,100 Kg and monthly 9,603,000 kg of food waste. This high amount of daily waste has become the concern of preparing compost along with it for commercial purposes as well as personal household use. In this research this idea was reflected by preparing a compost barrel in roof top by bringing the restaurant waste which consisted both biodegradable and non-biodegradable components. Around 4 kg waste was used initially to evaluate the composting practice. The primary weight of the waste was 4 kg (with jar weight 50 gm). There were high percentages of rice in the restaurant waste. Rather than rice, waste consists of potato, onion, and chili. Some tissue papers were also found which was being separated before preparing compost. After 15 days the weight was decreased to 2.7 kg. After 1 month the weight became less than 50% from its original measurement (1.91 kg). After 45 days the weight became 985g and finally, after 60 days the measurement was 326g. Initially the sample pH was 6.97 and during the entire compost preparation time the pH change was negligible. The moisture content of the compost was taken along with the pH measurement. The first value of moisture content has taken 5 days after the waste is generated. The moisture content was 95.58% on the first reading. The value of moisture content decreased in about 15 days. After that the value remained almost same. After 60 days the moisture content became 53.2%. The equation used to measure the moisture content is given below.

$$\text{Moisture content} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100 \qquad (1)$$

After waiting for two months the compost fertilizer was ready to use and the amount of compost fertilizer that comes from 3.9 Kg restaurants waste was 326 g. After separating non-biodegradable material like bone, oily tissue and bottle caps, the amount of compost reduced to 180 g. The overall cost was within 3000 BDT (35 US dollar) for preparing the composting barrel.

RECOMMENDED SURVEY REPORT

A study was done as recommendation survey. Only the restaurant authority and customer who agreed on the suggested approach was being recorded. The list is given below along with the asked questions towards them. The result showed that both the customer and restaurant authority suggested to feed the hungry poor people.

Table 1 Caption of the table

Question	Restaurant authority	Customer
1. Is reviewing stock management and food delivery processes for food item reduce food waste?	Two people agreed on this	Six people agreed on this

Question		Restaurant authority	Customer
2.	If restaurants modify ordering and menu planning will be helpful?	Two people agreed on this	Four people agreed on this
3.	If trained staff will ensure good management?	Eight people agreed on this	Eight people agreed on this
4.	If use excess food to feed poor hungry people will that be helpful?	Eight people agreed on this	Eight people agreed on this
5.	If using the Islamic value as not wasting food by practicing Islam?	Three people agreed on this	Four people agreed on this

The study reveals that people who are working in restaurants, mostly agreed on the issue that it is important to be trained regarding the developed waste management system along with the knowledge of reuse and recycling concept.

CONCLUSION

Present waste dumping situation is more or less cost effective but obviously not hygienic and environmentally friendly. The present situation is observed closely when the field work has been done. It can be said present condition is far better than the recent past, but that is not well enough. In most of the restaurants waste collecting person did not use hand gloves and they are not conscious about it because of carelessness or ignorance. No primary treatment has been done. Most of them did not separate biodegradable and non-bio degradable waste. Restaurants did not use proper primary dumping storage. It has been identified that many of the restaurants use normal buckets or baskets for storing waste. Many of them did not use garbage bag. Few of them use garbage bags, but they use one bag more than one time without proper cleaning which is not hygienic.

However, the result, as far get from the study, shows that the production of solid waste by restaurants is considerably good. In this study waste was brought for evaluating composting barrel. The amount of fertilizer was found 180 g which is almost 5% of the initial waste used for composting purpose. In large scale this amount will be higher which can be used for commercial purpose with little initial investment. The compost generated in the barrel can be used in different purposes. This fertilizer can be used in the seedling. The fertilizer produce in the barrel is not harmful for the environment. So this also can be used for gardening. This may be also a source of income.

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Assessment of WASH & HealthCare Waste Management in a District Hospital: A Case Study of Bangladesh

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Abstract: WASH and Waste management are essential part of the hospital management system with regard to healthy environment and infection control as a preventive measure from spreading diseases. Now-a-days the healthcare waste facilities are giving more emphasis on curative part of treatment rather than the preventative. A significant amount of resources are spent for patients infected with parasitic diseases caused by poor WASH and Waste Management practices. Study shows infected with diseases account for 50 percent of the in-patient bed occupancy, 33 percent of out-patient consultation adding an extra burden to hospital services that are often already overstretched (Adams et al. 2008). Providing access to sufficient quantities of safe water, the adequate and sound sanitation facility, proper health-care waste management system and introducing sound hygiene behavioral communication system can reduce the burden of disease transmission (Pruss et al. 1999). The Essentials of WHO guideline of Environmental Health for infection control and management in the health-care settings and Medical Waste Management Rules 2008 of Government of Bangladesh has been taken as reference to carry out the assessment of WASH and Healthcare Waste Management situation in a District Hospital. It is found from the assessment that both the WASH and Hospital Waste Management situation are not conforming to the standards stated in WHO guideline of Environmental Health and Medical Waste Management Rules of Government of Bangladesh.

Key words: WASH, Healthcare Waste Management, Hospital Management, Infection Control

1. Background

Water Supply, Sanitation & Hygiene (WASH) and Healthcare Waste Management (HWM) are one of the essential components of hospital management from infection control and management point of view. A reliable drinking water facility and sanitation service has to be in place in the hospital both for the in-patients and out-patients. In addition, adequate water supply facility including hand washing arrangement need to be ensured for personal hygiene practice. This would help to control feco-oral disease, save in-hospital stay and out-patient consultation. Essential standards defined by WHO recommended that drinking water should meet national standards and follow WHO guidelines for drinking water quality (Adams et al. 2008). Water for hospital use should be safe and of high quality. Sufficient water is available for use at all times. It is estimated that 40 to 60 liters of water is required for in-patients per day in hospital. This quantity can go up to above 100 liters per patient per day when surgical procedures are performed. Water should also be secured to flush toilets and for washing and hygiene purpose. Hand wash facilities with soap and alcohol based hand rub should be ensured for controlling feco-oral disease transmission.

A significant amount of medical wastes are usually generated every day from each of the health-care facilities (HCFs). The wastes are found over flowing of the bins, spread all over the premises of the health care facilities because of the absence of the dedicated waste management system which includes segregation process, collection method and disposal system. The health-care waste management rules 2008 has given directives for the proper management of healthcare wastes. The Directorate General of Hospital Services (DGHS) has also provided training, equipment and logistics to the hospitals for safe management of such wastes. But it is poorly practiced in many hospitals and health care facilities. Color coding for segregation and collection is not properly followed in most cases. In many cases it is observed that the general waste and the infectious waste are mixed which has been increasing risk of spreading the diseases among the service seekers (patents and attendant) and the providers (hospital staffs and workers) as well as the waste handlers. For example the sharps wastes, although produced in small quantities, are highly infectious, contaminated needles and syringes represent a particular threat because they are sometimes scavenged and reused. This unregulated practice spreads the germs of dreadful diseases such as hepatitis B, HIV/AIDS etc. (Rahman 2000)

Healthcare associated infections contribute to morbidity and mortality and to a loss of health-sector and household resources worldwide. 5-30% of patients develop one or more infections during a stay in hospital - a significant proportion of which could be avoided by proper management of WASH and health-care waste in the hospital (Adams et al. 2008)

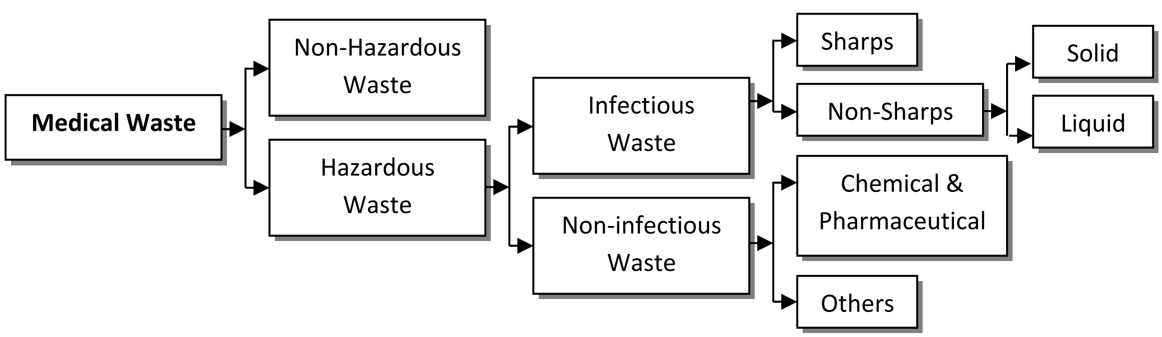


Fig. 1.1: Different types of wastes generated in the hospital

Generation of waste varies on a daily basis and it depends on the number of patients admitted, number of operations performed and number of patients visit to Outpatient departments (OPD). Medical wastes are mainly categorized into non-hazardous and hazardous wastes. The non-hazardous waste included kitchen waste etc. which is not required any special measure by the healthcare authority and is delivered to the municipality for management and disposal. This type of waste is generated in the patients' ward areas, out-patient-department (OPD), kitchens, offices, etc. The hazardous waste includes pathological, infectious, sharps and chemical wastes and are normally produced in labor wards, operation theatres, laboratories etc. (Coad and Christen 1999). The details are presented in the following schematic Fig. 1.1.

2. Purpose of the Study

This study seeks to help the HCF management in identifying the gaps and find out improved measures for a safe, effective, economic and appropriate environment friendly and sustainable WASH & Healthcare waste management in the health-care facility. The study also intends to help in improving the occupational health conditions for health care staff and caretakers through reducing the risk of people (patients, attendants, visitors, general public, scavengers etc., and animals (stray dogs, cattle etc.).

3. Objectives of the Study

The objectives of the study are to:

i. To assess the environmental health scenario that includes waste management, water, sanitation and hygiene in terms of the service availability and readiness in the hospital

ii. To assess the occupational health and safety status of the related hospital staff and patients and caregivers

iii. To identify the gaps of the environmental health in particular the HCWM and explore best possible solution to reduce the risk of health care acquired infection.

4. Methodology of the Diagnostic Assessment

The study mainly followed a qualitative approach. The study emphasized capturing the relevant information from the hospital by following different methods. The primary data were collected by visiting existing facilities of the hospital. A checklist was prepared based on WHO guideline of "Essential Environmental Health Standards in Health care facilities" (Adams et al. 2008) and "Medical Waste Management Rules 2008" of Government of Bangladesh (GOB 2008) for capturing data of the existing WASH and waste management facilities and practices and for designing future plans. The study was conducted by the following data gathering process:

i. A rapid assessment had been carried out using WHO's guideline on Essential Environmental Health Standards in Health care

ii. Visual observation was done to understand the existing situation

iii. Check list was used for the collection of data during the assessment period

iv. Meeting was conducted to analyze the occupational health and safety among the staffs

v. Waste pathway (generation-storage-collection-disposal) study was done to know the existing management system

4.1 Document Review

The WHO guideline of "Essential Environmental Health Standards in Health care facilities 2008" was reviewed to understand the standard requirements of WASH and HCWM in the Health-care facilities for infection control and management. The Medical Waste Management Rules 2008 of Government of Bangladesh was also reviewed. A checklist was prepared based on these two documents for the study of the water supply, sanitation, and hygiene practice and the health-care waste management system to identify the gaps in the existing practice.

4.2 Field Visit and Observation

Field-visits were performed to observe extensively the physical facilities and existing operational systems of WASH and HCWM facilities in Cox's Bazar Sadar Hospital by a two member team of consultant. A data sheet and a checklist were used for systematic data collection. Physical observation was carried out to assess the existing sanitation and hygiene practice; waste collection, storage, and disposal mechanism. Different steps of practices related with health-care waste management were documented in photos. Observation was carried out in different sections such as segregation practice, distribution of logistics and its proper use, cleanliness of waste bins, appropriate size of containers and locations etc.

4.3 Key Informant Interview

The Superintendent, the Resident Medical Officer (In-charge), Ward Master (In-charge), Store Keeper, Senior staffs nurses of the Cox's Bazar General Hospital, were interviewed to understand their views on hospital water supply, sanitation system and hygiene practice and health-care waste management. The Conservancy Inspector of the Cox's Bazar Pourashava was interviewed for the the support and plan of the Pourashava in relation to the waste management. Some patients and visitors were also interviewed to know about their views on infection control management system and their responsiveness toward using hospital facilities. All together 17 persons were interviewed by a Consultant team of Consultant. The details of the interviewed persons are presented in the following:

List of Responders

Personnel	Nos.
Hospital superintendent	1
Resident Medical officer (In-charge)	1
Ward master (in-charge)	1
Senior Staff Nurse	1
Nursing supervisor	1
Nurses in the wards	3
Store keeper	1
Medical Technologist (Blood bank)	1
Conservancy Inspector of Cox's bazaar Pourashava	1
Patients and Visitors	4
Cleaner	2
Total	17

5. Present Situation of Health-care Service in the Hospital

5.1 General

Cox's Bazar District Sadar Hospital is a 250-bed hospital. The number of inpatient at any point of time varied from 300 to 400. It is indicated that a considerable number of patients have no other choice but to lie on the floor. The UNHCR has provided 100 beds in addition to the official 250 beds of the hospital which are placed on the floors. The number of outpatient varied from 800 to 1000 per day while 150 to 200 patients receive emergency services per day. The hospital was headed by a Superintendent and the human resource consisting of 39 doctors, 64 nurses, 9 medical technicians, 45 class III & Class IV employees (Sweepers, Ward boys and Ayas) and 5 people in administration. Superintendent, Resident Medical Officer (RMO) and Ward Masters were responsible for the cleanliness and the health-care waste management of the hospital. There were 42 cleaners (4 from hospital, 8 from Municipality and 30 Rohingas provided by UNHCR) in the hospital.

5.2 Safe Water

The main source of water is the deep-tube well provided by UNHCR. The water is pumped into an overhead reservoir and distributed in various location of the Cox's Bazar Sadar hospital through piped reticulation. There is a water purifier in the Nursing hostel from where the hospital employees collect drinking water. Since the patients do not rely on tap water they collect drinking water from the water point in the pump house or from the nearby mosque in bottles or water pots. The tap water is not used for drinking purpose by anybody but used for hand washing, toilet flushing and medical activities only. To keep the bibcock serviceable is a challenge because it breaks or stolen by the outsiders very frequently. During the field visit, it was found that most of the taps in the washing basins were missing and the washing basins themselves were broken. The hospital authority seems to believe that ground water is safe therefore they never thought of carrying out microbiological test. In the Operation Theaters (OTs) and pathological laboratory, the same water is used. However, there was no shortage of water supply except during power failure.

5.3 Sanitation

The overall sanitation situation in the hospital is very grave. There are 2 toilets, 3 urinals and 2 bathrooms for excreta disposal, urination and bathing in each ward. The hand washing basins in some wards are either broken or with bib-cocks missing. Soaps are not provided for hand washing because of the fear of being stolen. Usually the patients bring soap of their own to meet their need. There is commode facility in the cabin which is comparatively clean and well fitted. . The sweepers clean the toilets of the wards twice a day. Some toilets are reserved for doctors and the staffs. The male and female wards are separated. There are separate toilets for male and female in the outpatients department. Hexisols, soaps are provided for hand washing of the doctors and nurses sufficiently from the store. Harpic, bleaching powder and finale is also supplied for cleaning the toilets. The waste water disposal system is covered and cleaned at regular interval. The septic tank is emptied when it is filled. The situation of sanitation facilities found during the field visit is presented in Fig. 1.2.

Handwashing basin

Urinal

Urinals

Toilets

Fig. 1.2: The photograph of the sanitation fcilities

5.4 Waste

Healthcare wastes are highly infectious and hazardous especially to human health because those carry the germs of dreadful diseases like hepatitis B and C, HIV/AIDS etc. Healthcare waste need to be segregated, collected, transported, treated and disposed of safely. Color code with proper labeling is essential for the separate collection and disposal.

In Cox's Bazar Sadar Hospital, such initiative was commenced in five years ago with the support of DGHS. The doctors, nurses, medical staffs including other relevant persons were provided training and the for waste disposal color coded bins were introduced and supplied. Three types of bins namely Black, Yellow and Red color with proper labeling were provided. The Black bins were provided for general waste, the Yellow bins were for infectious waste and the Red bins were for sharp waste. The bins were found in use but the color coding system was not properly followed for different types waste. The Bins were not properly located according to the signs and information. Three types of bin were used properly in the Operation theaters and pathological laboratory. It was found during the visit that the yellow bins were used for depositing general waste. There were huge amount of general wastes generated in the hospitals daily. It was found during the visits that other wastes like green coconut shells were also disposed in to the yellow bins without considering the designated wastes for the yellow type bins. The yellow bins were usually filled up within a short period of time and after sometimes overflowing of wastes were observed. The photographs of wrongly signed with wrongly placed bins are presented in Fig. 1.3

Wrong color coding bin

Wrong sign

Proper color coded waste bins in the laboratory

Fig. 1.3: Photograph of wrongly signed with wrongly placed bins

The UNHCR provided 40 Nos. of wheeled yellow bins for waste collection to fulfill the demand of the hospital authority. Proper color coding was not considered during the supply by UNHCR. The UNHCR also provided 3 hand trolleys for waste transportation. The hospital authority also procured 6 (six) trolleys for internal transportation of bins. Only 1 (one) trolley was found on the passage, 2 (two) were not used as the wheels were broken and 3 (three) were found in the store. It was pointed out by the Ward master that during the project period, the source-segregation and separate collection of waste was practiced but due to lack of monitoring and supervision, the initiative was stopped after sometime. Some photographs of the trolleys are presented in Fig. 1.4.

Fig. 1.4: Photograph of ttrolleys not used for internal transportation

Fig. 1.5: Photograph of storage and unloading of bins for washing

The cleaning of the bins was not properly done and was stored in an open place in the corridor. The workers were not taken any protective measure during the waste handling and cleaning operation. All types of bin were transported to the disposal point which is located in the hospital premise (Fig. 1.5)

Fig.1.6: Disposal point at hospital premise

The disposal point was a covered dustbin with a ramp (Fig. 1.6) and not protected from the scavengers or the stray animals. Cutters were provided in the respective medical units and wards for destroying the needles, needle In the laboratory, the needle cutter was found properly used but in other places, needle cutters were found on the table. The workers of the private contractor Gausia were found wearing gowns but no workers was found wearing mask and gloves during handling waste.

Two types of container (1 plastic bowl and 1 basket) were placed under the patient's bed in the wards and at regular intervals, the cleaner empties the contents of the bowl into a collection bucket with lid. It was also observed during the visit that after given an injection, the nurse bended the needle manually (no use of needle cutter), cut off the nozzle of the syringe and put everything into the plastic bowl. The IV lines and plastic infusion bottles were also placed in the bucket. It was also disappointing that used syringes with needle (both without cap and recapped) were seen in several collection bins. When observing black bins, the used syringes and empty infusion plastic bags with IV-line were found. All types of bin were taken to the disposal point and without treatment unloaded in the dustbin for municipal collection. Municipality truck comes daily for waste collection from the dustbin. Hospital authority paid money to the truck driver for ensuring daily collection. The wastes were transported openly and dumped in the disposal ground with other wastes.

Fig. 1.7 Photograph of Plastic bowl under the bed

5.4.1 Type and Amount of Waste Generated

A study was carried out by WHO and DGHS in 2012 on waste generation and composition in the Health Care Centers of Bangladesh including Cox's Bazar Sadar General Hospital. According to the study, average total waste generation per day was 485.5 kg of which general waste 249.6 kg (51.4%), sharp 12.4 kg (2.55%), liquid waste 107.2 kg (22.08%), recyclable 40.7 kg (8.38%) and infectious 75.6 kg (15.57%). Average waste generation per day per bed was 1.94 kg. During the study, it was difficult to estimate the different types of waste without separating as all the wastes were being mixed into same container without segregation except the pathological laboratory, blood transfusion centre and operation theatres.

5.4.2 Status of Waste Segregation Practice

According to the Medical Waste Management Handling Rules 2008, the hospital has to design the segregation system with non-infectious general waste to put in Black, infectious waste in Yellow and Sharp waste in Red color coded bins. Initiative was undertaken by a project of DGHS for waste segregation practice in the hospital. Doctors and Staffs were provided training on waste segregation practice and three types of bins were supplied with proper labeling. However, after the project period, the segregation practice was stopped due to lack of waste monitoring system. Enough containers were provided however, in practice proper color code was not followed. Bins were not placed in proper location and proper labeling was not found.

5.4.3 Collection and Transportation of Waste

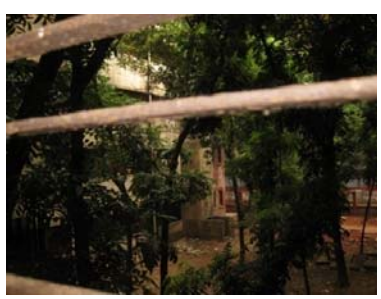
Wastes were collected and transported twice a day on a shift basis. Some of the containers during the collection were found empty and some were found overflowing. It indicated that the size of containers used for waste collection or the frequency of empting did not match the amount and type of waste generated in a day. The trolleys were not used for transporting the container. The containers were transported manually as found during the field visit. The wastes were collected when the patient flow in the hospital was high and transported through the patients' walking route which was a risky events for the patients and the visitors as observed.

5.5 General Cleanliness

Cleanliness is one of the basic measures for infection prevention and control in the health-care environment. In general, the hospital appeared clean and tidy. It was found during the visit that the outpatient, inpatients and waiting space of the hospital was crowded with patients and their attendants. Although the floors were found apparently clean but the bins were overflowing with wastes. Littering is also found a big problem in the hospital. Although bins were placed for waste collection, people threw various stuffs and other waste materials indiscriminately. Spitting with the coughs and sneezes were found in and around the corners where the bins are placed. A cleaning and mopping system existed in the hospital. Dry sweeping is done in offices and lounges twice a day followed by a wet mopping. The specialized rooms such as operation theatres, delivery rooms, pathologies were cleaned by detergents or disinfectants. The toilets were cleaned by disinfectant (bleaching powder and H*arpic*) daily and when required. The hospital out-premises were swept daily and drains were cleaned twice in a week.

Clean New-born unit

Wastes are collected in hand trolley



Waste dumping in hospital premise

Cleanliness message in the hospital

Fig,1.8: General Cleanliness of the hospital

5.6 Health Protection of Staff

Hospital waste carries germs. Staffs were found at risk because of their inadequate personal protective equipment (PPE) during waste collection and transportation. Staffs did not use masks and gloves. The awareness among the staffs was found absent regarding the waste handling. No strict monitoring on proper use of personal protective equipment such as protective clothing, gloves and masks was found among the different category of staff.

6. Gaps Identified in WASH and Waste Management in Hospital

6.1 Water Supply

In the healthcare facilities, water supply should be reliable. In hospital premises, water for drinking, cooking, personal hygiene, medical activities, cleaning should be safe, sufficient water should be available at all times and sufficient water points and water use facilities should be available. The standard measures (Adams et al. 2008) and existing situation of water supply with identified gaps is presented in Table 1.1.

Table 1.1: Comparison for standard measures and existing situation of water supply

Standard Measure	Existing Situation	Gaps
A reliable drinking water point is accessible for staff, patients and patient attendants at all times. Drinking water points should be clearly marked. Reliable water point with soap or suitable alternative is available at all critical points within the HCS (operation theatres, wards, consultation chamber, dressing stations etc.) and in the service areas (sterilization laboratory, toilets etc.). There need to be at least	There is no reliable drinking water facility found in the hospital accessible for staff, patients and their attendants. The deep tube well water is assumed as safe drinking water source. Water is available at all times except during long time power failure. The operation theatres, consultation chambers, dressing stations, pathological laboratory and blood transfusion centre are equipped with hand wash basin with soap or alcohol based rubbing. The wards are mainly 20	Reliable drinking water facilities with clearly marked as safe drinking water is absent. Piped water supply in the hospital is unreliable for drinking. No micro-biological test has been carried out of the supplied water so far. Public Works Department (PWD) is mainly responsible for the maintenance of the building and its plumbing system. But they hardly take care or response to this issue. Hand washing basins or the fittings in the wards

two hand washing basins in wards with more than 20 beds Drinking water supplied should meet national standards and follow WHO guideline for drinking water quality. Inpatient settings need to have sufficient showers (at least one shower for 40 users and separate showers for both sexes for privacy and safety).	bedded but 10 extra beds are also provided on the floor. There are two hand washing basins found near the toilets in the wards, however in most cases the taps of the washing basins are missing. There are two shower facilities in the wards which are sufficient for the patients admitted in the wards. The male and female patients has separate wards so in terms of privacy and safety, there is apparently no problem.	are mostly missing and inconvenient for the users.

6.2 Sanitation

Adequate, accessible and appropriate toilets for patients, staff & visitors need to be ensured for ensuring proper sanitation and hygiene facilities. The standard measures (Adams et al. 2008) and existing situation of sanitation is presented in Table 1.2:

Table 1.2: Comparison for standard measures and existing situation sanitation and identified gaps

Standard Measure	Existing Situation	Gaps
Sufficient toilets are available in HCFs (one toilet per 20 users for inpatient settings and four toilets for outpatients: staff-1, male patient-1, female patient-1 and children-1). Toilets are easily accessible for all users (no more than 30m from all users), lockable by the users and lighting facilities at night. Toilets provide privacy and security (male and female specified). Clearly sign posted to help users for finding those. Toilets have convenient hand washing facilities close by. A routine cleaning and maintenance is in operation that ensures clean and functional toilets are available at all times. Toilets are cleaned whenever those	There are two toilets in each ward for 20 patients in bed and 10 patients bedded on the floor. The toilets were not hygienic in terms of keeping them clean through proper flushing. The cleaners cleaned the toilets twice in a day but the users did not maintain the cleanliness. The taps of the wash basin in the toilets are missing. For the outpatient unit, there are separate toilets for hospital staff, male and female. No separate toilet facility exists for the children. The patients managed their own soap for hand washing. There was also a public toilet in the hospital premises leased out by the municipality. Lock and lighting facilities were not sufficient. There was support facility for the elderly or sick patients. Some toilet fittings had been broken and repair work was not done by PWD	Sanitation situation in the hospital is dismal from hygienic point of view. There is a cleaning program for the toilets from the hospital authority but the users often make them dirty. It is tried by the hospital authority to keep hand wash soap but difficult for them to maintain because of missing. The taps or other fittings are either broken or stolen. Locking and lighting facilities are insufficient and not regularly addressed. There is no regular monitoring of cleaning schedule and no initiative has been taken from the hospital authority for remedial measure or improving the situation.

Standard Measure	Existing Situation	Gaps
become dirty and at least twice per day (with brush and disinfectant). Toilets are connected to a sewer system or septic tank and drainage system. Toilets are equipped to make easy to use by people with physical handicaps, heavily pregnant women, elderly/sick people. Adequate drainage of waste water with cover to avoid the risks of disease vector breeding.	for a long time. Septic tanks usually emptying when they were overflowing.	

6.3 Cleaning and Hygiene Practice

Floors and the surfaces in the healthcare facility are to be kept clean. Routine programmed cleaning, sweeping and wet mopping is to be ensured. The standard measures (Adams et al. 2008) and existing situation of cleaning and hygiene practice is presented in Table 1.3:

Table 1.3: Comparison of standard measures and existing situation of cleaning and hygiene practice and identified gaps

Standard Measure	Existing Situation	Gaps
Sweeping daily (office and non-patient areas), wet mopping daily (waiting areas, consultation rooms, wards, pharmacy), cleaning with detergent/disinfectant (OT, delivery rooms, ICU, casualty departments, laboratory, kitchen etc.). Any area contaminated with blood or body fluids are cleaned and disinfected immediately, beds/pillows/linens are cleaned between discharged and admitted patients and whenever soiled with body fluid, beds are wiped with disinfectant solution following	Sweeping of the premises and the floors are done regularly. There was a cleaning schedule of the sweepers. The waiting areas, consultation rooms, wards were mopped twice in a day. The OT, delivery rooms, ICU, casualty department, laboratory rooms were cleaned by disinfectant. The toilets inside the OT and ICU were cleaned twice daily by using detergent. Hand washing facilities were not sufficient. It was difficult for the hospital authority to keep soap for hand washing in the hand washing basins. There was no committee existed to monitor the cleaning activities. The staffs were not	The supervision and monitoring of the cleaning service from the hospital authority is absent. Ward master is responsible on adhoc-basis. There is no committee for reporting or addressing the overall cleanliness of the hospital. There is no mechanism of training or rewarding the staff for encouragement. Patients or visitors are not informed about their responsibilities for cleanliness during their stay in the hospital. No visual advice or instructions are seen for awareness and practice on cleanliness and infection control.

Standard Measure	Existing Situation	Gaps
each hospitalization. Staff are trained and managed in a way that encourages consistent compliance with infection control procedures. Patients and attendants are informed about essential behaviors necessary for limiting disease transmission in HCS. Posters and other visual information should be used to promote disease control among patients and attendants.	trained and also patients and visitors were not consulted about the hygiene for infection control. Posters and promotional messages are absent.	

6.4 Waste Collection and Disposal

Management of health-care waste is an integral part of hospital hygiene and infection control. Health-care waste is considered as a reservoir of pathogenic microorganisms, which can cause contamination and give rise to infection. If waste is inadequately managed, these micro-organisms may be transmitted by direct contact, in the air or by a variety of vectors. Infectious waste contributes to the risk of noso-comial infections, putting the health of hospital personnel and patients, at risk. The standard measures (Adams et al. 2008) and existing situation of healthcare waste management is presented in Table 1.4:

Table 1.4: Comparison of standard measures and existing situation of health-care waste management and indentified gaps

Standard Measure	Existing Situation	Gaps
Health-care waste has to be segregated, collected, transported, treated and disposed of safely. Health-care waste is segregated at the point of generation according to its type & categories: sharps, non-sharps infectious waste, non-sharps non- infectious waste. Color-coded waste containers or containers bearing clearly understood signs and symbols are provided at convenient locations. They are collected	Three type bins following the color code were provided in the hospital by the DGHS. But segregation and separate collection and disposal are completely absent. All types of wastes are put together. Cleaners have no awareness and training on handling the wastes. Training was provided three years ago regarding the use of bins. But not continued or practice was monitored. The cleaners were found not wearing protective gears and reluctant of associated risks.	Waste segregation, separate collection and disposal are completely absent. Color code is not properly followed either in bin placement or in practice. The instructions or labeling are wrongly pasted on the wall. Cleaners are not aware of the danger with handling healthcare waste. Trolleys for internal transportation, internal storage of bins, cleaning of bins all are very improperly managed. Needle cutters are not used and syringes

Standard Measure	Existing Situation	Gaps
from all health-care services and stored safely before treatment and/or disposal. Each category of waste is treated and disposed of according to the safest feasible method.	Segregation of medical wastes was not conducted properly. Color code was not followed during source segregation except the pathological lab. In the wards, mixed waste including syringe with needle was found in the bins. Trolleys were not used for internal transportation of the bins. Needle cutters were not used in all medical units The bins were labeled with text but the pictorial representation was absent. The labeling and position of the bins were mismatched. The size of the black bin was very small. Most of the bins were full and overflowing. The lids of the bins were lost. The bins were taken to the disposal point for unloading and washed openly by water without using disinfectant. Bins placed in the wards, waiting spaces were found dirty. Bins were not properly cleaned and disinfected. The cleaning of bins was done in open place. The bins for infectious wastes need to be disinfected before placement which was completely missing. The municipality truck comes everyday for collection. There was no treatment system of any type of waste and systematic recycling system was absent. All types of waste were disposed of in a dustbin from where the municipality truck collects waste daily. The papers, cartons, plastic etc. were collected by the cleaners or ward boys of the hospital, stored in a room and sold to the scrap dealers. The	with needles are found in the bins or in the disposal points giving scope to the unscrupulous scavengers to collect and resale. There is no system of separate treatment of waste. Recovery of recyclable materials is done by both the hospital staff and the scavengers. Scavengers spread the waste in the disposal point and collect the soiled paper, plastic materials from the mixed waste. There is no record of waste generation and disposal. Municipal truck collects waste daily from the dustbin located in the hospital premises and dumped with general wastes in the disposal ground.

Standard Measure	Existing Situation	Gaps
	unscrupulous people collect the saline, blood bags and syringe from the dustbins which might have chance to resale and reuse in the hospital or any other healthcare establishment.	

7.0 Recommendations

WASH and Waste management are essential part of the hospital management system with regard to cleanliness and infection prevention and control as a measure of spreading diseases. The assessment of the existing situation has been done based on the essential environmental health standard in healthcare facilities and the gaps are identified for improvement. It is found from the assessment that the hospital has given too much emphasis on clinical intervention for curing diseases and very little on its prevention. Hospital needs to set an example of being a clean and hygienic place in the community. It needs to demonstrate how to maintain cleanliness of hospital by ensuring proper water supply, sanitation and waste management. The overall guiding principles for the improvement of the hospital sanitary environment are as follows:

i) For safe drinking water supply, at least 10 (ten) water points with filter (Outpatient Departments-2, Male ward-1, Female ward-1 in (1st floor & 2nd floor), doctors canteen-1, general canteen-1, Neo-natal unit-1, superintendent room-1) need to be installed and clearly marked as drinking water point.

ii) Existing toilets need to be repaired and maintained with hand washing facilities.

iii) A health education desk should be developed for raising awareness to patients and visitors to use the hospital's waste bins of different category and color coding system; explain them the implications of the dangers of using certain infected recycled medical items. Information by posters and leaflets on hygiene promotion and practice should be displayed in the hospital premises to educate the people.

iv) Regular sweeping, wet mopping and cleaning service should be closely supervised and monitored. For this a written reporting system can be developed and used.

v) Segregation following the color coding, separate collection, treatment and safe disposal of healthcare waste should be ensured in the hospital.

vi) A workable Infection Prevention and Control Committee including cleanliness and waste management should be formed for regular meeting and inspection of the hospital cleanliness and waste management facilities .

vii) Wastes from the pathological laboratory and isolation wards should be disinfected by autoclave before disposal

viii) Recycling practice of medical wastes may cause the risks of infection, so measures should be taken to prevent the recycling of hazardous items or otherwise reduce the risk associated with the items by disinfected them by chlorination before they are recycled.

ix) Reward system with clean ward contest should be conducted for encouraging the concern staffs of the hospital. It will motivate the staff to keep their working place such as wards clean.

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Annexure-I

CHECK LIST FOR WASH

Area	Indicators / Variables / Activities	Status		Remarks
		Yes	No	
Water quality (water for drinking, cooking, personal hygiene, medical activities, cleaning and laundry services)	Water source safe			
	Microbiological quality of the water supplied tested/monitored			
	Water storage tanks are cleaned and how often			
	Water is safe for drinking			
	Water is suitable for medical purpose			
Water quantity (Sufficient water is available at all times for drinking, food preparation, personal hygiene, medical activities, cleaning & laundry)	Sufficient water available at all times for all needs			
	Reliable drinking water points are accessible for staff,			

Area	Indicators / Variables / Activities	Status		Remarks
		Yes	No	
Water facilities and access to water (Sufficient water collection points and water use facilities are available in HCS for drinking, medical activities, personal hygiene, food preparation, laundry & cleaning)	patients and careers at all times			
	Drinking water points are sufficient and clearly marked			
	Reliable water point with soap or suitable alternative is available at all critical points (Operation theatre, wards, consulting rooms, dressing stations, laboratory, kitchen etc.) [At least two hand washing basins in wards with more than 20 beds]			
	Inpatient settings have sufficient showers (At least one shower is available for 40 users and separate showers for both sexes for privacy and safety)			
	Alcohol based hand rub facilities exist			
Excreta Disposal (Adequate, accessible and appropriate toilets for patients, staff and careers)	Sufficient toilets are available in HCS (one per 20 users for inpatient settings, four toilets per outpatients)			
	Toilets easily accessible for all users (No more than 30m from all users)			
	Toilets provide privacy and security (Male and Female specified)			
	Clearly sign posted to help users finding them			
	Toilets maintained and repaired			
	Toilets hygienic to use and easy to clean			
	Hand washing facilities close by the toilets			
	Toilets connected to septic tank and soak pit			
	Equipped to make easy to use by people with special need			
	Lockable by users and lighting facility at night			
	Cleaning and maintenance routine in operation			
	Clean at least twice per day			
Waste water disposal	Waste water is disposed of rapidly and safely			
	All open waste water drainage covered to avoid the risks of disease vector breeding			
	On-site disposal in soak away/pits			
Cleaning and laundry (Floors and surfaces, laundry are kept clean)	Sweeping daily (office and non-patient areas)			
	Wet mopping daily (waiting areas, consulting rooms, wards, pharmacy)			
	Cleaning with detergent/disinfectant (OT, delivery rooms, ICU, casualty depts., laboratory, kitchen etc.) daily			
	Any areas contaminated with blood or body fluids cleaned and disinfected immediately			
	Beds/Pillows/linens are cleaned between patients and whenever soiled with body fluid			
	Beds are wiped with disinfectant solution following each hospitalization			
	Food kept covered to protect from flies and dust			
	Refuge kept in covered bins			

Area	Indicators / Variables / Activities	Status		Remarks
		Yes	No	
Information and Hygiene Promotion	Staff trained in infection control procedures			
	Patients and careers informed about limiting disease transmission			
	Posters and other visual information used to promote disease control among patients and careers			

Annexure II

CHECK LIST OF IN-HOUSE HEALTHCARE WASTE MANAGEMENT

Area	Indicators / Variables / Activities	Status		Remarks
		Yes	No	
Placement of Bin	Bins are placed at the right site (accessible for patients)			
	Placed bins are correct in number according to need(All places) OT, emergency, Casualty, OPD, Gynae, dressing etc. (one set of waste container per 20 beds in a ward)			
	Placed bins are correct in color according to type of service delivery and also labeled			
	Bins are closed with lid and are clean			
	Surroundings cleanliness of the bins are maintained			
Segregation of waste according to classification	General waste segregated properly and placed in black color bin			
	Infectious waste segregated properly and placed in yellow color bin			
	Sharp waste are needle crushed and placed in red color bin			
	General waste but recyclable segregated properly and placed in green color bin			
	Liquid waste disposed properly (with treatment/without treatment)			
Collection of waste	Emptying of bins is done properly			
	Waste handlers are wearing protective materials during waste handling			
	System of cleaning bins after emptying are in place			
	Supervision and monitoring of collection of waste are done regularly			
Temporary waste storage room management	Dedicated temporary waste storage room			
	Concrete floor with good drainage			
	water supply for cleaning purpose			
	Inaccessible for unauthorized person, animals and insects			
	Easy access for the waste transportation trolley			
	Proper light, Passive ventilation			
	Situation of the room not near to the food preparation area			
	Wearing protective material like Service gloves, Apron,			

<table>
<tr><th rowspan="2">Area</th><th rowspan="2">Indicators / Variables / Activities</th><th colspan="2">Status</th><th rowspan="2">Remarks</th></tr>
<tr><th>Yes</th><th>No</th></tr>
<tr><td rowspan="9">Infection control and
Safety measure</td><td>Boot, Mask</td><td></td><td></td><td></td></tr>
<tr><td>Doctors, nurses including waste handlers developed capacity on safety measures</td><td></td><td></td><td></td></tr>
<tr><td>Training received by designated staff on HCWM</td><td></td><td></td><td></td></tr>
<tr><td>Aware of HCWM rules or guidelines</td><td></td><td></td><td></td></tr>
<tr><td>Proper hand washing is practicing by doctors, nurses especially for the waste handlers after waste handling</td><td></td><td></td><td></td></tr>
<tr><td>Incidence reporting system is in place, especially for needle prick</td><td></td><td></td><td></td></tr>
<tr><td>Waste management and supervision committee is in place and sit at a regular interval</td><td></td><td></td><td></td></tr>
<tr><td>Safety measure discussed in the monthly waste management implementation coordination committee meeting</td><td></td><td></td><td></td></tr>
<tr><td>Responsibilities are distributed among the supervisor and staff for effective waste management</td><td></td><td></td><td></td></tr>
<tr><td rowspan="7">Logistic management</td><td>Supply plastic bowls are adequate and properly used</td><td></td><td></td><td></td></tr>
<tr><td>Supply of protective material are sufficient in number</td><td></td><td></td><td></td></tr>
<tr><td>Supply of needle crushers are sufficient in number</td><td></td><td></td><td></td></tr>
<tr><td>Reserve stocks are available in the store for above mentioned material</td><td></td><td></td><td></td></tr>
<tr><td>Soap/hand washing materials are sufficient in quantity</td><td></td><td></td><td></td></tr>
<tr><td>Budgetary allocation available for logistic</td><td></td><td></td><td></td></tr>
<tr><td>Proper inventory system for waste management logistic</td><td></td><td></td><td></td></tr>
<tr><td>Waste transfer and disposal and treatment Facility</td><td colspan="4">Field Observation</td></tr>
</table>

PERFORMANCE ANALYSIS OF SEMI-AEROBIC LANDFILL UNDER DIFFERENT WATER AVAILABILITY CONDITIONS AND PUTRESCIBLE WASTE CONTENT

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ABSTRACT

The semi-aerobic method is considered an economically and technically sustainable landfill technology. However, the semi-aerobic landfills performance are strongly influenced by water availability and varying content of putrescible organics in the waste.

The aim of this study was to investigate the stabilization performance of semi-aerobic landfilling under inverse conditions for both parameters (high and low water availability -wet and dry conditions-, low and high content of putrescible waste fraction) and to identify practical solutions aimed at achieving an efficient control of these conditions. Six lysimeters were specifically set up: two simulating wet conditions, two simulating dry conditions, and two simulating artificially controlled watering under dry conditions. In each pair of lysimeters one was filled with waste with a low putrescible content and the other with waste with a high putrescible content. The performance of lysimeters was monitored by measuring the quality and quantity of emissions and carbon and nitrogen mass balances were calculated. The best performance for the semi-aerobic process was achieved at a water availability ranging between 1.5-2.4 kgH_2O/kgTS. These values were achieved under the following conditions:

– *Waste with high putrescible content and no addition of external water. In this case endogenous water in the waste (moisture) was sufficient to promote the biological stabilisation of waste (Respiration index in 4 days, RI_4 = 12.87 mgO_2/gTS, BOD/COD < 0.05)*

– *Waste with low putrescible content and controlled watering. Stabilisation performance was similar to that reported above (RI_4 = 12.25 mgO_2/gTS , BOD/COD < 0.04).*

In both cases, the presence of CH_4 in landfill gas (LFG) was limited (< 3%) and the quality of leachate demonstrated that when an appropriate water supply is ensured, semi-aerobic landfilling is a suitable technology for use in controlling long-term emissions and achieving the targets set for sustainable landfilling.

INTRODUCTION

Historically, landfilling has been the main management route for solid waste and it still is in many parts of the world, particularly in developing countries. Although in industrialised countries the emerging legislation supports many most preferable alternatives, landfilling remains an unavoidable step for closing the material cycle even in modern solid waste management. The very concept of the Circular Economy (EU, 2015) cannot be realistically achieved without a sustainable final disposal step for residues that are not technically or economically viable anymore (Cossu, 2010). The sustainable landfill, in particular, has been introduced as a system specifically designed to reduce the emission potential on long term in order to preserve the next generations from potential environmental risks and remediation costs (Cossu, 2005; Cossu and Stegmann, 2018). The need of innovative techniques addressed to the landfill sustainability has increased the interest in bioreactors landfills: systems planned and operated with the aim of enhancing stabilisation processes (Grossule et al., 2018). Effective design of sustainable landfills remains critical in most Developing Countries (DCs), where financial constraints and limited technical knowhow limit the availability of appropriate treatment and disposal technologies (Brunner and Fellner, 2007; Oman and Manandhar, 2011).

Among the other landfill types, the semi aerobic landfill may constitute a viable option with a view to both economic and environmental sustainability, since a cost–effective, low technology landfill system, whose stabilisation performance has been confirmed by several studies(Grossule et al., 2018). The semi aerobic landfill is based on a proper engineering design which enables the natural flow of the ambient air into the waste body through the leachate collection pipes, moved by the temperature gradient between inside and outside the landfill (Hanashima et al., 1981; Matsufuji et al., 2018). By achieving the aerobisation of the waste mass, landfill stabilisation is accelerated providing same benefits of the forced aerobic landfill, but lowering the typical operational costs associated to the air injection.

Specific in-situ conditions, such as climate conditions and waste composition should be carefully considered, as they may strongly influence landfill stabilisation performance (Chanton et al., 2011; Esteban-Altabella et al., 2017; Grossule et al., 2018; Levis and Barlaz, 2011). The main parameters in controlling stabilization performance of the semi-aerobic method are:

a. *Water availability.* It depends on natural or forced water input (rainfall or leachate/water recirculation) and on moisture content in landfilled waste. It is needed for biodegradation processes of putrescible wastes, flushes non-degradable contaminants but it reduces the free porosity of waste interfering with air flow.
b. *Putrescible organic content in the landfilled waste*. The higher the putrescible fraction, the higher the potential impact of leachate and gas emissions. In addition it may reduce permeability of the waste mass resulting in a reduction of the circulation of air and enhancement of anaerobic processes. Typically, high concentrations of putrescible wastes (kitchen waste, green waste, etc.) are present in wastes from developing countries (DCs), while low concentrations may be encountered in industrialised countries (The World Bank, 2018).

The aim of this study was to investigate stabilization performance of semi-aerobic landfill under extreme conditions for two main parameters (wet or dry climate, low or high putrescible fraction in the waste), and to identify an appropriate design and operational solution to be implemented to effectively address these conditions. Six lysimeters were specifically designed to simulate semi-aerobic conditions: two reactors were operated to simulate wet conditions, two reactors simulated dry conditions, and the last two simulated artificial watering under dry conditions. In each pair of lysimeters one was filled with low putrescible waste and the other with high putrescible waste.

The performance of semi-aerobic lysimeters under different operating conditions was compared in terms of waste stabilization, leachate and gas quality and a mass balance for carbon and nitrogen was calculated.

MATERIALS AND METHODS

Waste samples

Two different type of waste were tested: Low Putrescible (LP) and High Putrescible (HP) MSW. LP waste was represented by residues from MSW source segregation, after shredding and 6 cm sieving, yielding a 9% wt wet faction of kitchen waste. HP waste was obtained by mixing LP waste with source segregated kitchen waste to achieve a 50 % wet wt. The composition and physical-chemical characterization of the two waste samples are reported in Table 1.

Table 1. Composition and physical-chemical characterization of the two different kinds of tested waste.

		LP	HP
Categories	Kitchen residues (%)	9	50
	Green and wooden materials (%)	3	2
	Paper and paperboard (%)	20	11
	Textiles (%)	2	1
	Plastics (%)	18	10
	Metals (%)	2	1
	Glass and inert (%)	9	5
	Composites (%)	10	5
	Under-sieve (20 mm) (%)	27	15
Characterization	Waste mass (kg)	27.0	27.0
	TS (%)	56.9	39.5
	VS (%TS)	72.7	84.4
	TOC (gC/gTS)	34.5	40.3
	RI_4 (mgO_2/gTS)	38.4	93.3

Equipment

The experiment was carried out in six cylindrical Plexiglass lysimeters (1 m height, inner diameter of 40 cm). Each column was equipped at the bottom with a slotted pipe (8 cm diameter), open to air. A layer of 20 cm gravel (size 16-32 mm) was placed at the bottom of lysimeters to allow leachate drainage and facilitate air circulation. The columns were filled with 27 kg waste, reaching an approximate compaction of 0.5 kg/L. A 5 cm layer of the same sized gravel was placed on top of the waste to ensure a uniform water irrigation.

Gas sampling valves were fitted laterally, while leachate was collected at the bottom of each column. Columns were thermally insulated by a coating system made of polyethylene . Each column was equipped with Thermo Systems TS100 temperature probes for temperature control.
Water irrigation was provided using a perforated plate placed at the top of each column (Figure 1).

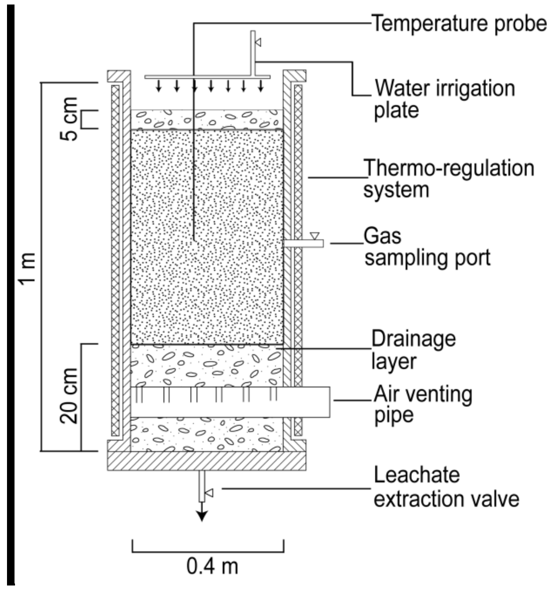


Figure 1. Construction scheme of individual reactors.

Methodology

Lysimeters were operated under different water input conditions to reproduce expected precipitation under wet climate conditions (W columns), absence of precipitation under dry climate conditions (D columns) and controlled water input for appropriate moisture content (C columns). In line with the type of process reproduced, water irrigation was defined based on previous experiments (Lavagnolo et al., 2018). In particular, water irrigation in W columns (3L/d) was intended to reproduce the flushing effect of 1400 mm precipitation (as an annual average) achieving final liquid to solids ratio (L/S) of 20.7 and 14.4 in W-HP and W-LP, respectively. No water input was applied to D columns, reproducing dry climate conditions. In C columns water input (0.25 L/d) was intended to reproduce an appropriate water input to optimise biodegradation processes, achieving a final L/S of 2.2 and 1.6 (L-water in/kg-TS) in C-HP and C-LP columns, respectively, as suggested by Lavagnolo et al. (2018).
Each pair of bioreactors operated under different management conditions was filled with two different types of waste: “HP” waste and “LP” waste, in order to investigate the influence of waste quality on reactor performance.

Environmental temperatures were maintained between 18 and 30°C to reproduce the day and night cycle.

During the experimental test, solid, liquid, and gas samples were analysed in line with International Standard Methods. Biogas concentrations of CO_2, CH_4 and O_2 were tested using a portable analyser (Eco-Control LFG20).

At the beginning and at the end of the experimental test, waste was sampled from each reactor to assess the following parameters: Respirometric Index (RI), Total Carbon (TC), Total Organic Carbon (TOC), Total Kjeldahl Nitrogen (TKN), total solids (TS), and volatile solids (VS). TC and TOC on solid samples were determined using a TOC–VCSN Shimadzu Analyzer. RI (RI4 mg O_2/g TS) was measured by means of a respirometer (Sapromat apparatus, H+P Labortechnik, Germany). Leachate was regularly tested for pH, alkalinity, TS, VS, volatile fatty acids (VFA), chemical oxygen demand

(COD), total carbon and total organic carbon (TC and TOC), five-day biochemical oxygen demand (BOD_5), nitrogen compounds (TKN, ammonia ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), nitrite ($N\text{-}NO_2^-$)) and chloride (Cl^-).

RESULTS AND DISCUSSION

Landfill gas (LFG) composition

The concentration of the most significant LFG components (CH_4, CO_2, O_2) are represented in the stacked area chart in Figure 2, jointly with the stability trend line and water availability (*wa*). Water availability can be defined as follows:

$$wa = ew + L/S = u \cdot \frac{kg\ waste}{kg\ TS} + L/S$$

Where:
wa: water availability ($kgH_2O/kg\ TS$)
ew: Endogenous water ($kgH_2O/kg\ TS$) = $u \cdot \frac{kg\ waste}{kg\ TS}$
L/S: liquid (input water) over solid ratio ($kgH_2O/kg\ TS$) in a given time.
u: moisture in waste to be landfilled ($kgH_2O/kgwaste$).
At the beginning of the experiment, CO_2 concentration in all lysimeters was around 20-30% with very low oxygen concentration (below 5%). This was the result of the aerobic conversion of the most readily-biodegradable fractions present in waste. Methane presence was observed from the 25th day; subsequently both methane and CO_2 decreased and O_2 consequently increased, with a pattern influenced by waste type and water availability. Faster decrease in CO_2 concentrations was observed in columns filled with the lower putrescible fraction content (LP). When comparing columns filled with the same waste type, a more rapid CO_2 decrease was observed in D columns (low wa conditions). In D-HP column, CO_2 decrease was indicative of a fast waste stabilisation, yielding the lowest RI_4 value among “HP” columns (Figure 2). Conversely, the sudden CO_2 decrease observed in D-LP column was due to a lack of moisture which halted the biodegradation process, as confirmed by the highest RI_4 final value among “LP” columns (Figure 2). Waste stability improved in “LP” columns on increasing water availability. On the contrary, in “HP” columns a *wa* higher than 1.5 (columns W-HP, C-HP) resulted in a lower waste stabilisation (higher RI_4 values), leading to anaerobic conditions and to highest methane concentrations (up to 10%). In both columns under wet conditions (W) the decrease of CO_2 was more evident than under controlled watering conditions (C) due to the considerably higher water availability, resulting in a higher flushing effect of degradable carbon (more in leachate, less in the gas).

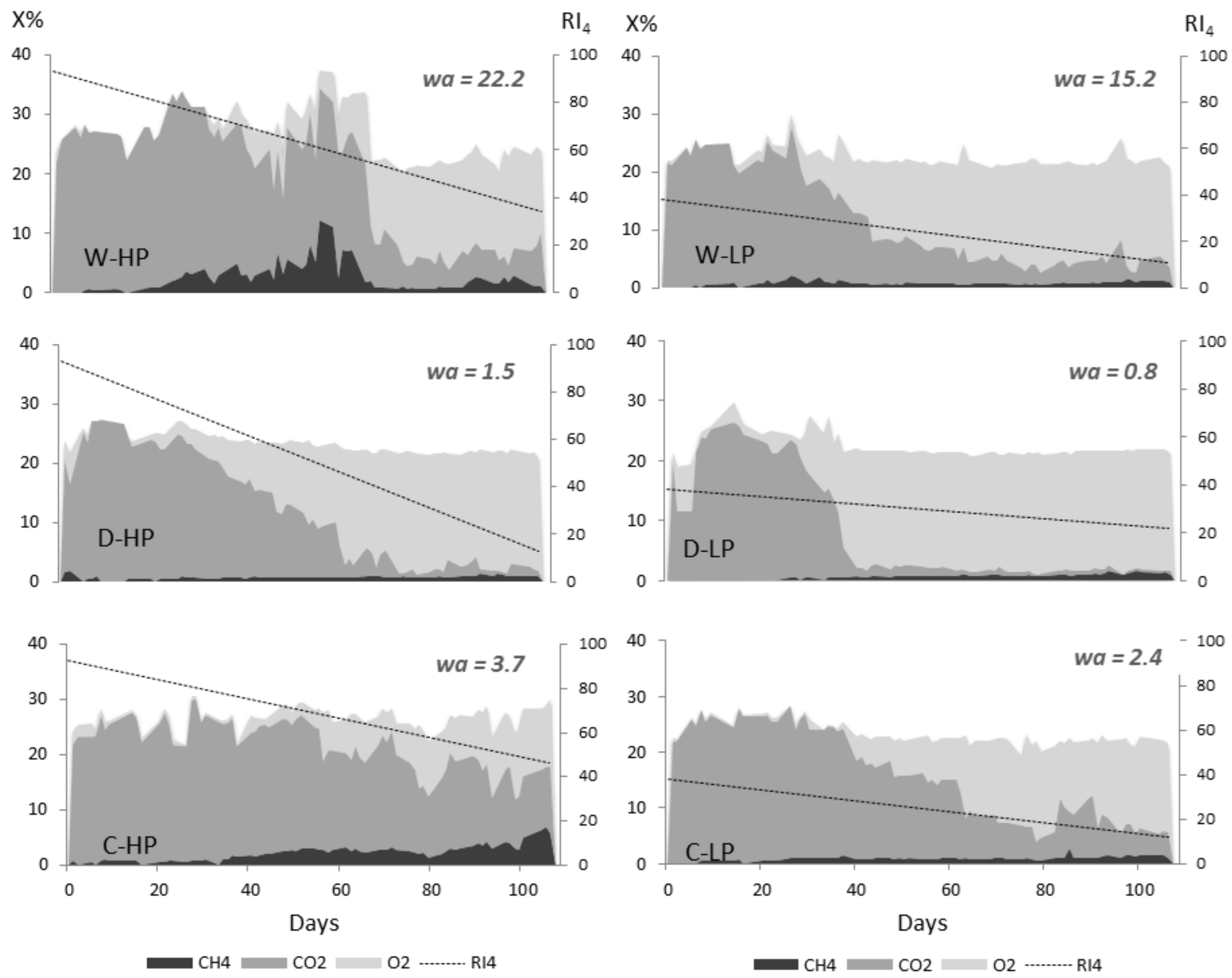


Figure 2. Landfill gas (LFG) composition (Stacked area chart) and waste stabilisation in the research lysimeters, along the testing time. (X%: volumetric gas fractions, % v/v; RI_4: 4 days Respirometric Index, $mgO_2/kgTS$; wa: water availability, $kgH_2O/kgTS$). Nitrogen gas is not represented.
W=Wet conditions, D=Dry conditions, C=Controlled watering; HP=Waste with high putrescible content; LP=Waste with low putrescible content.

Leachate quality and quantity

During the experiment, leachate production ranged between 83% (in wet column with "HP") and 15% (in dry column with HP) of wa (Figure 3). No leachate production occurred in D-LP column.
Figure 3 uses a stacked area chart to illustrate the $N\text{-}NH_4^+$, N Org, NO_2^- and NO_3^- concentrations in leachates during the experiment, jointly with water availability (*wa*) vs. time line.
Higher TKN concentrations (N Org + $N\text{-}NH_4^+$) occurred in columns filled with "HP" waste compared to those filled with "LP" waste. On comparing columns filled with the same waste type, the lowest concentrations of N Org and $N\text{-}NH_4^+$, and lack of NO_2^- and NO_3^- were observed in W columns due to the dilution effect and interference with proper waste aerobisation induced by the flushing effect. Conversely, effective nitrification occurred in C columns and in D-HP. In particular, mainly oxidised nitrogen compounds were present in leachate of D-HP column. Final $N\text{-}NH4^+$ concentrations were 50, 25, 38, and 8 mgN-NH4/L in C-HP, C-LP, W-HP, and W-LP, respectively.
Figure 4 uses a logarithmic overlapped area chart to illustrate TOC and VFA concentrations in leachate vs. time throughout the experiment, jointly with pH trend line. The effect of a more intense waste aerobisation in columns C is clearly reflected in pH values constantly above pH 7. On the contrary, the flushing effect in wet columns (W) caused predominantly acidic conditions (pH below 7) with high VFA concentration and insufficient buffering alkalinity. Consistently with nitrogen compounds, lowest TOC and VFA concentrations and faster VFA reduction occurred:

- in low putrescible columns (LP) when comparing waste types;

– in D-HP and wet columns (W) when comparing water availability conditions. In latter the main driving phenomenon was the flushing effect due to high water availability.

C-HP, C-LP, W-HP, and W-LP columns achieved a final TOC concentration of 865, 698, 85, and 57 mg_C/L, respectively.

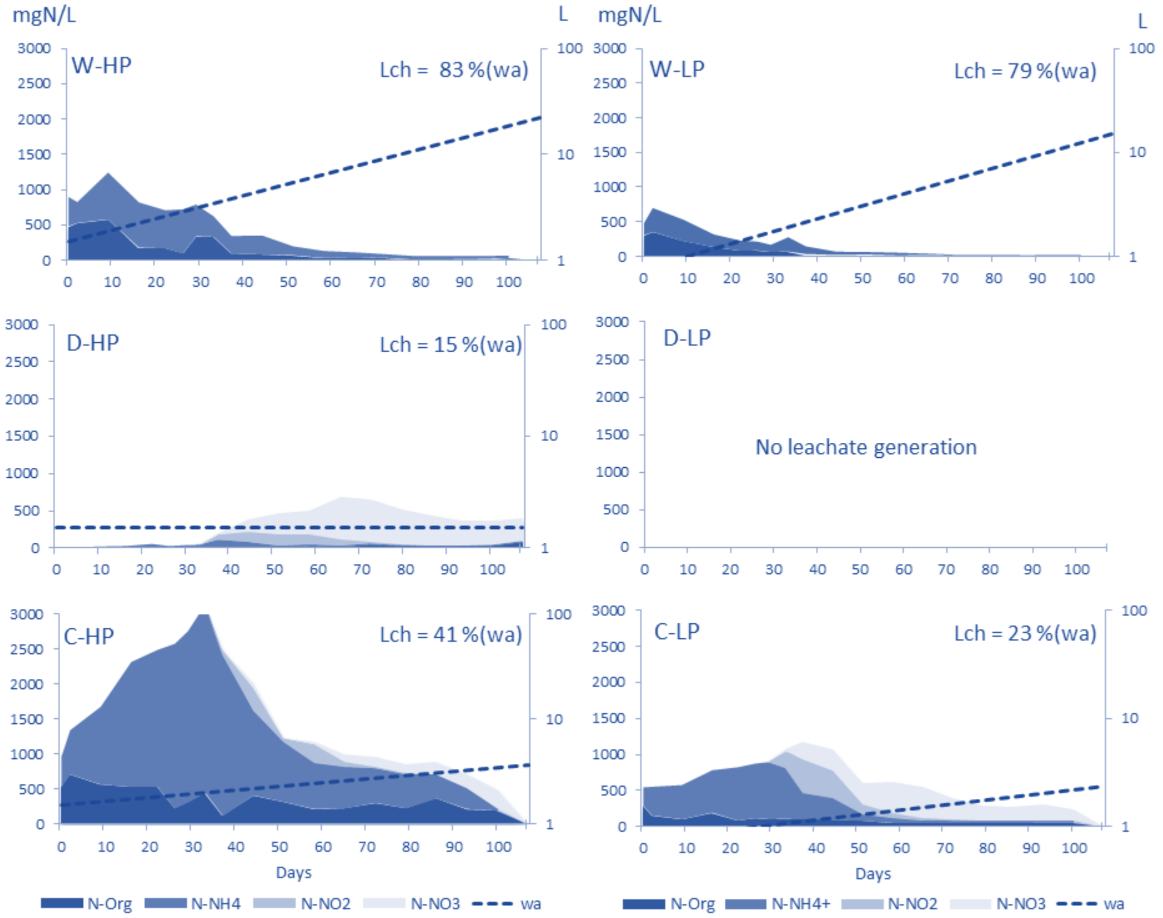


Figure 3. N-NH_4^+, N organic, NO2-, NO3- concentrations in leachate (Stacked area chart) vs. testing time measured for each individual lysimeter. Wa = water availability (endogenous water + water input), $kgH_2O/kgTS$; Lch= percentage of wa released as leachate. W=Wet conditions, D=Dry conditions, C=Controlled watering; HP=Waste with high putrescible content; LP=Waste with low putrescible content.

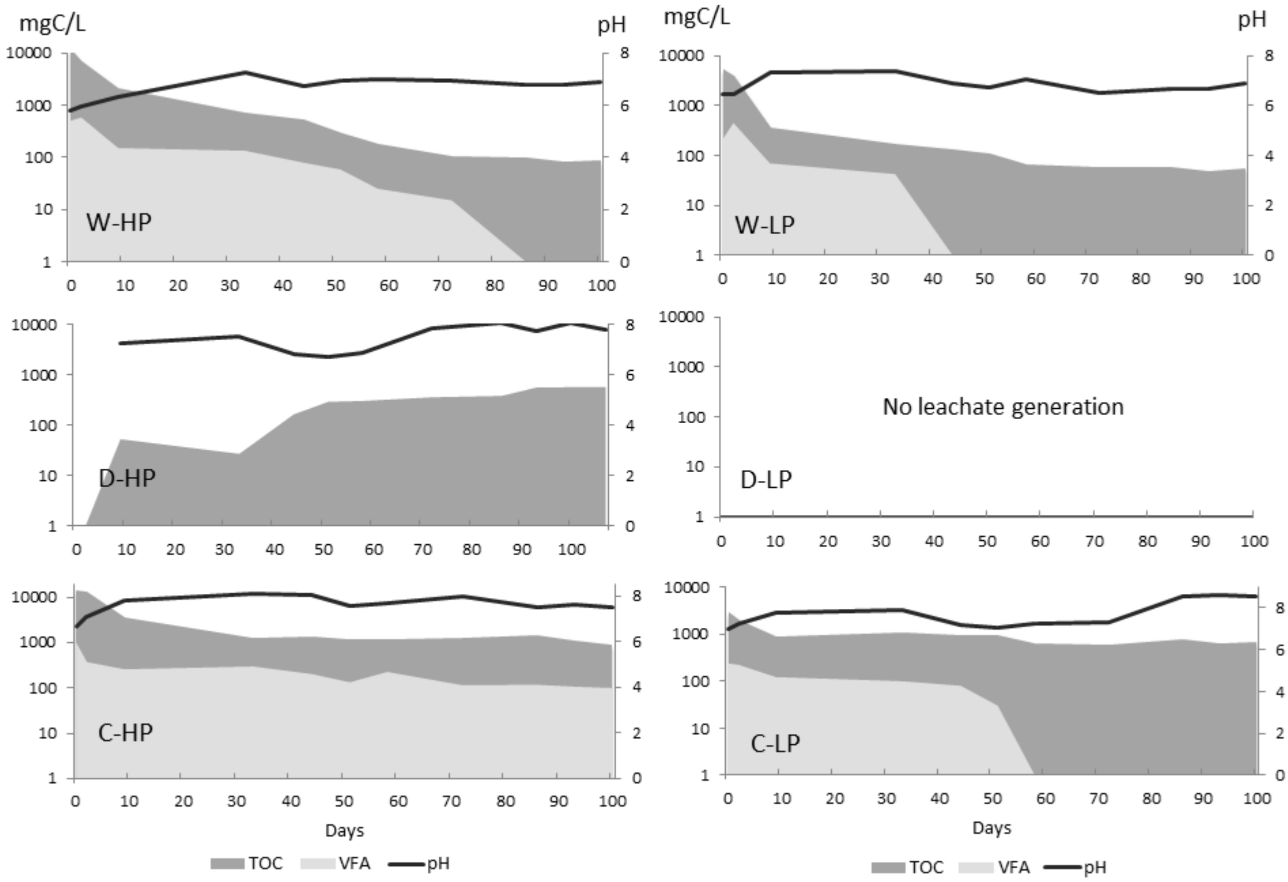


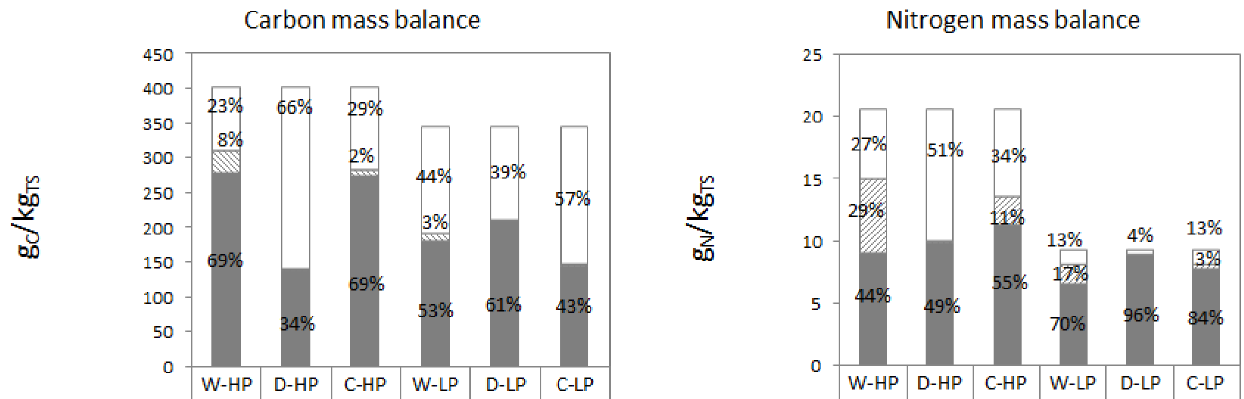
Figure 4. pH, VFA and TOC concentrations in leachate (overlapped area chart) vs. testing time, for the different lysimeters. W=Wet conditions, D=Dry conditions, C=Controlled watering; HP=Waste with high putrescible content; LP=Waste with low putrescible content.

Waste characterisation and mass balance

Input waste and final solid samples from each column were characterised to better evaluate stabilisation performance and the fate of contaminants in the different reactors operated under varying water availability and filled with different types of wastes. Considering the reactors filled with "HP" waste, the highest stabilisation performance was observed in the D-HP column, which achieved a final RI_4 of 12.87 mgO_2/g_{TS} (Figure 2). Water availability (represented solely by endogenous water in the waste) was sufficient to promote optimum moisture conditions for biodegradation. Conversely, the wa achieved through controlled water input in C-HP column was excessive. A different behaviour was observed in the columns filled with "LP" waste, in which final RI_4 values demonstrated the limited stabilisation performance of the D-LP column due to lack of moisture. Improved results were achieved under controlled water inputs compared to the D-LP column through a wa=2.4 $kgH_20/kgTS$.

Mass balance for carbon and nitrogen was evaluated for each individual column (Figure 5). The initial content of carbon and nitrogen in the solid waste (N solid, C solid) and leachate (N leachate, C leachate) were measured. Carbon and nitrogen gasification (C gas, N gas) were taken as the difference between the total content of contaminants in the input and output.

Flushing effects in both W columns were confirmed by the high release of carbon and nitrogen into leachate, achieving transferral of up to 8% carbon and 29% nitrogen to leachate in the W-HP column, and removal of 3% carbon and 17% nitrogen through leaching in the W-LP column. The positive effect of controlled water input observed in the C-LP column, was confirmed by the highest nitrogen and carbon gasification. Approximately 57% carbon and 13% nitrogen was transferred into the gas phase in the C-LP column with negligible loads in the leachate, while only 39% carbon and 4% nitrogen was released as gas in the D-LP column.



	W-HP	D-HP	C-HP	W-LP	D-LP	C-LP
C gas (g/kgTS)	91.02	263.95	118.52	153.40	133.91	197.59
C leachate (g/kgTS)	33.09	0.09	8.24	10.39	0.00	0.93
C solid (g/kgTS)	278.89	138.96	276.24	181.21	211.09	146.47

	W-HP	D-HP	C-HP	W-LP	D-LP	C-LP
N gas (g/kgTS)	5.52	10.47	6.90	1.17	0.42	1.21
N leachate (g/kgTS)	5.95	0.09	2.27	1.64	0.00	0.31
N solid (g/kgTS)	9.13	10.05	11.44	6.61	9.01	7.90

Figure 5. Total mass and percentage distribution of Carbon and Nitrogen in the different solid, liquid and gas phases, for each individual lysimeter. W=Wet conditions, D=Dry conditions, C=Controlled watering; HP=Waste with high putrescible content; LP=Waste with low putrescible content.

CONCLUSIONS

The results may provide important applicative suggestions for use in optimizing the performance of semi-aerobic landfilling under different conditions of water availability and putrescible fraction content. Based on the results, extreme climate situations characterized by both heavy rainfalls and complete absence of water could have negative impact on the stabilisation performance of the landfill, according to the waste characteristics. Under wet climate conditions high leachate volumes are produced, moreover in case of high putrescible content waste anaerobic conditions are established due to the high water input and moisture content in landfilled waste. Under dry climate conditions, the proper functioning of the semi aerobic landfill was critical in case of low putrescible content waste. The semi aerobic landfill is shifted to a “dry tomb landfill”, limiting the biodegradation activity and keeping carbon contaminants in the solid phase. The best performance was achieved at water availability ranging between 1.5-2.4 kgH_2O/kgTS. These values were achieved under the following conditions:

- Waste with high putrescible content and no addition of external water (D-HP) as endogenous water in the waste (moisture) was sufficient to promote biological stabilisation of waste
- Waste with low putrescible content and controlled watering (C-LP).

In both cases, the presence of CH_4 in landfill gas (LFG) and the quality of leachate demonstrated that when an appropriate water supply is ensured, semi-aerobic landfilling is a suitable technology for use in controlling long-term emissions and achieving the targets set for sustainable landfilling. In order to overcome the issues related to extreme climate conditions a controlled water availability can enhance the performance of semi aerobic landfill, by an engineering top cover to reduce water infiltration under wet climate conditions and by leachate or fresh water recirculation under dry climate to control biodegradation according to the variation of putrescible fraction content. Under tropical climate, with alternating dry and wet climate conditions, storage of rain water/leachate for recirculation during the dry season may be adopted.

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Status of Municipal Faecal Sludge Management Planning in the New Constitutional Arrangement of Nepal

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Abstract

This paper discuss on existing FSM planning status in new municipal re-structure declared on January 2017 that brought change in both land area and population. The study is limited to six municipalities of Kavre district in Province 3 that is mainly hilly region. Key methodologies for the research are Focus Group Discussion (FGD), semi-structured interview, site observation and literature review. The findings across the FSM service chain are presented. 99% of the users are washers using pour-flush and commode toilet. The containment system is mainly 'holding tank' which is perceived as septic tank. For emptying there is lack of motivation in workers and it's done without considering health & safety. The transfer of sludge is difficult due to hilly geographical terrain. There is no well-established FS treatment system except one at Dhulikhel covering 300 households. In end use, the officials are unaware of the standard of final disposal. FSM is less in priority of municipality planning among other infrastructure development sectors. The level of awareness is present in collection and transport of FS but not the final disposal standards. Hence, development of FSM implementation standard is required to assure quality of overall performance in service chain.

Keywords: Faecal Sludge Management, New Constitution, Municipalities in Nepal, Sanitation, FSM Service Chain

1. Introduction

Safely Managed sanitation is the ultimate goal of all faecal sludge management (FSM) initiatives. The Sustainable Development Goals (SDG) defines: "Safely Managed Sanitation is the use of improved facilities which are not shared with other households and where excreta are safely disposed in situ or transported and treated off-site" (SNV, 2018).

Poor FSM has huge health and environmental risks (Government of Nepal, 2018), while Nepal is in the track of achieving safely managed sanitation. The National Demographic Health Survey report 2016 presents that only 4.4 percent of household have improved toilet facility connected to sewer network. Baseline sanitation data for Nepal given by JMP Report 2017 to achieve the SDG is 30% doing open defecation and 46% have access to improved sanitation until 2015 (SNV 2018, p.2). While the Ministry of Health report indicates that three out of five households i.e. 62% HHs in Nepal have improved sanitation facilities (Ministry of Health, New Era and ICF International, 2017). The coverage percentage seems to be improved from the 46% to 62% between 2015 and 2017.

Government of Nepal has also incorporated the safely managed sanitation agenda in its 'Sustainable Development Goal Status and Roadmap 2030'. The SDG indicators in this document are based on sectoral data from the 14th plan of the Government and publication by development agencies (Government of Nepal – NPC, 2017). Earlier in the study made for Bagmati river development plan in 2011 has suggested that building FS treatment system under a responsible authority is one of the most important part of the FSM service chain (HPIDBC, 2011). The sanitation status of Nepal 2018 indicates Kavre district in province 3 has 93% of toilet coverage (Government of Nepal – MoWS, 2018).

On April 2017, The FSM Regulatory Framework of Nepal was published by the Ministry of Water Supply and Sanitation. Sections 4.3, 4.4 and 4.5 of the framework has provided guidelines on FSM services chain that incorporates User interface, collection, transport and final disposal of the faecal sludge (MoWSS, 2017).

The local government election was held on May 14, 2017 (Europe Solidaire, Online) that allowed the people to have elected local representative after 20 years. With new federal administrative structure the country is divided into seven provinces with 719 local governance units (Kathmandu Post, Online). The study covers situational analysis at Kavre district in Province 3 that has six municipalities. The municipalities are; Dhulikhel, Panauti, Banepa, Paanchkal, Namobuddha and Mandan Deupur. The new constitution and Local Government Operation Act has allowed the municipalities to manage the overall municipal waste including faecal sludge (FS) on their own (Government of Nepal, 2015).

2. Objectives

This paper discuss on the situation of Faecal Sludge Management (FSM) planning in Nepalese municipalities after the new Constitutional arrangement from September 20, 2015 onward. It aims is to analyze the challenges and possible interventions in FSM with the new elected leadership in local governance authority. It also explore the level of awareness among the leaders and officials at the municipality.

3. Methodology

The presented research is qualitative with the standard methods such as; Focus Group Discussion (FGD), semi-structured interview, site observation and literature review. There were 50 participants at different level of interaction with the target participants in the research from the six selected municipalities.

Focus Group Discussion:
FGDs were held at two different levels, one with the decision makers (the Mayors and Deputy Mayors) and other with the municipality engineers and planning officers. An interaction group discussion was held with Mayors, Deputy Mayors and Executive officials from six different municipalities on February 2018. Then, FGD with engineers and planning officers was conducted along with training sessions for the six municipalities between April and October 2018. At Banepa municipality, separate FGD was held with the members of Executive Board including ward chairpersons from different wards. The participants were asked questions related with FSM planning and also provided a worksheet to writer up possible actions.

Semi-structured Interview
Semi-structured interview was conducted with the Mayors, community users and engineers to explore more information.

Site observation and literature review
Site observation was done to cross verify the gathered information. Also relevant literatures were reviewed from the government and international agencies.

Estimation of change in volume of faecal sludge
For the estimation of possible increase in faecal sludge (FS) from the new federal state municipal re-structuring, population is multiplied by FS generation volume per person per day. i.e.

$$\mathbf{FS = P \times (F + U + AW)} \qquad \textbf{(i)}$$

Where,

FS	: Total faecal sludge generated	[Unit – m^3/ day]
P	: Population	
F	: Faeces generated by a person	[Unit – kg/person/ day]
U	: Urine volume generate by a person	[Unit – liter/ person /day]
AW	: Anal cleansing water consumed	[Unit – liter/ person /day]

Averages values are taken for the fixed parameters in equation (i) as;
F = 0.128 kg/capita/day, (Furlong, 2018)
U = 1.2 liter/capita/day (Furlong, 2018) and
AW = 5 liter/capita/day (assumed).
Also it is assumed that 1kg of F in equation 1 is equal to 1 liter volume.

4. Results and Discussion

The study results include information on change in demographics, current status in FSM service chain, key challenges and possible interventions.

4.1 Changes in Demography

Out of various demographic indicators, design population and land area are significant for the proper FSM planning. There has been change in both the area and population of the municipalities after the new federal structure is implemented from the new constitution. Information on these indicators was received through personal communication with officials at respective municipalities and also from (Wikipedia, 2019).

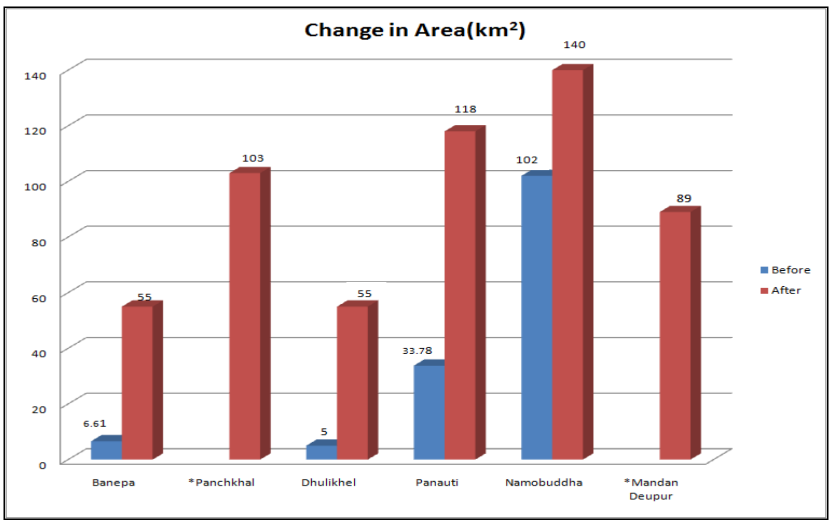

Figure 1: Change in area with the municipal re-structure from New Constitution

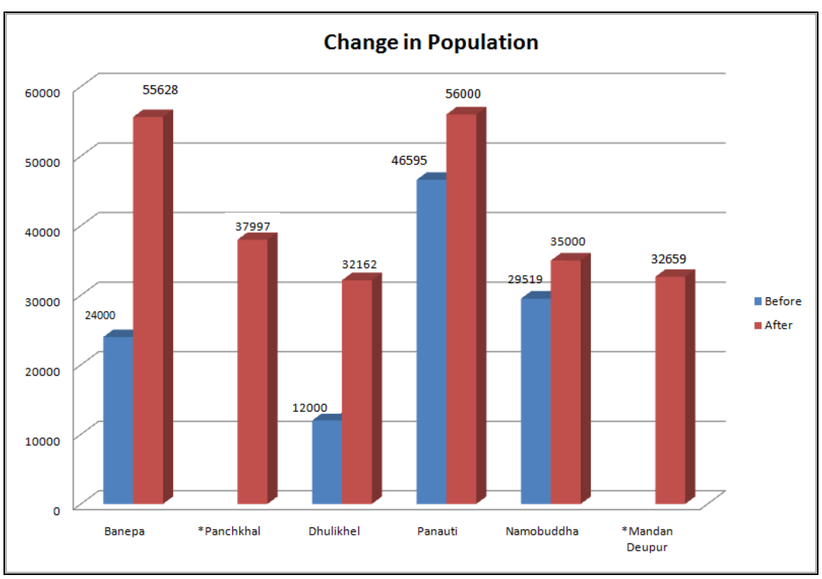

Figure 2: Change in population with the municipal re-structure from New Constitution

*For Paanchkhal and Mandan Deupur municipalities, past data on area and population is not available since they were in the category of Village Development Council (VDC) until 2017. However for Namobuddha municipality, the area difference from converting VDC to municipality is noted as the information was provided.

4.2 Situation across the FSM service chain

At present, there is absence of well-established faecal sludge management system in the municipalities at Kavre district of Province 3. For each section across the FSM service chain, the situation is presented ahead.

User Interface
Most of the toilets used are pour-flush and the users are washers. 99% of users in hilly region use pour flush and only 1% use dry pits (SNV 2018). Squatting pan is mostly used however commode system is also getting popular. But with limited water supply expensive household reservoir installment, the commode system is lesser in use. The toilet coverage is above 90% and the municipalities are in the process of becoming complete Open Defecation Free (ODF) Zone.

Containment
There is complete misconception about Septic tank. Users and construction workers both perceive that the 'holding' tank as septic tank. Even they are convinced that the faecal sludge decomposition in soil inside holding tank will prolong the life of their septic tank, which is just a well covered soak pit. Meanwhile the seepage is occurring to that can contaminate both groundwater and soil. In the village there is simply soak-pit constructed to store the faecal sludge. The Purna Sarsafai Marga-Nirdeshan 2073 (a guideline document) has mentioned septic tank as one of the indicators from which the house or area can be declared as zone with total sanitation (Government of Nepal – MoWS, 2017).

Emptying
Emptying is being done by both manually and fewer sludge truck usage. Due to expensive price and busy schedule of the service providers, users sometime do it manually. But the health and safety consideration to handle the faecal sludge is lacking by large. Lack of motivated worker is another problem related to waste management in every municipality.

Transport
The complex geographical structure is the main barrier for the collection and transfer of the waste for most of the municipality in this region. Some parts of hilly region are not accessible to the road and those with access are not completely blacktopped. During rainy season it is almost impossible to transfer the waste material due to the bad road condition. At some parts in the plain land areas like Banepa municipality, it is easier to transport the sludge.

Treatment
The municipalities have some provision of FSM with decentralized waste-water treatment system connected with sewer. There are eight waste-water treatment units at three out of six municipalities but only one of them located at Shreekhandapur, Dhulikhel municipality is functioning. The existing treatment system is unable to intake all the faecal sludge produced. Although there is new constitutional provision and FSM Regulatory framework, an implementation standard is not available.

Disposal
There has been lack of guidelines and strict legal framework to control the unsafe disposal. Awareness has been raised at certain level, but the precise information is lacking. The containments when emptied are normally used in the farmland directly after open drying.

4.3 Key Challenges
There are few major challenges for the municipality officials towards having proper FSM system. One of them is the hilly geological terrain of Kavre district and narrow off-roads in these hilly areas. Due to scattered settlement across the hilly area, it is also difficult to mobilize enumerators to collect data for planning. Another major challenge for the faecal sludge management is the selection of the waste disposal site and the management of treatment plant. Municipality also lacks proper manpower, mechanical equipment and limited transfer vehicle for the collection of the waste generated.

4.4 Possible Interventions

From the study, some interventions are listed that can be carried out by municipality itself immediately. First the municipalities can develop and implement their own FSM policy at municipal level with the new constitutional arrangement. The municipalities can also find and allocate land for treatment units which are otherwise a challenging aspect of implementing FSTP (Singh, DD Bhatta, 2017). Existing vehicles can be used for the transport of FS from different households. Public awareness programs can be conducted at different locations of the municipality. However, training on FSM system is to be provided to municipal staffs.

While there are some interventions that can enhance present FSM system with minimum external input. For instance, rehabilitation of existing non-functional waste-water treatment plants can be done. The houses in rural part except town area of the municipality can be supported with biogas plant attached to toilet where on-site sludge treatment and energy recovery is possible. Also providing technical skills to household owners and masons to maintain existing biogas can improve and sustain the on-site management of FS in rural parts.

4.5 Discussion

With the new administrative boundary of the municipalities and changed number of population, there is change in the volume of FS generated. With simple calculation method presented in Section 3 above, the change in volume of FS generation is estimated as follows;

Table 1: Estimated change in FS generation volume with the new federal municipal re-structure

Municipality Name	FS Genration Volume (Liter/ day)		Changed volume	Changed %
	Before municipal restructure	After municipal restructure in 2017		
Banepa	151,872	352,014	200,142	132
Panchkhal*		240,445		
Dhulikhel	75,936	203,521	127,585	168
Panauti	294,853	354,368	59,515	20
Namobuddha	186,796	221,480	34,684	19
Mandan Deupur*		206,666		

The estimated FS generation data in table 1 indicates that the municipalities should be aware of the required increase in land, financial and other resources required to manage the escalated volume of FS generated. In case of Banepa and Dhulikhel municipalities, the volume generated with new municipal re-structure is more than double. Since, these two municipalities are trade and administration center of the district and already had new settlements in surrounding areas which were later assimilated into the re-municipalized boundary resulting the doubled population and FS volume generation.
*In case of Panchkhal and Mandan Deupur municipalities, they received the municipality status in 2017 and the exact previous information on population and area is not available.

From the overall analysis, it is learnt that FSM issue has not been in the priority of municipal planning as public are also more interested towards other infrastructure development such as road network and water supply. Municipalities and VDCs are not fully prepared to make their own policies to implement the FSM. For the detailed plan preparation, data collection is also challenging due to scattered houses in hilly terrain. With increased awareness, the municipalities have planned to make request with National Government towards financial and technical support in FSM.

5. Conclusion

With the current status of Open Defecation Free (ODF) Zone declaration, the municipalities have opportunity to upgrade from basic sanitation - SDG 1.4.1 to reach the ‘Safely Managed’ sanitation service ladder - SDG 6.2.1 (JMP, 2017). Full authority to the local government on the planning and implementation allows the officials to prepare their own guideline and service delivery. However, development of FSM implementation standard is required to assure quality of the overall performance in service chain.

There is increased level of awareness among the elected officials towards FSM. As Mr. Ashok Byanju, the Mayor of Dhulikhel municipality was quoted as saying, “Sarsafai ra dishajanya fohormaila byawasthapan ahile nagarpalikaley prathamikta ma rakhnu pardacha; na ki kewal chunaab lai sochera bato, khanepani ra bijuli subidha pradaan garna matra prayaas garney ho”. (In English: “Sanitation and faecal sludge management should be current priority of municipality, not only focusing on election focused populist initiative on road, water supply and electricity.”). However, the municipality officers are concerned mainly about lack of manpower, mechanical equipment and transfer vehicle, they are less aware about the sludge treatment options and standards of final disposal.

In terms of technical improvement, there is need to train construction workers and engineers in septic tank construction which is completely lacking with perception of ‘holding tank’ as septic tank. Next the operation and maintenance skill is to be raised along with knowledge on updated products in market. Also health and safety procedure is to be trained for sludge handling and disposal.

For financial ease, the municipalities stress on participation of private sector with business on faecal sludge transport and treatment. Public private partnership could be the best model to efficiently operate entire FSM system (HPCIDBC, 2011). To reduce additional investment and land requirements for new FSTPs, existing wastewater treatment plants should be revived. To achieve successful FSM implementation, good stakeholder participation and collaboration from initial stages of planning and design is desired (S. Singh, D. D. Bhatta, 2017). Also the FSM program is to be implemented with city-wide perspective (Andres Heuso, 2017) considering entire sanitation value chain.

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Comparative Study of the Methods Used for Faecal Sludge (FS) treatment in an Emergency Human Settlement – Rohingya Camps in Ukhia, Cox's Bazar

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ABSTRACT

Sustainable sanitation is a global need. To make sanitation sustainable, faecal sludge management (FSM) is a must. But FSM is a great challenge which becomes more acute if it is asked to manage within limited spaces with a high population density. Ukhia is a high population density area because 72% of Rohingya population have taken shelters in 24 camps of Ukhia. The aim of this study is to identify and compare the methods used for faecal sludge treatment in Rohingya camps in Ukhia of Cox's Bazar district. 5 FSM sites in Ukhia were studied based on treatment methodology. These sites are Brac FSM, Practical Action FSMU, UKAID FSTS, Brac CWL and WaterAid FSTP. Treatment process, different units of treatment and their specification, management of sludge and wastewater were identified in this study. Treatment process used for Faecal sludge, wastewater treatment efficiency and specification of different treatment units were compared in this study. WaterAid FSTP and Brac CWL have high FS treatment efficiency and treated FS has an end use value. Practical Action FSMU and Brac FSM have high wastewater treatment efficiency compared with other treatment facilities.

INTRODUCTION

To facilitate sustainable sanitation system with high population density is really a great challenge in limited spaces. The rapid increase of fixed-place defecation has created a new challenge for faecal sludge management in Bangladesh (Opel et al., 2012). Due to lack of availability of spaces, the majority of people in low and middle income countries especially living in urban areas rely on on-site sanitation which generates a mix of solid and liquid wastes generally termed 'faecal sludge' (Jahan and Al-Muyeed, 2015). Sanitation is still one of the biggest challenges for Bangladesh although the open defecation rates have been gradually reduced to 3 per cent (Jahan and Al-Muyeed, 2015; Opel et al., 2012; WHO and UNICEF, 2014). In fact, construction of thousands of on-site sanitation technologies (e.g. Pit latrines, septic tanks) without thinking of ensuring proper faecal sludge management (FSM) eventually emerge as a second generation sanitation problem for Bangladesh (Jahan and Al-Muyeed, 2015; Kengne et al., 2014). In Bangladesh, a little percent faecal sludge is managed and treated properly (Jahan and Al-Muyeed, 2015). Every day, about 80 metric tomes of sludge is generated among 24 metric tones in urban areas of Bangladesh (Jahan and Al-Muyeed, 2015). Only 4 per cent of urban sludge is being treated at Pagla treatment plant in the country (Jahan and Al-Muyeed, 2015).

Recently, Bangladesh has received an influx of 7,06,324 Rohingya population to Cox's Bazar district who have been driven to seek refugee due to the outbreak of violence on 25 August 2017 in the Rakhine State of Myanmar (IOM, 2018; WHO, 2018).The momentum and scale of arrivals make this the world's fastest growing refugee crisis (Noor et al., 2017). A fluctuating, but persistent, influx of Rohingyas has been experienced from Myanmar since 1992 and it has been estimated 9,21,000 in total population (IOM, 2017; WHO, 2018).A large majority of them were living in 34 Camps at Ukhia and Teknaf Upazilas of Cox's Bazar with hilly and coastal area that covers 5,800 acres of forestland and 380 hectares of agricultural land (Humanitarian Response, 2018; IOM, 2017). So, these areas are highly populated. These high population densities and challenging environmental conditions produce a crisis with especially acute water, sanitation and hygiene (WASH) needs (REACH, 2018). The initial strategy focused on the emergency provision of water, emergency latrines and the distribution of hygiene materials (ISCG, 2018a). Around 45 organizations have been working with WASH program under UNHCR, UNICEF and IOM. They constructed 45,181 numbers of latrines specially pit latrines which filled up and were overflowing and contaminating the water sources (Jahan, 2018). FSM in situations of rapid mass displacement is important to public health and providing for a better environment (Rohwerder, 2017). In spite of being important, FSM is often neglected in WASH programs (Rohwerder, 2017). Considering this issue, some organizations have come forward to facilitate, manage the safe disposal of FS through faecal sludge treatment plant (FSTP). They are different in methods to treat and manage the FS. The main aim of this study is to identify and compare the methods used in the existing FSTP for the treatment of FS in Rohingya Camps.

METHODOS

Methods of a research work are indispensable. A research work can be possible to be more precious with quality and quantitative methods. Because it is significant that outcomes of research work may differ due to the disparity of methods.

Literature Review

Before starting a research work, literature review is must. Because, literature review may help anyone to determine whether the level of existing knowledge leads to a clear-cut prediction that anyone wishes to one or more research questions. It may also help to cite conceptual and theoretical annotations by researchers or experts which can explain some aspects of the research questions.

In this study, existing status of the Rohingya and their living camps, sanitation behavior at those areas, existing FSTP and their ways to management and treatment of FS are mainly tried to cite from literature review. Research that has already done on the different methods of FS treatment all over the world are also studied. Besides, FS management and treatment in any refugee camps in the world are considered in this study. Using google and google maps, study relevant Figures and maps are collected as secondary data.

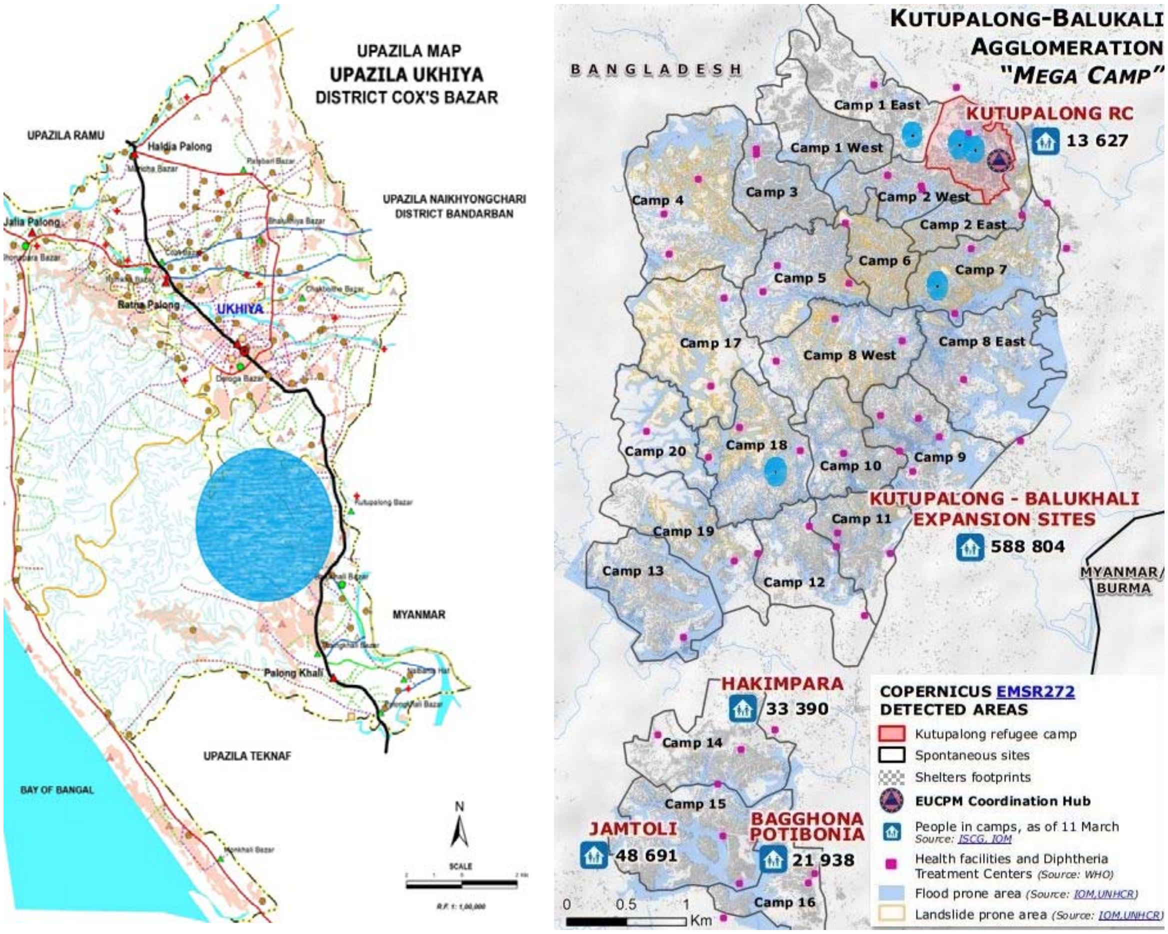
Study Area

The incoming refugees are housed or have sought shelter in Cox’s Bazar and its upazilas (Noor et al., 2017). This movements within Cox’s Bazar remain highly fluid, with increasing concentration in Ukhia (Noor et al., 2017). 72% of the total Rohingya population in Cox’s Bazar is residing in collective sites in Ukhia Upazila (IOM, 2018). So, Ukhia Rohingya Camp is selected as the study area.

Ukhia is an upazilla of Cox’s Bazar district under the division of Chittagong (Imran and Mian, 2014). It is located in between 21°08' and 21°21' north latitudes and in between 92°03' and 92°12' east longitudes (Imran and Mian, 2014). Ukhia upazilla is with the border line of Arakan State of Myanmar on the east (Imran and Mian, 2014). Rohingya refugee camp has been established in the hilly areas of Kutupalong Bazar, Balukhali Bazar, Jamtoli, Hakimpara and Bagghona Potibonia in Ukhia (JRC, 2018). These areas are divided into 24 camps (ISCG, 2018b). Total number of FSM sites is 180 and 146 FSM sites are located in Ukhia Refugee Camp (ISCG, 2018b). In this research, total 5 FSM sites are studied and they are located in 1East, 7, 18 and Kutupalong camp. Figure 1 shows the location of Ukhia Rohingya Refugee Camp and the location of FSM sites.

Identification of FS Treatment System

In this study, 5 FSM sites have been selected based on treatment methodology. The sites are Brac Faecal Sludge Management (Brac FSM), Practical Action Faecal Sludge Management Unit (PA FSMU), UKAID Faecal Sludge Treatment Site (UKAID FSTS), Brac Constructed Wetland (Brac CWL) and WaterAid Faecal Sludge Treatment Plant (WaterAid FSTP). Brac FSM is located in Kutupalong RC camp, PA FSMU is located in camp 7, UKAID FSTS is in camp 18, Brac CWL is in camp 1 East and WaterAid FSTP is in camp Kutupalong RC. Through FSM site visit, field data was collected. FSM site visit was done in the month of September, 2018. How collect FS from storage pit, methods of treatment, function of each components in treatment process, cross section of each component, construction material of treatment technology, final output of FS and wastewater (WW) etc. were collected as field data during the FSM site visit. Discussing with FSTP conductor, collecting documents, inspecting treatment process and taking photos were performed to amass field data.



(a) (b)

Source: (a)Google Maps and (b) ERCC – DG ECHO daily map, 21/03/2018

Figure 1 (a) Location of Ukhia Rohingya Refugee Camp and (b) Location of FSM sites

Comparative Study

After collecting field data, some comparison was made. Since, no laboratory data was collected; comparison was done theoretically based on literature review. From literature review, previous study and experimental data was collected on treatment methods, treatment unit's specification, removal efficiency, wastewater quality etc. Existing FSTPs are compared with these previous study and experimental data. In this study, three comparisons are made - comparison on FS treatment process, comparison on specifications of different units of treatment process and comparison on wastewater treatment process.

RESULTS AND DISCUSSIONS

Existing FSTP and Their Treatment Methods

Total existing FSM sites are 180 whereas 146 FSM sites are existed in Ukhia Rohingya Refugee camp (ISCG, 2018b). Since Rohingya Refugee Camp is very restricted, it is not possible to go and access everywhere. So, inspite of having 146 total FSM sites in Ukhia, study was performed only on 5 FSM sites. Brac FSM, PA FSMU, UKAID FSTS, Brac CWL and WaterAid FSTP are those 5 FSM sites. These sites are different from each other based on their treatment methods. Detailing of those FSM sites is mentioned below.

Brac FSM

Brac FSM site is situated in Kutupalong RC camp. The site covers total 5 numbers of latrines within its 100 m radius. This FSM site comprises with five chambers. First two chambers are receiving as well as chemical mixing chamber. Then third chamber and fourth chambers are unplanted sludge drying bed with shallow filtration unit in the bottom. Final or fifth chamber is water disposal unit. The whole unit is covered with greenhouse plastic poly at the roof and fenced around with bamboo mat. Besides, one secondary chamber is attached with the FSM site through pipeline. At first, FS are collected from storage pits and transported to the secondary chamber through mechanical way. Then wastewater with FS goes to the first two receiving chambers through 10 inch diameter pipeline. In the two receiving chambers, lime is mixed with the sludge. 1 kg lime is mixed with 20 liter of sludge. Due to mixing lime, the pH value of the liquid sludge at receiving tank is 13. After mixing lime, the liquid sludge is remained in the receiving chambers for more than two hours and then transfers it from two receiving tank to the third and fourth chambers-unplanted sludge drying bed. These beds are composed of two layers consisting of stone chips. First layer is ¾" stone chips that are 1 foot thick followed by ½" stone chips of 1 foot thick. In these chambers, sludge is separated from the wastewater through the filter beds. Sludge depth is kept 1 foot. Wastewater is percolates to the first and second layers and sludge is impeded at the top of the beds. Here, sludge is dried for 1 to 2 weeks depending on weather condition. If it is winter then, it takes 2 weeks to dry whether it is 1 week in dry season. So, the loading rate of this site is 1 to 2 weeks. After percolating, water is collected at the drainage pipe which is laid in the middle of the last layer. The percolated water then goes to the fifth chamber or disposal unit. In this unit, *Canna Indica* is planted to removal of carbon, nitrogen, and phosphorus from wastewater. Finally, the water is discharged into the nature. On the other hand, dried sludge is collected from the top of the beds and dumped into the open field without any further treatment. Since, no laboratory analysis has been performed in this study, so treatment efficiency of this FSM cannot be ascertained.

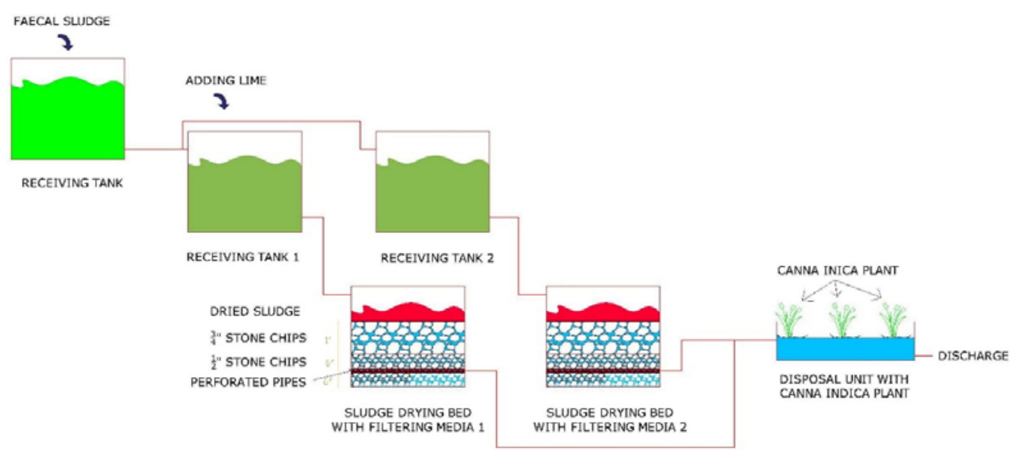


Figure 2 Schematic diagram of Brac FSM process flow

(a) (b)

Figure 3 (a) Secondary chamber is connected with the Brac FSM site through pipeline (b) Different chambers of Brac FSM site

WaterAid Faecal Sludge Treatment Plant (WaterAid FSTP)

WaterAid FSTP is also located in the camp Kutupalong RC. Total 5 numbers of latrines are within 100 m radius of this site. This FSTP is comprised with two chamber and no secondary chamber is existed. First chamber is planted drying bed which is composed of two layers of stone chips. Bottom layer is ½” stone chips locally known as ‘Bujuri’ and the immediate upper layer is ¾” stone chips. Both layers are 1 foot thick and the bottom layer is divided in the middle by perforated pipes which carry the percolated water. *Canna Indica* is planted at the top of the upper layer. Some Vent pipes are also provided at the top of the first layer to escape the gaseous odor produced from biological reaction. The second chamber is up-flow filtration which is composed of one layer of ½” stone chips. This layer is 2 feet thick and vent pipes are also provided here at the top. Both chambers are 6 feet in depth from ground level. This FSTP is roofed with white transparent plastic sheet and surrounded by barbed wire fencing. In the treatment process, collected FS from pits is transported to the FSTP by manual carrying at first. Then liquid FS is poured into the first chamber directly since no secondary tank is here. No Lime is added in this process. In the first chamber solid and wastewater are became separate due to the percolating of water through first and second layer. Then solid portion is impeded at the top. This solid portion is dried for 1 to 2 weeks depending on weather condition. So, the FS loading rate is varied from 1 to 2 weeks. At the same time, *Canna Indica* plants uptake the nutrients from the sludge as well as the wastewater to reduce the excessive amount of nutrients. Percolating water is conveyed to the second chamber through perforated pipes. In the second chamber, Water up-flows through the ½” stone chips layer and stored at the top of the layer. From here water becomes evaporated. No water is discharged into nature. Some vent pipes are kept at this chamber due to escape gas as well as odor if somewhat is remaining. During site visit, the plant conductor had not taken any firm decision about the disposal or further processing of dried sludge. Initially, they have been dumping the dried sludge into the ground.

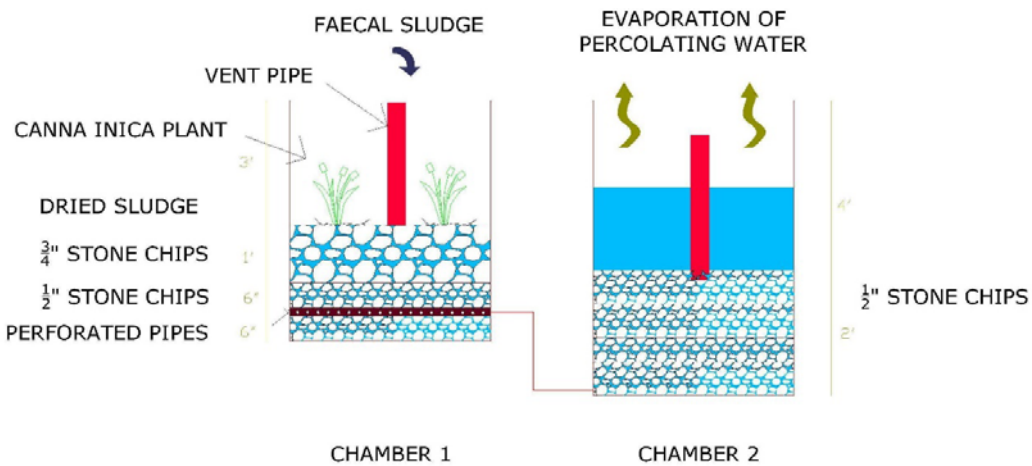


Figure 4 Schematic diagram of WaterAid FSTP process flow

(a) (b)

Figure 5 (a) First chamber (b) Second chamber of WaterAid FSTP

Brac Constructed Wetland (Brac CWL)

Another treatment plant of Brac is constructed wetland. It is located in the camp 1 east. Within the 100 m radius of it, there are 28 number of latrines. Like WaterAid FSTP, this site is also comprised with two chamber however there are some sorts of difference in the treatment methods. Both chambers of Brac CWL are planted drying bed and composed of 2 layers of stone chips. First layer is composed of ¾" stone chips of 1 foot thick followed by ½" stone chips layer of 1 foot thick at the bottom. First chamber is 5 feet deep and second chamber is 6.5 feet deep from the ground level. *Canna Indica* has been planted in both of the chamber. Vent pipes are also provided in the both chambers. Perforated pipes are provided at the bottom of the first chamber but in the second chamber, these are provided in the middle of the bottom layers. The whole CWL is roofed with tin and fenced around with barbed wire fencing. Brac CWL has a secondary chamber. At first FS has been transported to this chamber from the pits. FS are transported by manual ways because the site has no access by road. From second chamber, FS goes to the first chamber. Here, solid and liquid portion are separated by two stone chips layer. Water percolates through those layers and sludge remains at the top. Sludge is dried for 1 to 2 weeks and this duration depends on the weather condition. The loading rate also depends on the drying period of sludge. After drying the sludge, new FS is loaded in the chamber. So, the loading rate also varies from 1 to 2 weeks. Dried sludge is finally dumped into the ground and no further treatment has not yet taken. Percolating water from the first chamber then goes to second chamber. In this chamber, water becomes filtrated passing downward through two layer of stone chips and finally water is discharged into the nature. *Canna Indica* plants in the both chamber uptake excessive amount of nitrogen and phosphorous from the sludge and the wastewater. This helps to reduce the algal growth in the natural stream.

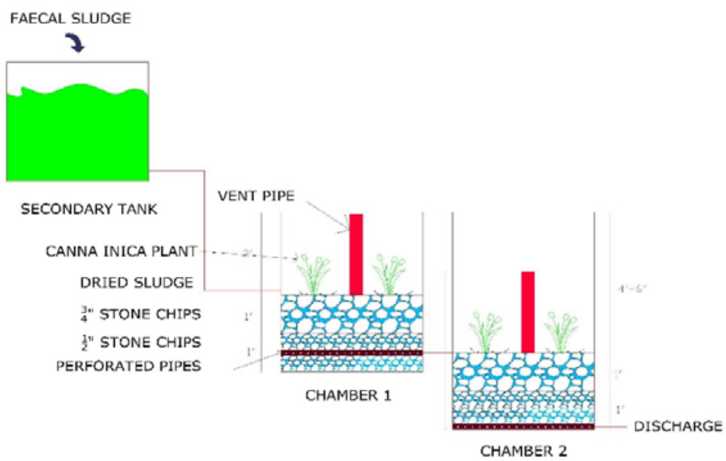


Figure 6 Schematic diagram of Brac CWL process flow

(a) (b)

Figure 7 (a) First chamber (b) Second chamber of Brac CWL

Practical Action Faecal Sludge Treatment Unit (PA FSMU)

PA FSMU is a rain proof over ground unit with up-flow filtration system. It is situated in the camp 7. This unit covers around 20 latrines within its 100 m radius. This unit is consisted of disposal chamber, up-flow filtration chamber, constructed wetlands and burial pits. PA FSMU has 1 disposal chamber, 3 filtration chamber, 1 constructed wetlands and 8 burial pits. Filtration chamber is composed of three layers of sand, char coal and stone chips and a solid storage pit at the bottom. Sand layer is at top followed by char coal and stone chips layer respectively. All layers are 8" in thickness and storage pit is 20". Storage pit is immediate beneath the stone chips layer and separated by GI wire mesh and fishing net. Finishing net is under the GI wire mesh. Filtration chamber is 10' length, 5' feet wide and 5' in height. The purpose of this chamber is to separate wastewater and solid and filter the wastewater. Constructed wetlands is a pond which is 36'x3.5' in bottom, 36'x4.5' in top and 3.5' in height. The bottom and side of the pond is covered with tarpaulin so that no water can infiltrate into the ground. A 2' thick stone chips layer is positioned above the tarpaulin. Its capacity is 6000 liter. *Canna Indica* is planted at the top. The main aim of this unit is to reduce the nutrients of water through consuming by *Canna Indica* plant. Burial pit works as sludge drying bed. It is nothing but a sanitation ring whose top is open and bottom is on the sandy layer so that liquid portion of sludge can be easily infiltrate through the sandy layer into the ground. Since sandy layer is not available everywhere so the dimension of burial pit depends on it. Here, burial pits are in different sizes. However, their capacity is kept minimum 1000 liters and depth depends on the context. Dumping chamber is the earliest chamber of this FSM unit and FS is first dumped into this chamber. FS is carried from the defecation pits by both mechanical and manual process because all latrines cannot be accessible by mechanical way. Dumping chamber is 3' long, 3' wide and 1.5' in height. From the dumping chamber, liquid FS is conveyed to the first filtration chamber. Liquid FS is up-flowed through this chamber. In this chamber, sludge remains at the bottom storage pit and water portion is flowed above and is stored at the top passing through the stone, char coal and sandy layer. Having fishing net and GI wire meshing between storage pit and stone chips layer, maximum solid portion cannot move up with water. Some dilute solid can move up with water however they are caught in the next two chamber. Stored percolating water is further passed through the next two filtration chamber at the same way. Finally filtrated water is flowed through the constructed wetlands. During passing through wetlands, *Canna Indica* plants uptake nutrients from the water and reduce the nitrogen and phosphorous as well as BOD of the water. After that water is stored into the soak pit and its quality is monitored. If it meets the standard, then it is discharged into the nature. On the other hand, when storage pit of filtration chamber is fill up with the sludge, then the sludge is pumped to the burial pit. In the burial pit, sludge becomes dried and liquid portion is infiltrated. Further treatment of dried sludge has not yet done in this unit. However, this FSM unit conductor is thinking about the process of sludge so that it can be used as fertilizer. During the site visit, the burial is fill 1/4th of its depth with the sludge.

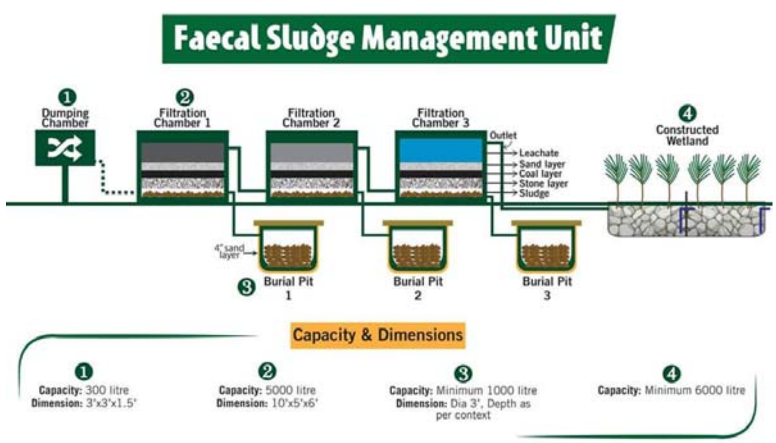


Figure 8 Schematic diagram of PA FSMU process flow

(a)

(b)

Figure 9 (a) Filtration chamber (b) Constructedwetland of PA FSMU

UKAID Faecal Sludge Treatment Site (UKAID FSTS)

UKAID FSTS is funded by British RedCross. The site is located in camp 18. It covers 45 latrines within its 100 m radius. This FSTS site is mainly comprised with unplanted sludge drying beds. There are 13 sludge drying beds and these beds are worked as alternatively. Sludge drying bed is composed of two layers of sand and gravel. At the bottom of the bed, gravel is placed and sand is above it. Thickness of gravel layer is 10 cm and sand layer is 20 cm. These two layers work as filtration media. Sludge drying bed is covered with greenhouse plastic poly that reserves heat into the bed chamber. This helps to dry the sludge fast. A maintenance house is built beside the beds. Inside the house, incoming FS from onsite pits is mixed with lime in the barrel and dried sludge is stored. In this site, the major challenge is collecting FS from the latrine pits and transporting them to the FSTS. Per day 3 m^3 or 60 barrels FS are put into the sludge drying beds. Each barrel has capacity of 50 liters. At first 1 kg lime is diluted in 1 L of water and then mixed with 1 barrel or 50 liters. The mixing is kept for 2 hours to increase its pH level and it becomes 11. After two hours from mixing, it is put into the sludge drying bed. In the bed, sludge is remained at the top and wastewater is percolated through the filter beds of sand and gravels. After percolating water is directly discharged into the nature. During discharge, the pH of the water is almost 8.5. Sludge is required to dry 4 to 5 days in dry season and 6 to 9 days in rainy season. After drying, sludge has been yet stored in the maintenance house. However, it is tried to Compost and use as soil conditioner. AT the same time, they are trying to treat the FS with vermicomposting process.

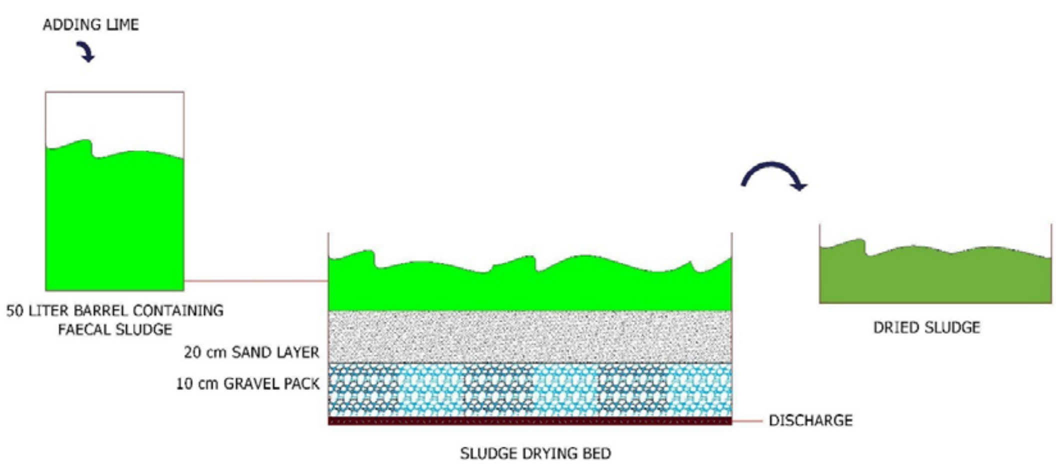


Figure 10 Schematic diagram of UKAID FSTS process flow

(a) (b)

Figure 11 (a) Sludge drying bed (b) Dried sludge stored in the house of UKAID FSTS

Comparative Study on Existing FSTP

Existing FSTP are functioned based on different treatment methods. Since, no laboratory analysis has been done, so theoretical comparative study was to be done. Before comparison, it is important to focus on some key points. These key points are unplanted drying bed, planted drying bed, lime addition, constructed wetland and up-flow filtration process which are the core parts of treatment process used in the FSTP discussed above.

Unplanted sludge drying beds are shallow filters filled with sand and gravel (Strande et al., 2014). The drying process in a drying bed is based on drainage of liquid through the sand and gravel to the bottom of the bed, and evaporation of water from the surface of the sludge to the air (Strande et al., 2014). Depending on the faecal sludge (FS) characteristics, Heinss et al., (1998) reported removal of 50 to 80% by volume due to drainage, and 20 to 50% due to evaporation in drying beds with FS. A review of the literature shows that sludge is typically applied in a layer of 20 to 30 cm in depth, with a preference for 20 cm (Strande et al., 2014). Cofie et al., (2006) made use of gravel with a diameter of 19 mm and 10 cm depth and above it, 15 cm sand layer is applied. After drying of sludge, further processing for stabilization and pathogen reduction are required depending on the intended end use optional though some biodegradation may occur (Strande et al., 2014). Drain off liquid, is also needed to be treated prior to discharge (Tilley et al., 2014).

Planted drying bed (PDB) refers to as planted dewatering beds, vertical flow constructed wetlands and sludge drying reed beds, are beds of porous media (e.g. sand and gravel) that are planted with emergent macrophytes (Strande et al., 2014). Macrophytes are plants found in wetlands, marshes and swamps, and are distinguished by their ability to grow when partially or fully submerged in water (Strande et al., 2014). In Bangladesh region, *Canna Indica* plant is like Macrophytes. An important aspect associated with *Canna* plant is its higher growth rate with significantly high biomass production (Chen et al., 207AD) which is directly related to nutrient uptake, and tolerance to water stress and chemical fluctuations, making it a suitable candidate for phytoremediation (Strande et al., 2014). In the PDB, gravel and sand are used for filtration matrix. 2 cm diameter of gravel is used at a depth of 15 cm and 0.1 cm diameter of sand is used at a depth of 10 cm (Strande et al., 2014). If 5 cm diameter of gravel is used, the depth should be at least 45 cm (Strande et al., 2014). Using a semi-empirical equation, researchers determined that in order to maximize water-loss and minimize costs, 11 days was the optimum number of days between loadings (Giraldi and Iannelli, 2009). When sludge is applied on the beds, solids are retained on the surface of the filtering matrix while the liquid drains vertically through the media where it is collected (Kadlec and Knight, 1996). Collected liquid should be treated with a subsequent treatment technology prior to discharge to the environment (Strande et al., 2014). The treatment of sludge in PDBs is achieved through a combination of physical and biochemical processes. In wet, rainy climates, macrophytes play an essential role in almost all processes, and are responsible for the higher levels of treatment in terms of stabilization and pathogen removal in PDBs compared to unplanted drying beds (Brix, 1997; Kadlec and Knight, 1996). The PDB achieved over 95% volume reduction (Strande et al., 2014). Dense macrophyte root helps to stabilize the sludge layers (Strande et al., 2014). The process of stabilization reduces the odour of the sludge and destroys the pathogenic organisms (Strande et al., 2014). Nitrate removal rates in the PDB can be 60 to 70% depending on the level of water saturation (Strande et al., 2014). Phosphorus removal, on the other hand, is found to be fairly similar between planted and unplanted beds; the primary removal mechanism for phosphorus appears to be sorption onto the porous media and plant roots (Stefanakis and Tsihrintzis, 2012). Ingallinella et al., (2002) summarise various reports and show that treatment of FS in a PDB reduced the concentration of Helminth eggs from between 600-6000 helminth eggs/ L of FS to 170 eggs /g TS, with an egg viability of between 0.2 and 3.1%.

Lime is used for wastewater sludge treatment to achieve the reduction of pathogens, odors, degradable organic matter, and also as sludge conditioner to precipitate heavy metals and phosphorus (Strande et al., 2014). This process is known as lime stabilization process. The aim of this process is to achieve a pH higher than 12 (Farzadkia and Bazrafshan, 2014). High pH value creates an environment to decelerate the reaction of microorganisms and production of odor in addition to inactivate viruses, bacteria, and other present microorganisms (Farzadkia and Bazrafshan, 2014). Its effect is enhanced by a longer contact time and higher dosing amount (Strande et al., 2014).

Up-flow filtration has been used for a few potable water treatment plants in the UK, but its use is more appropriate to industrial water applications (Brandt et al., 2017). The principle used in up-flow filters is to have progressively finer sand in the direction of flow, which allows the filter to carry a greater load of impurity before backwashing because the larger particles tend to be held in the lower, coarser part of the filter, leaving the upper layers to deal with the smaller particles (Brandt et al., 2017). The up-flow filter is generally consisted of 32-38 mm gravel of 101 mm thick at the bottom, 10-16 mm gravel of 254 mm thick, 2-3 mm sand of 305 mm thick and 1-2 mm sand of 1524 mm thick layer respectively from bottom (Stewart and Arnold, 2009). Up-flow filters may remove up to 6lb/ft^2 (29. 3 kg/m^2) of solids (Stewart and Arnold, 2009). Freeboard area should be 50 to 70% of the total media depth (Stewart and Arnold, 2009).

Constructed wetlands (CWs) have been recognized as cost-effective alternatives or useful compliments to conventional wastewater treatment systems (Brix and Arias, 2005; Tsihrintzis and Gikas, 2010; Vymazal, 2009). CWs are effective treatment systems for decreasing concentrations of the total suspended solids (TSSs), biological oxygen demand (BOD), nitrogen, bacteria (Escherichia coli, total coliforms) and metals (IWA, 2000; Kadlec and Knight, 1996; USEPA, 2000). At present, there are many different types of constructed wetlands like surface flow (SF) and subsurface flow (SSF) systems (Vymazal, 2010). The most widely used concept of SSF CWs is that with horizontal subsurface flow (HSSF) and indeed, the most common use is for municipal and domestic sewage (Vymazal, 2010). The depth of vegetated beds with horizontal subsurface flow was initially based on the requirement that roots and rhizomes of the vegetation should penetrate the full depth of the bed in order to eliminate totally anaerobic zones and recommended bed depth is 0.6-0.8 m (Vymazal, 2010). The most commonly used filtration materials are washed pea gravel and crushed rock (Vymazal, 2010). The fraction size varies among countries but in general, size between 5 and 20 mm and 400 mm thick is the most common (Vymazal, 2010). However, HSSF CWs require good pretreatment to reduce the suspended solids because it may cause filtration bed clogging and subsequent surface flow (Vymazal, 2010). Removal of organics (BOD5, COD) is usually high and exceeds 85% in case of sewage. Suspended solids are removed in HSSF CWS were effectively, commonly >90%. Nitrate reduction in constructed wetlands can account for 60 to 70% of nitrogen loss (Strande et al., 2014). Removal of phosphorus is generally low (<40% in sewage) and could be enhanced by the use of filtration media with high sorption capacity (Vymazal, 2010).

According to Strande et al., (2014), solid-liquid separation, sludge stabilization, nutrient management and pathogen inactivation are the core process for the treatment of FS. In absence of any of the processes, no appropriate FSM can be possible. Following chart shows a comparative scenario of the process used in the existing FSTPs.

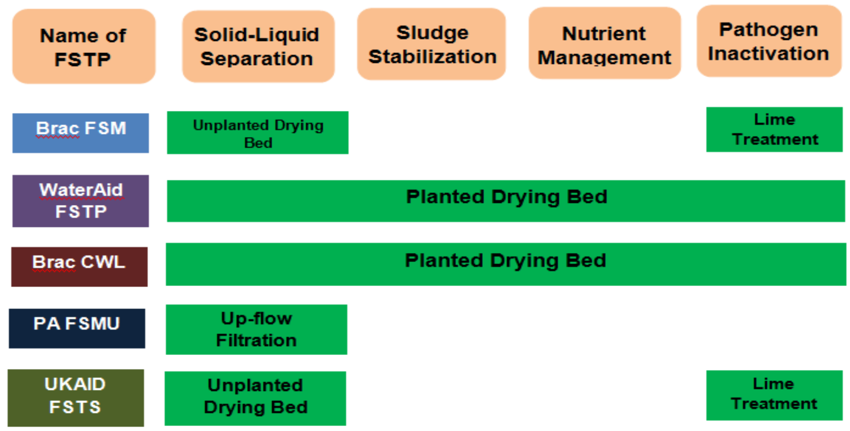


Figure 12 Comparative flow chart of the process used in FS treatment

In figure 12, it has been found that theoretically WaterAid and Brac CWL have completed the core processes of FS treatment. So, theoretically it can be said that the dried sludge of those treatment plant has an end use point.

In existing FSTPs, there are different units used in the treatment process. These units are different from each other in specifications. From studying previous works related to these type of treatment processes, specifications of these units have been found. In table 1, a comparison of specifications between existing FSTPs and previous works has been shown.

Table 1 Comparison on specification of different units used in treatment process

Unit	**Brac FSM**	**WaterAid FSTP**	**Brac CWL**	**PA FSMU**	**UKAID FSTS**	**From Literature**
Unplanted Drying Bed						
Gravel Depth	30 cm	-	-	-	10 cm	10 cm
Sand Layer Depth	30 cm	-	-	-	20 cm	15 cm
Sludge Depth	30 cm	-	-	-	20 cm	20-30 cm but 20 cm preferrable
Unplanted Drying Bed						
Larger Size Gravel Depth	-	-	-		-	45 cm
Medium Size Gravel Depth	-	-	-		-	15 cm
Sand Layer Depth	-	-	-		-	10 cm
Drying period	-	-	-		-	11 days
Lime addition						
pH value	13	-	-		11	>=12
Up-flow Filtration Unit						
Fine Sand Depth	-	-		0.202 m		1.524 m
Coarse Sand Depth	-	-		-		0.305 m
Medium Size Gravel Depth	-	0.60 m		0.202 m		0.254 m
Large Size Gravel Depth	-	-		0.202 m		0.1 m
Constructed Wetlands						
Bed Depth	-	1.52 m	1.52 m	1.07 m	-	0.6-0.8 m
Gravel Thickness	-	0.6 m	0.6 m	0.6 m	-	300-400 mm

From table 1, it has been found that all in lime stabilization process of UKAID FSTS, pH value is less than 12 which should be equal to or greater than 12 found in literatures. In up-flow filtration unit of PA FSMU, sand layer is provided only 0.202 m but it should be 1.524 m based on literature review.

All the existing treatment processes have different wastewater treatment efficiency. A comparison is made theoretically on wastewater treatment efficiency based on studying previous works related to these type of treatment processes.

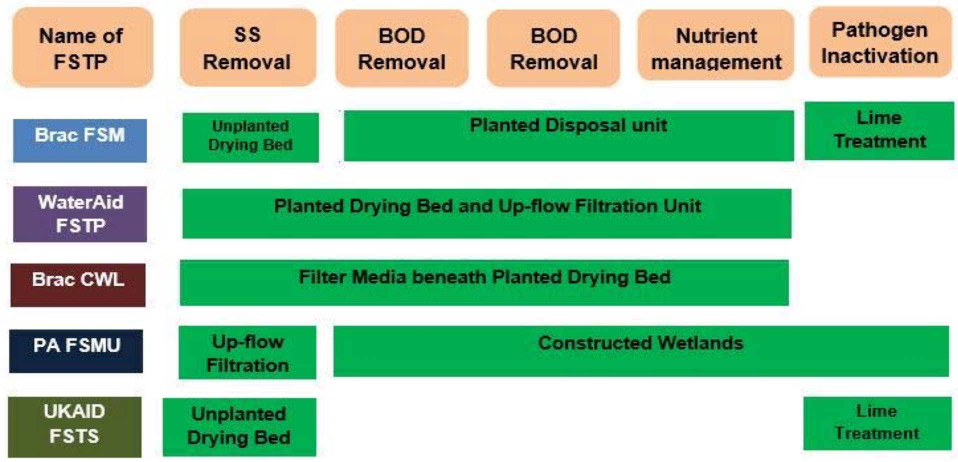


Figure 13 Comparative flow chart of wastewater treatment efficiency

It has been found from figure 13 that the treatment process of Brac FSM and PA FSMU are a complete process for treatment of wastewater theoretically compared with other treatment facilities.

CONCLUSIONS

In this study no laboratory works have been done. So, comparative study was done based on field data and related previous works. From this theoretical based study, following conclusions can be drawn:

- WaterAid FSTP and Brac CWL have high FS treatment efficiency and treated FS has an end use value.
- PA FSMU and Brac FSM have high wastewater treatment efficiency compared with other treatment facilities.
- Since pH value is less than 12 in lime stabilization process of UKAID FSTP, pathogen may not be expected to be inactive properly.
- No laboratory analysis has been done for the assessment of treated water quality in all the treatment plants.
- In all treatment process, dried FS has been stored or dumped and not yet managed to use as end product.

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ASPECTS FOR THE UTILIZATION OF MOBILE FERMENTATION FACILITIES IN REFUGEE CAMPS AND DISASTER AREAS

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Keywords: refugee camp, mobile reactor, biogas

ABSTRACT

War-like disputes, famine and natural catastrophes lead to the march of refugees. Most of the time the decision to settle down in a more or less adequate spot is met with spontaneously. In spite of these tentative camps being supervised by aid organisations, these locations are often subject to degrading conditions. One of the main problems at refugee camps is the hygienic disposal of faeces and organic waste. The proper disposal of this waste is one of the main requirements for the prevention of diseases and energy supply. Mobile and modular anaerobic facilities for the disposal of faeces and the simultaneous utilization of biogas at refugee camps might be part of a solution.

1. SITUATION

By the end of the year, 70 million individuals were forcibly displaced worldwide as a result of persecution, conflict, or generalized violence. As a result, the world's forcibly displaced population remained yet again at a record high.
The number of registered and recognised refugees is less than this as it is very difficult to obtain accurate statements from disaster struck areas and the numbers given therefore are based only on assumptions. According to the world refugee statistics of 2017 given by the UNHCR, the number of refugees and other people needing protection increased to 68,5 million. It is a nation. They might be divided into 25,4 million refugees, 40,01 million internally displaced people and 3,1 million asylum-seekers (UNHCR 2017)

During 2017, nearly 5 million displaced people returned to their areas or countries of origin, comprising 4.2 million internally displaced people and 667,400 refugees. Returns have not kept pace with the rate of new displacements. Table 1 shows an extracted overview to the pure statistics of refugees and internally displaced persons (IDP`s).

Table 1: Countries of origin of the refugees end 2017 based on UNHCR, 2018

Country of asylum	Total refugees and refugee like	Assisted by UNHCR	IDP`s and IDP`s like by UNHCR	Stateless	Others of concern	Total population of concern
Afghanistan	75,928	75,928	1,837,079	-	448,032	2,454,451
Azerbaijan	1,121	1,121	612,785	3,585	-	617,614
Bangladesh	932,216	877,166	-	932,204	-	932,334
Cameroon	337,388	314,406	221,695	-	40	598,570

Table 2: Countries of origin of the refugees end 2017 based on UNHCR, 2018 (cont.)

Country of asylum	Total refugees and refugee like	Assisted by UNHCR	IDP`s and IDP`s like by UNHCR	Stateless	Others of concern	Total population of concern
Central African Rep.	10,036	6,675	688,700	-	-	866,948
Chad	411,482	411,482	99,983	-	99,103	612,197
Côte d'Ivoire	1,564	1,564	-	692,000	168	702,415
Dem. Rep.	537,087	423,710	4,351,376	-	-	5,144,932
Egypt	232,648	162,648	-	-	-	289,231
Ethiopia	889,412	889,412	1,078,429	-	530	1,970,983
France	337,177	-	-	1,425	-	401,729
Georgia	2,091	387	278,103	587	-	281,321
Germany	970,365	-	-	13,458	-	1,413,127
Iran (Islamic Rep. of)	979,435	979,435	-	-	-	979,525
Iraq	277,672	277,672	2,615,988	47,630	-	4,501,786
Italy	167,335	-	-	715	-	354,698
Jordan	691,023	691,023	-	-	-	734,841
Kenya	431,901	431,901	-	18,500	-	506,915
Lebanon	998,890	998,890	-	-	4,193	1,018,416
Libya	9,352	9,352	180,937	-	-	375,840
Myanmar	-	-	353,108	621,514	-	849,733
Niger	165,732	165,732	129,015	-	14,820	315,723
Nigeria	1,922	1,922	1,704,080	-	-	2,379,195
Pakistan	1,393,143	460,024	174,354	-	-	1,852,650
Philippines	522	128	311,943	2,678	68	633,918
Somalia	14,567	14,567	2,116,705	-	129	2,187,585
South Sudan	283,409	283,409	1,903,953	-	10,000	2,202,145
Sudan	906,599	368,398	1,997,022	-	3,880	3,323,629
Sweden	240,962	-	-	35,101	-	327,709
Syrian Arab Rep.**35**	19,429	19,429	6,150,005	160,000	11,213	7,033,119
Thailand	104,615	104,615	-	486,440	109	593,241
Turkey**36**	3,480,348	1,194,381	-	117	-	3,789,320
Uganda	1,350,504	1,350,504	-	-	180,000	1,575,148
Ukraine	3,257	640	1,800,000	35,294	-	1,844,785
United States	287,129	-	-	-	-	929,850
Yemen	270,919	121,187	2,014,062	-	16	2,419,806

Most refugees had their origin in Afghanistan, Myanmar, Syrian Arab Republic, Somalia, South Sudan and Dem. Rep. of the Congo. In Europe the refugee problem manifests not more in the Balkans, only. War-like disputes are however not sufficient for prognosis humanitarian catastrophes and state of emergencies. A hazard analysis of diverse natural catastrophes will occur and have to be taken into account. It is assumed that in the 20th century, earthquakes have cost more than 1 million human lives.

According to rule of thumb at least 30 m² should be available per person at a camp. These 30 m² include roads, footpaths, sanitary facilities, schools, safety set-ups, administration, market place, water-tank, distribution points, stores and naturally the place for living. If agriculture is also taken into consideration, the space requirement per person is increased to a minimum of 45 m². Encampments having more than 20,000 people are to be generally avoided. The size of a camp with 20,000 people including gardens should be 90 hectares (UNHCR 2003, 2018). The camps should be placed at the maximum possible distance. The refugee camp should be designed to expand and be able to accommodate births and new arriving people. The average growth of a refugee camp owing to births and constant arrival of new refugees is 3 to 4% per year (UNHCR 2003).

The manner in which the camp is organized will have a lasting influence on the health and welfare of the people. A refugee camp should be planned taking the family as the smallest element and begin by considering the requirements of an individual household on e.g. water and latrines, relationship to other members of community and traditional living habits. The development of a community from this point of view i.e. from small to large is easier to represent than the other way round. A refugee camp could be subdivided as shown in table 2 (UNHCR 2003).

Table 2: Refugee camp module distribution

Module	Comprising of	No. Of persons
1 Family	1 Family	4 – 6 Persons
1 Group	16 Families	80 Persons
1 Block	16 Groups	1.250 Persons
1 Sector	4 Blocks	5.000 Persons
1 Camp	4 Sectors	20.000 Persons

Subdividing into modules does not have to mean implementation of a grid network for the encampment. The linear appearance, subdivided by parallel streets as can be clearly recognised in figure 1, It has been often chosen since the camp had to be installed fast.

Figure 1: Example of a refugee camp in Ruanda (UNHCR 2003)

The disadvantage is that the strict development of such a network provokes a high population density. Whereas the availability and requirement of water often determines the location of the refugee camp, the sanitary facilities are often responsible for the its appearance. If the density of people is high and the sanitary conditions are bad, the danger of diseases and epidemics increases. This happens when refugee camps are built spontaneously and without planning. For this reason, such nuisances e.g. uncontrolled deposit of waste and faeces will have to be eliminated quickly and forbidden and public toilets installed as these measures occupy a key position in the prevention of epidemics and possess the biggest potential against the spread of difficult diseases. Such installations will have to be easily accessible for maintenance and cleaning and not be located too far away from the refugees. Planning an adequate sanitary area is difficult, but trying to eliminate mistakes at a later stage is often even more difficult. It is therefore advisable to integrate the refugees while installing the facilities. They should also be assigned the duty of independently operating the facilities as far as possible. In the preliminary stages of the refugee camp, prior to installing the sanitary facilities, a location should be defined where people can take care of their pressing needs (shitting fields) and dispose waste. The time span between the implementation of both these measures should be very small, as it will be difficult to relocate these people because they will simply have got used to these conditions (UNHCR 2003). Even accepting the shitting fields could prove to be problem (Stäudel 2004). According to the emergency manual of the UN refugee commission there should be at least one sanitary facility installed for every 5000 persons. For 20,000 people in families having an average of 4 persons, there should be at least 5000 latrines (Vogler 2003). The construction of many single latrines could take under the circumstances much time and continue creating large hygienic problems. It is difficult to keep such facilities clean often leading to the emission of bad smell. Furthermore, these locations are often the ideal breeding ground for insects some of which are also a hazard to ground water (UNHCR 2003). It is worth to think about an installation of a system of common toilets and bio-reactors to recycle the faeces hygienically with the great advantage of also winning biogas. Constructing the toilets in containers is a simple method by which it is quickly possible to build according to the requirements of the people. In order to ensure that the installations are utilized the distance between the living quarters and the toilet facility should be kept as short as possible. The distance should not be more than 200m as otherwise the people are not prepared to walk the distance and will seek alternate possibilities. In order to abide by these regulations, a refugee camp with 20.000 people and having a dimension of 1 km x 1 km should plan at least 12 large toilet installations (Vogler 2003). Figure 2 shows one possibility of construction.

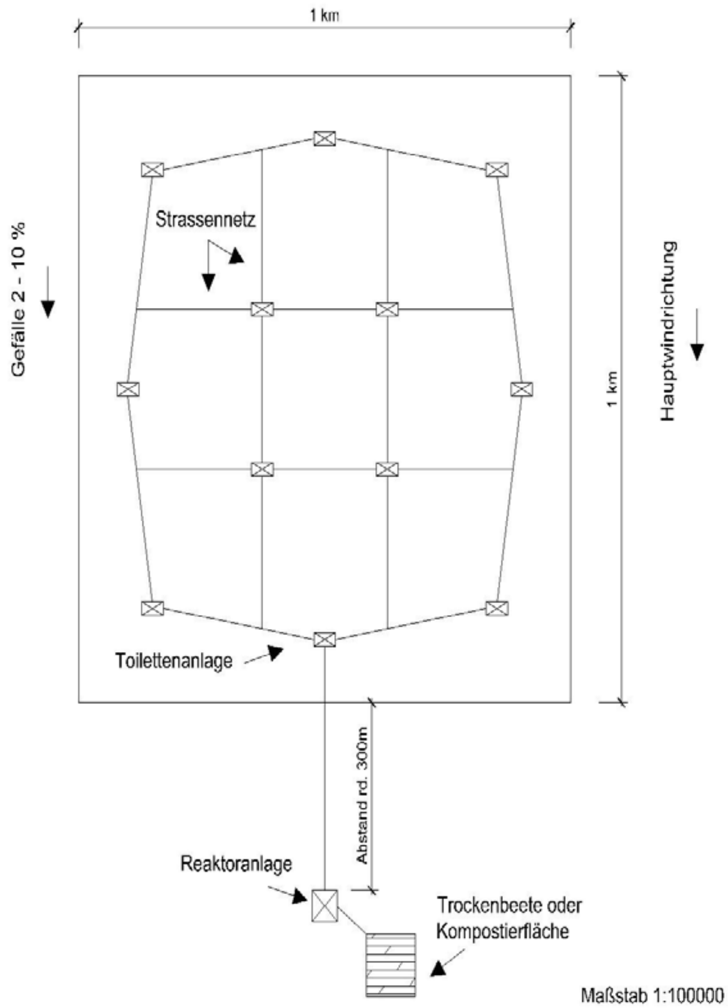

Figure 2: Possible arrangement of sanitary areas and treatment facilities, central and external

Five fundamental scenarios for the arrangement are imaginable. This selection is a deciding factor for the implementation.

Possibility 1 (decentral)

Treatment and disposal of faeces in the immediate vicinity of the sanitary facilities

Advantages	Disadvantages
• Very short transport distances	• Many alloted facilites, higher costs for operation and material per unit • Increased emmissions within the camps and as a consequence health hazards • Disposal appears to be more difficult • Possible problem of space

Possibility 2 (central)

Treatment and disposal of faeces outside the camp

Advantages	Disadvantages
• Combining multiple units possible, therefore less costs for operation and material per unit • Emmissions outside the camp • Disposal simpler • More space available	• Very long transport distances

Possibility 3

Treatment of the faeces in the immediate vicinity of the sanitary facilities and disposal outside the camp

Advantages	Disadvantages
• Short transport distances between the sanitary facilities and fermentation facilities • Centrally located place of disposal outside the camp possible, therefore lower operational and material costs per unit	• Long transport distance between the fermentation facility and the place of after-treatment or disposal • Many alloted fermantion facilities, therefore higher costs for operation and material per unit

Possibility

Treatment of the faeces at a few central points within the camp and disposal outside the camp

Advantages	Disadvantages
• Short transport distances to the anaerobic facility	• Faeces transported twice • Damaged facilities are contamination centres

Possibility 5

Treatment and disposal of the faeces at a few central points within the camp

Advantages	Disadvantages
• Short transport distances	• Damaged facilities are contamination centres • Smell nuisance

The amount of faeces excreted daily by a person varies strongly. The volume, the composition and the consistence depend strongly on the climate, nutrition of the individual person and their state of health.

Table 3: Faeces per person

Region / groups	daily [g/ l, d]	Fluctuation range [g/l, d]
U.K. (Burkitt, et.al 1972)		
Soldiers	104	39 – 223
School students	110	71 – 142
Vegetarians	225	71 – 488
Hospital patients	175	128 – 248
USA (Greenberg 1976)		
Cincinatti	115	76 – 148
Philadelphia Students	148	--
South America (Crofts, et.al. 1975)		
villagers	325	60 – 650
Kenia (Cranston, et.al. 1975)		
Hospital staff	520	--
Uganda (Burkitt, et.al 1972)		
School students	185	48 – 348
villagers	470	178 – 980
Malaysia (Balasegeram 1976)		
Chinese (rural)	489	386 – 582
Chinese (urban)	277	180 – 270
Malay (rural)	465	350 – 550
India (Tandon 1975)		
< 15 years (New Delhi)	374	50 – 1060
> 15 years (New Delhi)	311	19 – 1505
South Africa (Burkitt, et.al 1972)		
adults (rural)	--	140 – 220
adults(urban)	--	120 – 180
Students	173	120 – 195
European food (Lentner 1981)	104	104 -110
Mixed food (Lentner 1981)	155	155 - 165
food of hogh dietary fiber content (Lentner 1981)	225	225 – 275

The excrement can daily contain between only 20 grammes and upto 1.5 kilogrammes of moisture. If the national and regional particularities are taken into consideration, Europeans and North Americans produce about 100 to 200 g daily, whereas in the developing countries the amount can be between 130 to 520 gms. Vegetarians generally produce more faeces than other groups just as is the case with rural inhabitants as compared to those from urban areas (Feachem, et.al. 1980). The Technische Hilfswerk (Federal Agency for technical relief) estimates 0.3 Kg faeces and 1.5 l urine per person (THW 2004).

Water for flushing and cleaning the toilets is not taken into consideration here, as these values strongly depend on local particularities. Besides, most toilet facilities do without flushes.

The chemical composition of faeces is very complicated and can vary strongly. Some typical values are given in table 4. The amount of carbon and nitrogen are of special importance when assessing toilet facilities. The faeces contain about 9.6 g BSB_5 per 100 g wet mass and the urine about 8.6 g per litre (Feachem, et.al. 1980). The use of toilet paper and similar material has been taken into account in this evaluation.

Subdividing into modules does not have to mean implementation of a grid network for the encampment. The linear appearance, subdivided by parallel streets as can be clearly recognised in figure 1, was often chosen because the camp had to be installed fast.

Table 4: Quantity and composition of urine and faeces (Feachem, et.al. 1980)

		Faeces	Urine
Quantity (moist substance)	[kg/P*d]	0,1 – 0,4	1,0 – 1,31
Quantity (dry substance)	[g/P*d]	30 – 60	50 – 70
Water content	[wt.-% FS]	70 – 85	93 – 96
Average composition			
Organic	[wt.-% TS]	88 – 97	65 – 85
Nitrogen	[wt.-% TS]	5,0 – 7,0	15 – 19
Phosphate(P_2O_5)	[wt.-% TS]	3,0 – 5,4	2,5 – 5,0
Potassium (K_2O)	[wt.-% TS]	1,0 – 2,5	3,0 – 4,5
Carbon	[wt.-% TS]	44 – 55	11 – 17
Calcium (CaO)	[wt.-% TS]	4,5	4,5 – 6,0

Depending on age the water content of the faeces can vary between 70% and 85%. The average value can be assumed at 76% (Kunsch 1998). Newer surveys found for European as an of average of 21 citations a dry substance content of 38 [g/P*d] with an average of 35 [g/P*d] of organic substance (DWA 2008). Londong and Hartmann published as result of a literature review for faeces a dry substance content of 31 [g/P*d] with an average of 23 [g/P*d] of organic substance (Londong, Hartmann 2006).

2. THEORETICAL APPROACH

Mobile anaerobic facilities could be introduced to refugee camps for disposing and simultaneously recycling faeces. Mobile anaerobic facilities principally have a broad spectrum of application that ranges from the treatment of faeces and bio waste in refugee camps to the recycling of temporarily produced agricultural organic waste.

The success of such mobile facilities is however connected to a number of conditions. Thus it should be possible e.g. to construct the facility economically, economic operation models should be available for the individual cases of application, the on-site logistics for input materials and products should be guaranteed etc. The aim of the present research is to develop such mobile anaerobic systems specially for the application in refugee camps.

Generally, two complexes can be distinguished for this new application

- scientifically unexplained problems and
- Planning adapted to existing components according to the state of technology.

Uninterrupted operation poses a special scientific challenge. The possibility of supervising and controlling the mobile anaerobic facility by external experts should be given. One cannot naturally assume that this is available on-site. Therefore, remote supervision and remote controlling should be made possible. One of the focal points is therefore the identification of controlling and regulation parameters for the process, the necessary hard and software for recording and transferring data (Kraft 2004). These will have to be not only significant but also available online. The intervention possibilities on-site will be limited. Figure 2 shows the basic sketch of a remote supervision.

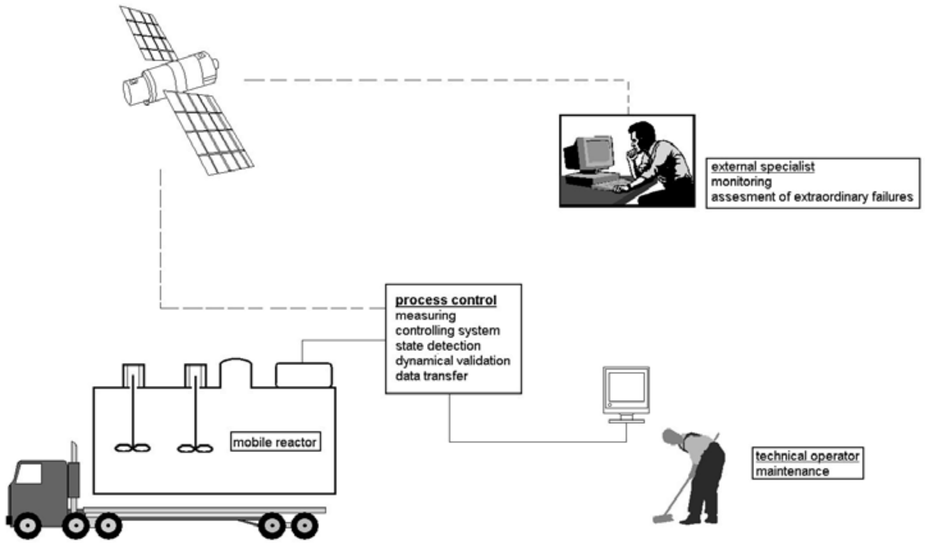

Figure 2: Basic sketch of a remote control of the fermentation facility at a refugee camp (Liebetrau, et.al 2002)

With all existing methods and fermentation facilities, the start up operation even in highly mechanised countries having a lot of experience with anaerobic technology is a bottle neck of the whole process. A quick start up operation is essential for the situation in the refugee camp. The aim is to investigate the possibilities of shortening the starting phase of the anaerobic degrading process of organic waste and residual materials. Optimizing and mastering the start up operation poses a special challenge owing to the complex reaction processes, due to the numerous essential participants and inter-dependant micro-organisms as well as the abundance of metabolic products. The shortest time in which a stable anaerobic biocoenosis is formed and the methane content in the biogas flow increases to over 55 Vol.-% during the process, is a deciding factor. If both these pre-requirements are fulfilled the start up operation can be considered completed. With the help of optimized start up strategies, the existing mixed-population and above all the very slowly growing methanogenic bacteria can be positively influenced in relation to its growth rate and metabolism activity.

For developing optimized start up strategies with anaerobic treatment of selected organic waste, faeces and residual food, experiments having the following targets should be conducted:

- Investigating the application of adapted inoculation sludge for shortening the start up phase
- Developing an inoculation sludge that can be applied universally and manufacturing different individual inoculation sludges i.e. adapted to various organic waste respectively (faeces and residual food)
- to hold out and provide the inoculation sludge – storing (investigation and development of possibilities)

The anaerobic facility is modular and mobile. This idea is classified in a concept of modularity of the UNHCR, to hold out assistance (GSP, Government Service Packages) (Eldagsen 1997). For this reason it should be possible for moving all components of the facility easily. It would be reasonable to construct the facility and its components in a standardized container (maritime container), which should fit into vehicles designed for this purpose. It should be possible to construct the facility by unskilled workers i.e. connections (electrical, substrate supply and discharge, gas connections etc.) must be clearly marked and assignable. It would be even better if there were special joints or couplers each of which would only fit on a particular system (electrical, gas, fluids). This will ensure that no damages are caused by improper joints. A ”Black Box” system could be a possibility. The requirements can be summarized as follows: robust, less technique, easy to repair and inexpensive. Figure 3 shows the cross-sectional view of a container, comprising of fermenter and collecting tank, whereas figure 4 shows the complete arrangement (Kraft 2008)

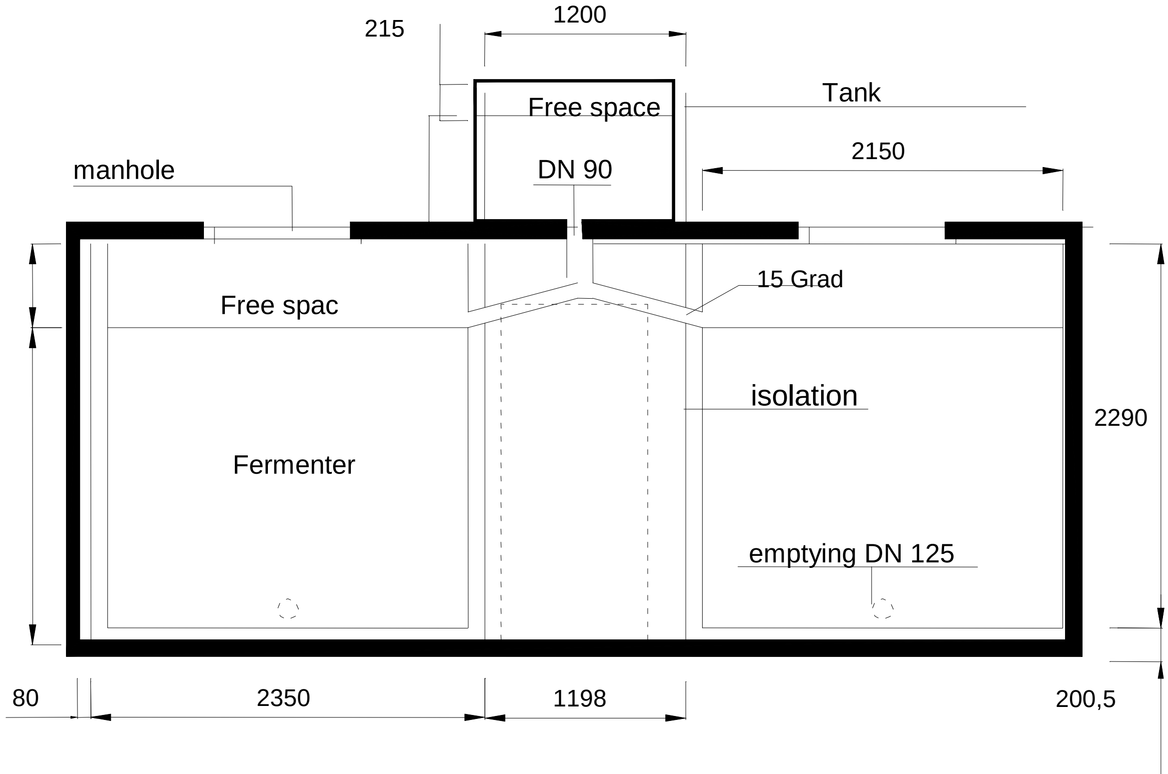

Figure. 3: Cross-section of an anaerobic container and collecting tank

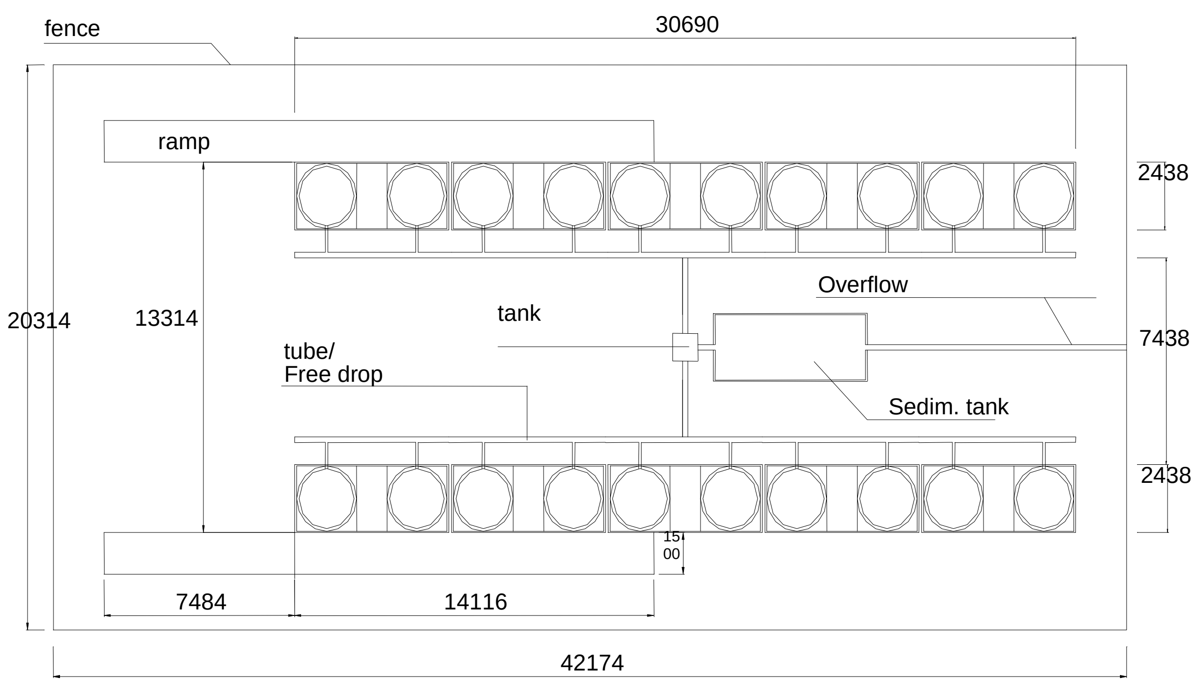

Figure 4: Arrangement of the container units in combination, measurements in [mm]

The individual components of the anaerobic facility such as the biogas reservoir, gas generating and recycling unit and substrate reservoir are thoroughly constructed and combined in an optimal way. Possibilities for disposing fermentation residue should be clarified before implementation. As it is not possible to use the fermentation residue a secure spot will have to be found for depositing it and its suitability tested. The aim should be to find a motivated (e.g. contribution in kind such as biogas etc.) group of people to collect, transport, to operate and recycle self-sufficiently. Educational measures for future users should be considered. Here too information to the operator is indispensable.
Eye-witnesses report that during the developmen of a refugee camp fuel scarcity (wood) occurs within a very short time (Städel 2004). Utilizing the biogas as fuel and if necessary for lighting follows. Long time encampments should take cooling facilities in central facilities such as for medicine in sanitary tents into consideration.

3. SUMMARY

In 2017 there approx. 70 million people are refugees or displaced. The hygienic conditions of those, who are living in camps, is often were depressing. It partly results from inadequately explained instructions on the disposal of faeces and organic waste. On the other hand the limitation of water and fuel are big problems. Mobile anaerobic facilities could contribute to improve the situation. For this scientific questions of remote controlling and shortening the starting up phase as well as adapting to the present state of technology are necessary to answer. The concept might be further developed to Government Service Packages of Anaerobic Digestion.

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A NOBEL WASTEWATER TREATMENT ECOTECHNOLOGY APPLIED TO IMPROVE ENVIRONMENTAL SANITATION IN KHULNA SLUM

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ABSTRACT

Poor sanitation in urban slums results in increased prevalence of environmental pollution. This situation coupled with the destitute economic condition of poor migrants has given rise to the formation of many slums where service inadequacies on sanitation have been compounded and multiplied on a massive scale, resulting in hazardous environmental condition. Decentralized wastewater treatment system (DWTS) has recently gained much attention due to its build-as-you-go principal. Rapid urban development and the wide spread impact of wastewater require sustainable ways to test the DWTS. This paper aims to examine and discuss the potential of a novel DWTS for urban development. The pilot DWTS was established in Panchtola colony located at Khalishpur, Khulna. The paper firstly depicted how the environmental sanitation of slum was improved with inclusion of ecotechnology. The DWTS treatment unit comprises of anaerobic baffled reactors with settlers, planted constructed wetland (CW) made of porous filter media followed by planted surface flow constructed wetland at the end. The samples were tested at inlet and outlet of each component of DWTS and it was found that overall removal efficiency of pollutants is more than 80% (COD, BOD_5, PO_4 and fecal bio-indicators) from influent, which met national standard of effluent. The inclusion of cupola slug in constructed wetland led to remove significant PO_4. Therefore, the inclusion of CW with combination of horizontal and vertical flow controlled by baffled separators was found very effective in treatment of wastewater. The paper may attribute to further research on environmental sanitation study and it will guide those who will work to improve the present wastewater treatment technology.

INTRODUCTION

Khulna is the third largest city in Bangladesh which is known to all as an industrial area. Most of its industries such as Jute mills, News print mill, and Hard board mill are situated in Khalishpur, Khulna. In the past, Khalishpur was very busy and crowdie area when mills were active. To meet up the accommodation of factory workers a total of eight buildings were constructed at Peoples jute mill area in 1982 (Saha and Alamgir, 2013). Every building has five floors, and for this reason it is called Peoples Panchtala Colony. To address the pollution from the Peoples Panchtola Colony at Khalishpur in Khulna, the wastewater that is being discharged directly into the nearby open areas, would require proper treatment with regards to environmental conservation. Prior to the start of Nabolok Enhancing Environmental Health by Community organization (EEHCO) project which was funded by WaterAid Bangladesh, mostly the residential wastewaters including sewage were being disposed directly either into storm water drains or open areas without any treatment. Due to unaffordable cost of construction, most of the drains in the towns and cities are open as a result they are misused, sometimes serving as defecating sites for homes without adequate toilet facility. In consequence, self-purification capacity of receiving water bodies is overloaded and it causes surface and ground water pollution, impacting directly to the health of community, reducing the value of environment. To improve this situation, wastewater treatment plant was therefore needed. But the municipality could not afford a centralized system for its entire area. For the circumstances, decentralized wastewater treatment system (DWTS) would be the most suitable to reduce the pollutant to an acceptably low level. Decentralized wastewater management may be defined as the collection, treatment, and disposal or reuse of wastewater from individual homes, clusters of homes, isolated communities, industries or industrial facilities, as well as from portions of existing communities at or near the point of waste generation (Battilani et al., 2010). DWTS applications are based on the principle of low - maintenance since most important parts of the system work without electrical energy inputs and cannot be switched off intentionally (Butler and Mac Cormick, 1996). Targeting a sustainable communal wastewater treatment solution for urban areas where no wastewater management system is available, DWTS was established at the Panchtola colony premise.

SANITATION SITUATION IMPROVEMENT

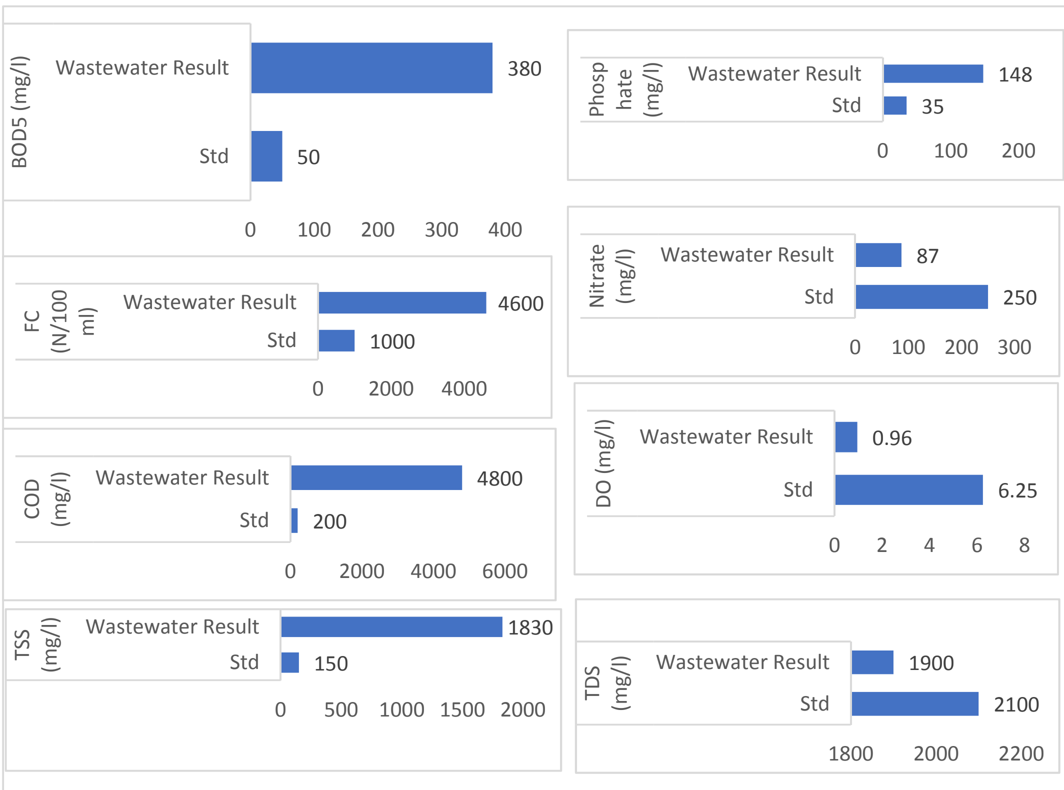
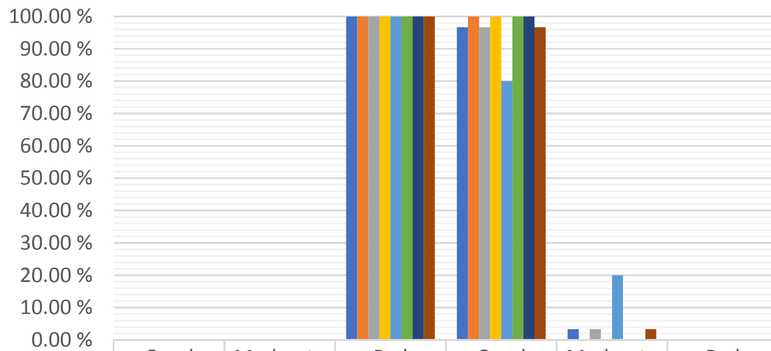


Figure 1: Pre-intervene wastewater quality from the community with Bangladesh Standard, 1997

In the past, residential wastewater even sewage and wastes were dumped beside Panchtola colony residences and near about the premises of their residence because there were not any sewerage systems or dumping place. Thus, foul odor was emitted which pollute the environment. Blockage of drainage systems occurred for wastewater overflow during rainy season. For that reason, surface water bodies as well as groundwater was polluted. Moreover, wastes were spread of by scavenging birds and animals. As a matter of fact, the level of environmental pollution due to wastewater discharge was severe. The graphs presented in the Figure 1 show the level of pollutant found in wastewater from stack of fecal matter accumulated in nearby premises before DWTSs were implemented. It also shows the comparison of found pollutants with Bangladesh Standard for the effluent discharge to inland surface water. To identify improvement of sanitation situation, a questioner survey was conducted among the inhabitant House Holds (HHs) of Peoples Panchtola Colony, Khalishpur, Khulna. The survey was conducted among 15% of HHs on sample basis. The survey was conducted on 08 parameters considering pre and post DWTS intervene situation. The responders expressed their statement on each condition as good, moderate and bad. The Figure 2 portrays that, with the implementation of DWTS, all the conditions that represent overall situation of the community rapidly turns from 'Bad' to 'Good' or 'Moderate' scenarios. Presence of faecal matter in open space removed by 100% leaded towards the improvement of surrounding environmental condition up to 96.67% (Figure 2). During the pre-intervene circumstances water-borne diseases seems as an obvious phenomenon of the respective community. Drainage condition has also been improved as of post-implementation situation. Moreover, as DWTS treats a substantial health hazardous contaminant with its praiseworthy efficiency, sanitation situation of community people has also enhanced. With the value addition of sanitation situation improvement, it depicts that both of economic and social status improves for most of the community people.



	Pre Intervene Situation			Post Intervene Situation		
	Good	Moderate	Bad	Good	Moderate	Bad
Surrounding Environmental Condition	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0 %
Presence of Foul Odor	0.00 %	0.00 %	100.00 %	100 %	0.00 %	0.00 %
Water-borne Disease Contamination	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0.00 %
Spreaded Faecal Matter	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Filthy Drainage Condition	0.00 %	0.00 %	100.00 %	80.00 %	20.00 %	0.00 %
Sanitation Situation Improvement	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Social Status Improvement	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Economic Status Development	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0.00 %

Figure 2: Comparative Analysis between pre & post intervene situation of DWTS.

COMPONENTS OF DWTS

Decentralised system is the combinations of aerobic and anaerobic treatment process (Feng et al., 2013). The anaerobic treatment process comprises of settlers, baffle reactors and anaerobic filters. The aerobic treatment process has horizontal/vertical/combine planted wetland and a polishing pond/surface flow constructed wetland (Figure 3). The basic idea of that is to treat the wastewater on-site by means of low-cost treatment systems and make environmentally safe discharge of effluent according to standard.

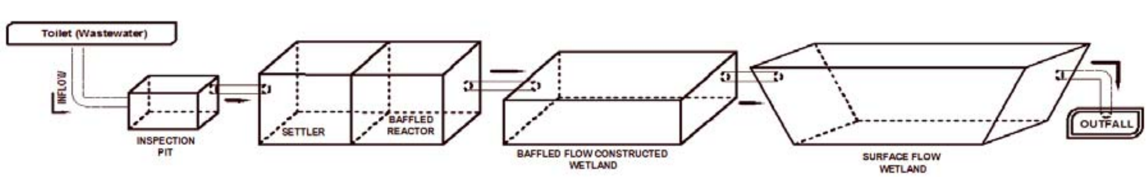


Figure 3 Components of DWTS.

TREATMENT MECHANISM OF DWTS

DWTS refers to a specific system comprises of settler with anaerobic baffled chambers, sub-surface constructed wetland made of porous filter media followed by surface flow constructed wetland or polishing pond. The mechanism of removal of pollutants in each component is presented in the Table 1.

Table 1: DWTS stages linked with conventional wastewater treatment system.

Sedimentation in Settler				
Primary Treatment	Removal of easily settleable solids →	Beginning of anaerobic fermentation of bottom sludge possible →		Removal of Sludge
↓				
Anaerobic digestion in Baffled reactor				
Secondary Treatment (anaerobic)	Removal of easily degradable organic solids →	Mineralization of suspended or dissolved organic compounds, biogas production. →	Settling of mineralized particles, collection and ventilation of biogas →	Removal of Sludge
↓				
Aerobic and facultative decomposition in HF/VF/Hybrid constructed wetland				
Secondary Treatment- (aerobic and facultative)	Removal of easily and more difficult degradable solids →	Mineralization of suspended or dissolved organic compounds. →	Settling of mineralized particles. →	Removal of residual sludge.
↓				
Post-Treatment in polishing pond/surface flow constructed wetland				
Post-treatment	Removal of suspended digested solids a de-active bacteria mass. →	Settling of finest suspended solids, removal of algae. →	Retaining of living and dead algae. →	Removal of residual sludge.

Primary treatment of domestic wastewater starts with ‘Sedimentation’ process. Two settlers of size 3.35x2.1x1.67m^3 and eight baffled reactors of size 1x2.6x1.67m^3 having continuous horizontal flow of wastewater helps particles to settle at terminal settling velocity. Particles in settlers often do not follow discrete settling. Then it encounters each other resulting agglomeration of size acceleration faster settling. The clarified effluent is then collected through an outlet weir and discharged to the following secondary anaerobic treatment stage. DWTS’s secondary system refers to ‘Anaerobic Baffled Reactor (ABR)’ of size 1x 2.6x1.67m^3 facilitating anaerobic bacterial environment that develops in the tank. Anaerobic process refers to decompose or mineralizes the wastewater discharged in the tank. Anaerobic and facultative biological process in the oxygen-deficient environment facilitates partial digestion of some of the wastewater components. Baffle walls allow the separation of solids from wastewater as heavier solids settle and lighter particles float. However, settling process is a pre-requisite of turbulence-free environment.

Furthermore, DWTS comprise of combined flow constructed wetland. In this component, wastewater flows beneath the media surface, where it encounters an inter-connected mesh of plants (Canna Indica, Phragmytes Australis) root, filter media and attached biofilms. Stabilisation occurs in the biofilms through degradation of organic substances via chemical processes, which are biologically mediated (bio-chemical processes). The processes are the result of the metabolism by micro-organisms, in which complex and high-energy molecules are transformed into simpler, low-energy molecules (Saeed et al., 2014). Metabolism is the break-down of organic matter (from feed to faeces) to gain energy for life, in this case for the life of micro-organisms, which store and release the gained energy in the form of ATP (adenosine triphosphate). A few chemical reactions happen without the help of micro-organisms. Most of the micro-organisms involved are biologically classified either as bacteria or as archaea. Considering available land area, initial wastewater load pattern length, width and height of the combined flow constructed wetland units were determined as 12.9, 4.27, and 1.75 m. Two baffle walls of 0.7m height and 4m length facilitating aerobic and anaerobic phases of Vertical Flow (VF) and HF wetland respectively refers to 'Combined Flow Constructed Wetland' (Saeed and Sun, 2011). To maintain necessary retention time and most importantly energy efficient gravitational flow is maintained with 1% of bed slope. In case filter media, 'Cupola Slag', an iron rich by-product of cast iron melting process is used (Saeed et al., 2012), for the anaerobic zone size of the employed cupola slag ranged 25 to 40 mm. Along with this, for the aerobic zone cupola slag of size 75 to 100 mm was used. Lastly, surface flow wetland treats the wastewater with certain sedimentation, filtration, and oxidation in presence of sunlight. Length, width and depth of this component are 7.62x4.27x0.6m^3.

POLLUTANTS REMOVAL EFFICIENCY

DWTS at Panchtola colony, Khulna is designed to treat 22,800 liter/day of wastewater produced by 285 inhabitants. Wastewater/Effluent test result of pre-intervene scenario shows that parameters like BOD_5, COD, FC, TSS, TDS, DO, NO_3, PO_4 have crossed the permissible limit by 3 to 4 times more as shown in Figure-1 (According to Bangladesh Standard 1997). To evaluate the effluent quality, the wastewater samples were collected from four different points such as middle of settler, outlet of ABR, outlet of combine flow constructed wetland and outlet of surface flow constructed wetland of DWTS of the Panchtola Colony after 3 months of operation. Different parameters such as BOD, COD, NO_3, PO_4, Total Dissolve Solid (TDS), Fecal Coliform (FC), Dissolve Oxygen (DO), Total Suspended Solid (TSS) were determined of collected wastewater samples.

Table 3 indicates pollutant removal profiles and removal efficacy (expressed as percentages) of each component of DWTS established in Khulna city. As observed in Table 3, the first stage of treatment facilitated by number of settler and baffled reactors provided higher removal efficacy especially for BOD5, TSS and NO_3 despite of higher concentrated influent pollutants. Anaerobic decomposition expedited through ABRs commenced reduction of TDS with furthermore removal of TSS. Also, in this stage FC concentration reduced by 52.94% of respective influent. A small amount of DO reduction depicts the anaerobic condition as well. Table 3 shows the combined flow constructed wetland facilitates COD abstraction fright with 52.66% of effectiveness. Significant percentage of PO_4 removal take in place, compared with the first and second stages of treatment because of presence of cupola slag. In the last stage of the system shows momentous reduced amount of FC. Furthermore, with the process of oxidation & sedimentation in this phase most of the pollutants (COD, TSS, TDS, FC, PO_4, NO_3) have shown detrimental phenomena towards meeting the limit for effluent in surface water-bodies according to Bangladesh Standard.

Table 3 and Figure 4 depict that the highest removal percentages of 97.81%, 89.47%, 89.13% and 96.25% respectively for the parameter of TSS, BOD_5, FC and COD and therefore DWTS meeting wastewater effluent Bangladesh Standard. In case of other major chemical parameters like PO_4 and NO_3 eliminated up to the desired level with the efficacy of 82.43% and 34.48% correspondingly.

Again, the increase of DO from the influent indicates that it can be mixed together with surface water for further utilization like agriculture that attributes to environmental sanitation

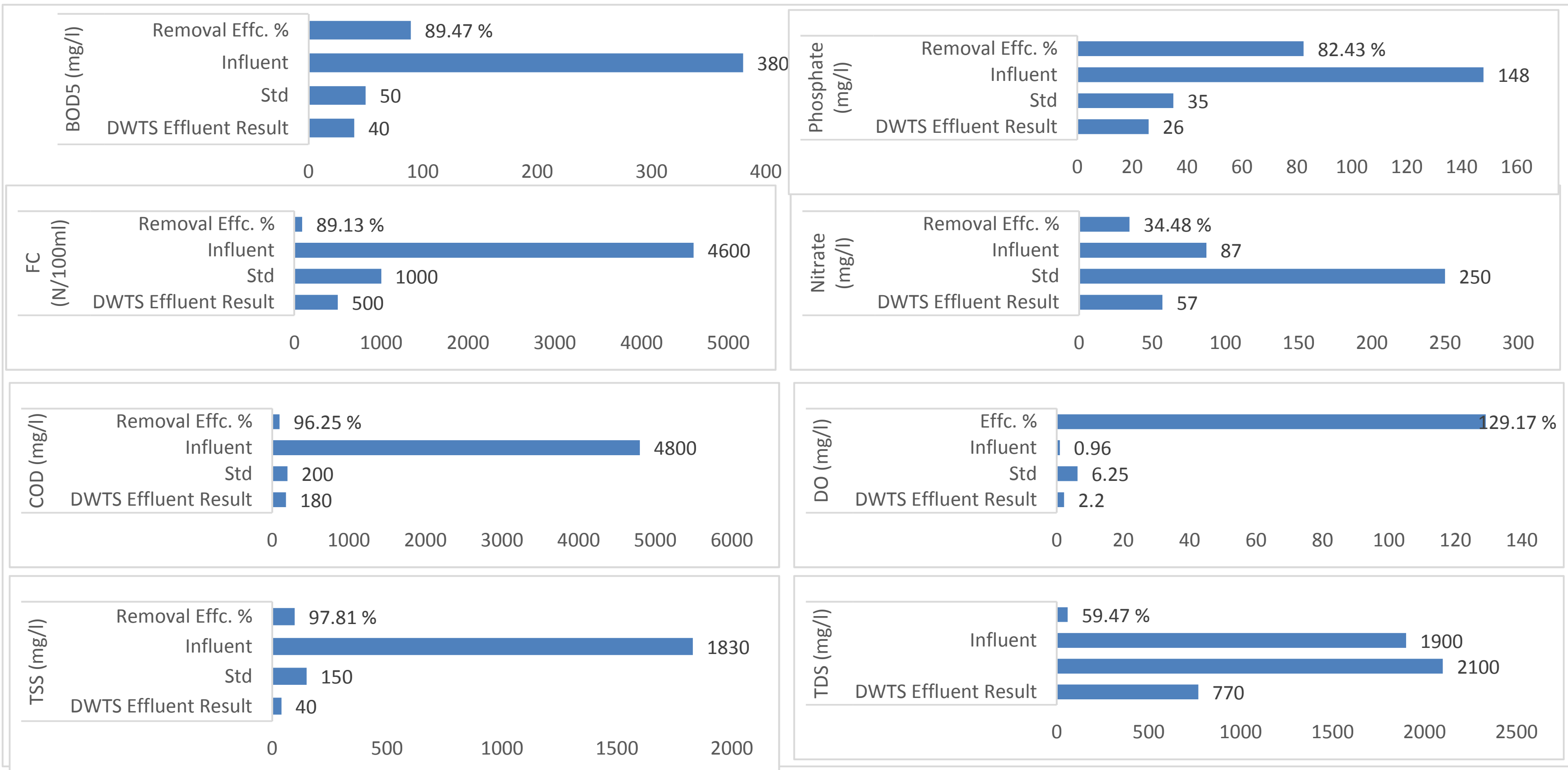


Figure 7: Overall removal efficiency against Pre-intervene Wastewater quality and Bangladesh Standard for different parameters.

Table 3: Pollutants removal efficiency at DWTS.

Parameter	Unit	Bangladesh Standard	Influent Concentration	Settler and Baffled Reactor		Anaerobic Baffled Reactor		Combined Flow Constructed Wetland		Surface Flow Wetland		Overall treatment efficiency of the system
				Effluent Concentration	Removal %	Effluent Concentration	Removal %	Effluent Concentration	Removal %	Effluent Concentration	Removal %	Removal %
pH		6~9	6.85	7.02		6.99		7.16		7.16		
BOD_5	mg L^{-1}	50	381	141	62.99	69	51.06	48	30.43	40	16.67	89.50
COD	mg L^{-1}	200	4800	3072	36.00	2180	29.04	1032	52.66	180	82.56	96.25
TSS	mg L^{-1}	150	1830	600	67.21	110	81.67	60	45.45	40	33.33	97.81
TDS	mg L^{-1}	2100	1900	1860	2.11	1228	33.98	1130	7.98	770	31.86	59.47
FC	N/100 ml	1000	4600	3400	26.09	1600	52.94	1100	31.25	500	54.55	89.13
DO	mg L^{-1}	6.25	0.96	1.15	-19.79	0.9	21.74	1.32	-46.67	2.2	-66.67	-129.17
PO_4	mg L^{-1}	35	148	131	11.49	123	6.11	73	40.65	26	64.38	82.43
NO_3	mg L^{-1}	250	87	69	20.69	67	2.90	63	5.97	57	9.52	34.48

* Negative percentage indicates incremental phenomena

CONCLUSION

Considering the small isolated cluster having substantial numbers of people, DWTS seems to the perfect choice for wastewater treatment in Khalishpur People's Panchtola Colony. Also, the effluent quality of DWTS conforms Bangladesh Standard and therefore this option has been scientifically tested for further replication to the diverse contexts of Bangladesh. The beneficiaries along with the respective ward councilor have been very active and sincere in terms of participation in the process, significant contributions in terms of money, labor and land; playing very sincere roles on operation and maintenance; which indicates that option despite being a new piloting has been owned by the community. Also, in times of climate change, Khulna is one of the climate threatened divisions where DWTS should be perfect solution for wastewater management considering its proven climate change adaptation capacity. Apart from all positive findings with experience of DWTS in Khulna, there should be some challenges in future as of injecting the facilities within the City Corporation for future operation and replication. Construction cost as well as space would be another challenge as both the communities and government are still not yet prepared to spend such amount for improved sanitation where they have still been fighting with low cost latrines. But overall as second-generation sanitation problem is already knocking the door, therefore based on this successful experience in Khulna, DWTS must be considered as one of the ideal solutions where motivation, implementation, dissemination, advocacy and influencing should go in parallel.

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ANAEROBIC DIGESTION OF MACROALGAE

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ABSTRACT

Macroalgae biomass is a promising substrate for biogas production since it contains high amounts of carbohydrates, no lignin and little cellulosis. With the latter being difficult to digest anaerobically, the biogas production from macroalgae is likely to meet or surpass the methane yields achievable with terrestrial plants. However, to date macroalgae fermentation for energy production has barely been investigated, let alone implemented on large scale. This is even more surprising since all over the world macroalgae blooms degrading on the shores pose a threat to humans and the environment.
Fermentation experiments in batch flasks showed promising methane yields for the macroalgae Ulva lactuca, Fucus vesiculosus and Palmaria palmata. With 519 ± 90 mL CH_4 per gram organic dry mass, especially the latter came close to the methane yields achievable with maize (570 mL CH_4/g oDM) – a well-established bioenergy substrate.

INTRODUCTION

Starting with some early research in 1979 [Wise et al., 1979], the idea of using macroalgae as a substrate for anaerobic digestion has continued to evolve over the last decades with a large number of publications on the topic in recent years, [Cecchi 1996], [Matsui 2006], [Guiry & Guiry, 2010], [Roesijadi 2010], [Nikolaisen 2011], [Hughes 2012], [Viaroli 2012], [Jung 2013], [Wei 2013], [Balina 2015]. However, to date, macroalgae are still considered detrimental to the anaerobic digestion process especially because of their high salt content, [Baumann 2007], [Chen 2008]. The lack of knowledge on their properties in codigestion processes with for instance manure or slurry from animal farms is hindering large scale and thus an economically viable implementation to date.

STATE OF THE ART

Combining high water with low lipid and protein contents, the biochemical composition of macroalgae seems rather unfavorable for anaerobic digestion. Since macroalgae grow in high-energy environments, their tissues are characterized by a high tensile strength and flexibility, [Jeon 2012]. Compared to terrestrial plants, the chemical structure of the cell walls is more complex and thus more robust. Mainly consisting of polysaccharides hard to crack for microorganisms, the composition of the cell walls seems contradictory to high methane yields. However, the high content of monosaccharides together with a low cellulose content encourage investigating the anaerobic digestion properties of macroalgae. Consequently, several experiments have already been done to test the biogas- and methane yields of macroalgae as a co-substrate. Until now, the focus has been laid on the green algae *Ulva lactuca* with some studies dealing with the brown algae *Fucus vesiculosus* and the red algae

Gracilaria vermiculophylla and *Palmaria palmata*. *Ceramium rubrum* has not been investigated until now. The results of the studies are summarized in tableTable 1.

Summarizing, the anaerobic digestion of macroalgae led to 101 – 253 ml CH_4/g oDM with values varying according to the algae type as well as the chosen pretreatment strategy (fresh, dried, chopped, ground, etc.) and inoculum (cattle slurry, grass silage, waste water, etc.). Until now, only a few macroalgae species have been investigated under comparable circumstances making the documented results difficult to compare. It remains unclear which combination of algae and pretreatment strategy is most promising.

Table 1 Literature review for methane yields of different macroalgae depending on inoculum, algae type and pretreatment

	Parameters	Pretreatment	Algae	Methane yield [ml CH_4/g oDM]
Bruhn 2011	Inoculum: cattle slurry Ratio: 0,12 (based on oDM) 500 ml flask, 42 days at 55°C	unwashed, chopped,	*Ulva l.*	174
		unwashed, macerated		271
		washed, chopped		171
		washed, macerated		200
		washed, 20 min 110°C		157
		washed, 20 min 130°C		187
	500 ml flask, 58 days at 37°C	dried 45°C, ground		176
		unwashed, chopped		162
Allen 2013	Inoculum: cattle slurry, grease decantatation residues, Ratio: 1:3 (based on oDM), 500 ml flask, 28 days at 37°C	unwashed, fresh	*Ulva l.*	183,2
		unwashed, dried (air),		165,0
		washed, dried (stove),		250,2
		washed, dried (air)		221,1
Allen 2015	Inoculum: grass silage, cattle slurry, macroalgae Ratio: 1:2 (based on oDM) 400 ml flask, 30 days at 37°C	chopped < 4mm	*Fuc. v.*	126,3
			Fuc. s. [b]	253,2
			Fuc. s. [c]	101,7
Jard 2013	Inoculum: Waste water from sugar production industry Ratio: 1:2 (based on oDM) 500 ml flask, 40 days at 37°C	washed with sea water, dried (24 h, 40°C), chopped 2x2cm, ground	*Ulva l.*	241
			Grac.v.[a]	139

MATERIALS AND MEHODS

Biogas and methane yields of 5 macroalgae species, namely *Ulva lactuca, Fucus vesiculosus, Palmaria palmata, Ceramium rubrum* and *Gracilaria vermiculophylla*, are being assessed using pig slurry as inoculum. Following the german norm VDI4630, each algae type and pretreatment option is being tested in batch fermenters (triplicate). The pretreatment strategies are chosen in accordance of their feasibility on agricultural biogas plants. Varying between untreated, chopped (<1cm) and dried algae, the results of this experimental setup is giving first hints on the optimization of biogas production from algae at large scale. Furthermore each algae is being tested in different ratios of organic dry matter from inoculum to algae. Beginning with a ratio of 0.2, the amount of algae is being increased stepwise to 0.4 and 0.5 (only for *Palmaria palmata*) to assess possible negative impacts of algae on the fermentation process. The experimental setup is shown in figure Figure 1. The results are being interpreted using the algae-specific methane yields based on the organic dry mass in the batch fermenters.

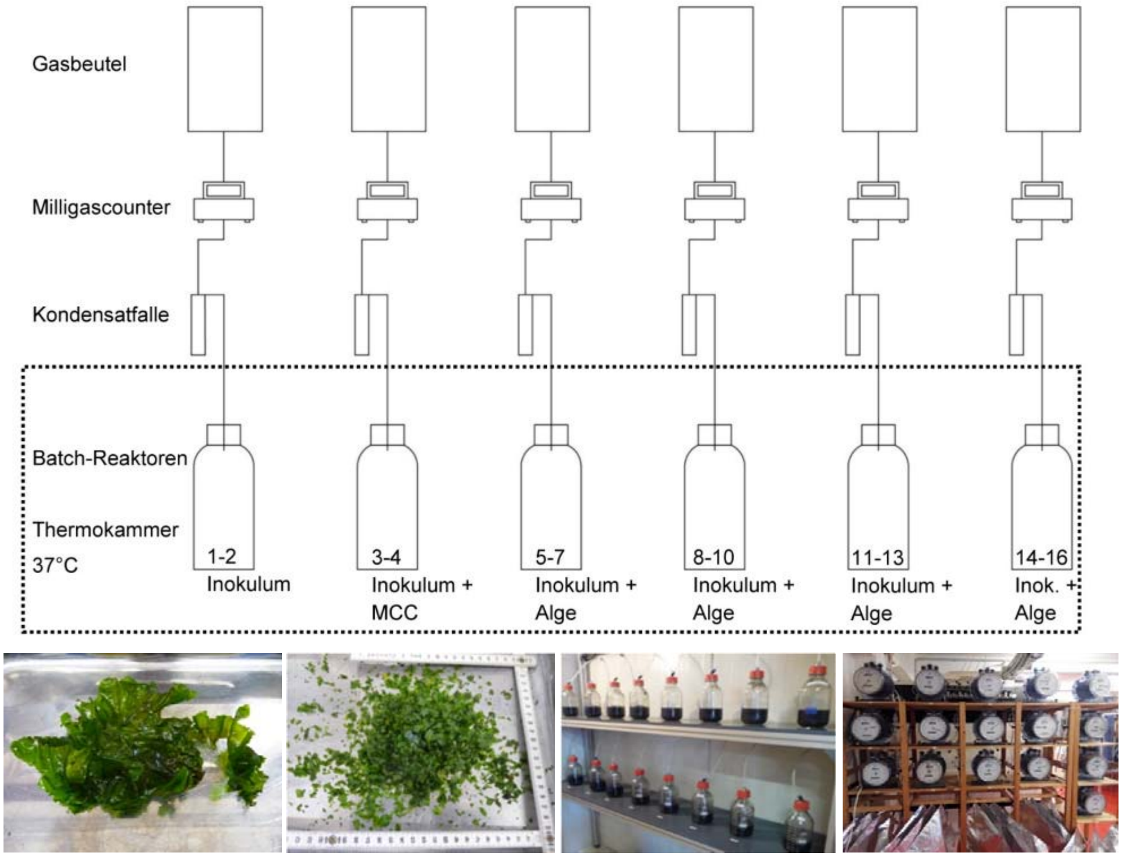

Figure 1 Experimental setup for batch tests investigating the biogas potential of macroalge

RESULTS

The results of the batch tests are displayed in Figure 2 and Table 2. Based on the organic dry mass, the red algae *Palmaria palmata* achieved the highest methane yields with gas amounts ranging from 112.07 (ratio 0.2, untreated) to 517.73 NmL CH_4/g oDm (ratio 0.5, chopped), followed by the brown algae *Fucus vesiculosus* (97.54 dried, at ratio 0.2 to 145.16 NmL CH_4/g oDm untreated, ratio 0.2) and the green algae *Ulva lactuca* (59 dried, at ratio 0.2 to 139.72 NmL CH_4/g oDm at ratio 0.4). Comparing the methane yields of differently pretreated algae, it becomes obvious that drying the algae is detrimental to gas yields, while chopping the algae mainly increases the methane yields. Except for the algae *Fucus vesiculosus*, increasing the ratio of algae biomass to inoculum leads to higher methane yields, thus showing that most algae have no negative effect on the biogas process itself. Comparing the achieved methane yields of algae reaching from 140 to 518 NmL CH_4/g oDm with the results for maize – commonly used as biogas substrate in Germany – it becomes clear that especially *Palmaria palmata* is achieving similar levels of methane.

Summarizing, mesophile anaerobic codigestion of macroalgae in pig slurry seems promising. However, as shown in Table 2, the achieved methane yields were significantly lower than those documented in literature. Only Gracilaria vermiculophylla achieved higher yields than published in [Jard 2013].

Table 2 Summarized results of the achieved methane yields compared to literature data. . [1][Bruhn 2011], [2][Allen2013], [3][Jard 2013], [4][Allen2015]

	Methane yield in [ml CH_4/g oDM]	
Species	Literature	Exp. Results
Ulva lactuca	157 – 271 [1,2,3]	68 – 139
Fucus vesiculosus	101 – 293 [4]	97 – 145
Ceramium rubrum	-	115 – 212
Gracilaria vermiculophylla	139 [3]	82 – 208
Palmaria palmata	-	112 - 517
Maize		570

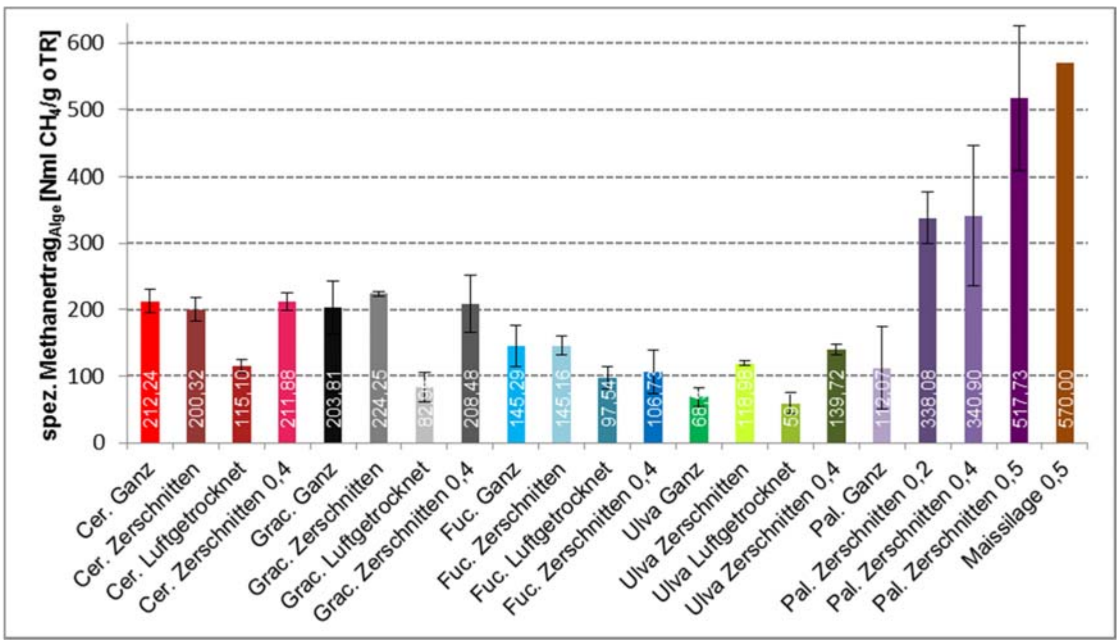

Figure 2 Algae-specific methane yields based on organic dry mass (oDM) using 3 pre-treatment methods (untreated, chopped, dried) and 2 respectively 3 ratios of algae to inoculum.

CONCLUSION

The anaerobic digestion of macroalgae seems promising. To confirm the batch-test results, lab-scale experiments in continuously stirred 40-liter fermenters with the macroalgae *Ulva lactuca, Fucus vesiculosus* and *Palmaria palmata* are being carried out currently to test macroalgae properties in anaerobic digestions in larger scale and over time.

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EXPERIANCE SHARING OF EMERGENCY FAECAL SLUDGE MANAGEMENT WITH BIOLOGICAL TREATMENT PROCESS IN ROHINGYA RESPONSE

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ABSTRUCT

Fecal sludge management is always challenging specially in emergency Rohingya response where thousands of toilets are filling up daily and increasing the risk of fecal contamination. Managing fecal sludge is a multidimensional problem and the solution includes end up open defecation, Fecal Sludge Management (FSM), proper hygienic practice and so on. To address the problem and ensuring safeguard from fecal contamination about 30 FSM plants are constructed. Each system comprises full sanitation chain and capability to serve about 150 toilets in stated context. Till now about 4.00 million liters sludge are safely managed with those units. As an example, in camp 6 total 9 FSM unit is covering 11 out of 41 blocks (27%). More than 20 diseases are classified in seven categories can be spread out from unmanaged fecal sludge. Each unit of about 50 sqm. have capability to treat 10 cum. FS weekly up to 7 years and per cum. sludge management cost is only about 5 USD.

INTRODUCTION

Bangladesh opened its border officially for forcibly displaced Myanmar nationals from 25 August,2017. Since then about 905,000 people fled to Bangladesh from persecution of Myanmar military in Rakhine state. First, they started trespassing to Bangladesh in 1970. From 1970 to before opening border officially about 300000 to 500000 people entered Bangladesh different time. About every family here in refugee camp lost someone nearest; killed or raped in front of their own eye. As a part of planned ethnic cleansing, Myanmar military set fire on thousands house of Rohingya, killed and torturing them in tormenting way, raped their women and child. When Bangladesh government has opened its border officially, they found the hope of light towards life. A new journey began in Rohingya camp.

It was not too easy to manage a huge influx of Rohingya population, their food, shelter, health, water and sanitation facilities. Specially managing water sanitation and hygiene (WASH) facilities are very tough here. Dense population, hilly and rocky terrain, lack of transport facility available materials and technicians, urgent need of huge number of toilet and most importantly they are not used to using proper sanitation system and they feel free in open defecation. Challenges to provide the WASH facilities for them are not limited to above and mostly all of them are illiterate about sanitation and hygiene practice. Different government, non- government organizations, local host community, rich people, different companies and groups came forward to help Rohingya people. Among them so many are involved with installation of tube wells and toilets. As there were no proper management and coordination different parties are installing tube wells and latrines here and there, and within a short time latrine are being filled up. As there were no desludging and Faecal Sludge Management (FSM) system, decommissioning existing toilets and finding another place for new toilet was the only option. At the beginning there were enough land to find out another place for latrine after buried one but within a few months finding land also became hard due to huge influx of Rohingya population. Burying latrines with untreated faecal sludge also increased the risk of health hazards for people.

BACKGROUND AND APPROACHES

To solve the faecal sludge management problem, WaterAid planned to introduce context specific Faecal Sludge Management (FSM) plant for refugee camp. Some emergency low cost, low maintenance and low land required biological FSM plant is designed for Rohingya response at kutupalong . Primarily total twenty FSM (20) are established in different zone of kutupalong Rohingya camp. Each FSM plant are designed to serve about 150 toilets surrounding of plant and it can accumulate about 10 cubic meter faecal sludge per week. Total land required for biological treatment unit is about 50 to 60 square meters. An intermediate transfer station is required to transfer sludge form toilet to treatment unit. To complete the whole operation two group of ten Rohingya people are trained on communication with Mazhi(Rohingya Leader), Stabilization of sludge, desludging it and maintaining the biological treatment plant. When any toilet filled up or seems going to filled up within few days, responsible mazhi or nearest household member contacts with focal of trained team and tells him the location of toilet. Desludging group goes there and complete sludge stabilization which generally takes about two days. Then they use special type of pump to transfer stabilized sludge from toilet pit to transfer station. From transfer station, sludge automatically goes to treatment plant by gravity flow. In treatment plant biological treatment process is conducted automatically by constructed wetland plant. The details of treatment process will be discussed in technical part. As the treatment process run automatically and no intervention required from outside, no or very less technical support required for managing the system and trained group of Rohingya people can manage this system. Till January 2019, total 30 FSM plant are constructed in different camps.

TECHNICAL DETAILS OF FSM FOR EMERGENCY ROHINGYA RESPONSE

MAIN IDEA: This is a simple biological system where a special type of generator driven motor is used for emptying fecal sludge and sent to transfer station (TS). From TS, sludge goes to constructed wetland-based treatment plant in gravity flow. This treatment plant takes about 50-60 squire meter land and divided into two parts. One is planted with different types of wetland plants where sludge comes from transfer station and treated in root zone of plant by root zone bacteria within a certain period of time in dry-wet-dry-wet cycle. Treatment Process includes but not limited to nitrification denitrification, phytoremediation, complexation, Rhizofiltration, aerobic/anaerobic microbial degradation, filtration, predation etc. The liquid of FS flows horizontally and passes the longest route to go to sand filter, where liquid part further refined in up flow method. After chlorination it become ready for final disposal.

TECHNICAL DETAILS: Before two days of emptying any toilet, 250 gm of Alum is poured in faecal sludge of pit and stir it with bamboo and the same process is done in second day. In third day, only alum is poured not stirred to ensure the final stabilization of sludge. Alum is used here as flocculants, so that solid and liquid part can be separated. At a time, desludging team clean about 50% of a toilet to keep more toilet functional with desludging same volume of sludge. With a motor and pipe system the sludge is transferred to transfer station. Transfer station is a 1 cubic meter box which is constructed with brick wall and cement plaster over it. This transfer station is connected with biological treatment unit by PVC pipe. Generally, transfer station situated uphill and biological treatment unit is in downhill so that sludge can automatically have transferred from transfer station to biological treatment unit in gravity flow.

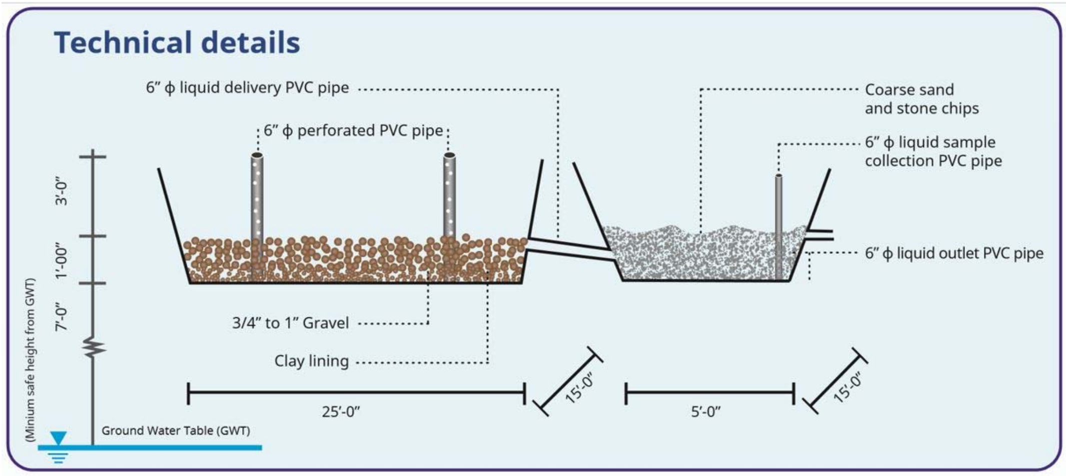

Figure 1: Design of Biological Treatment Part

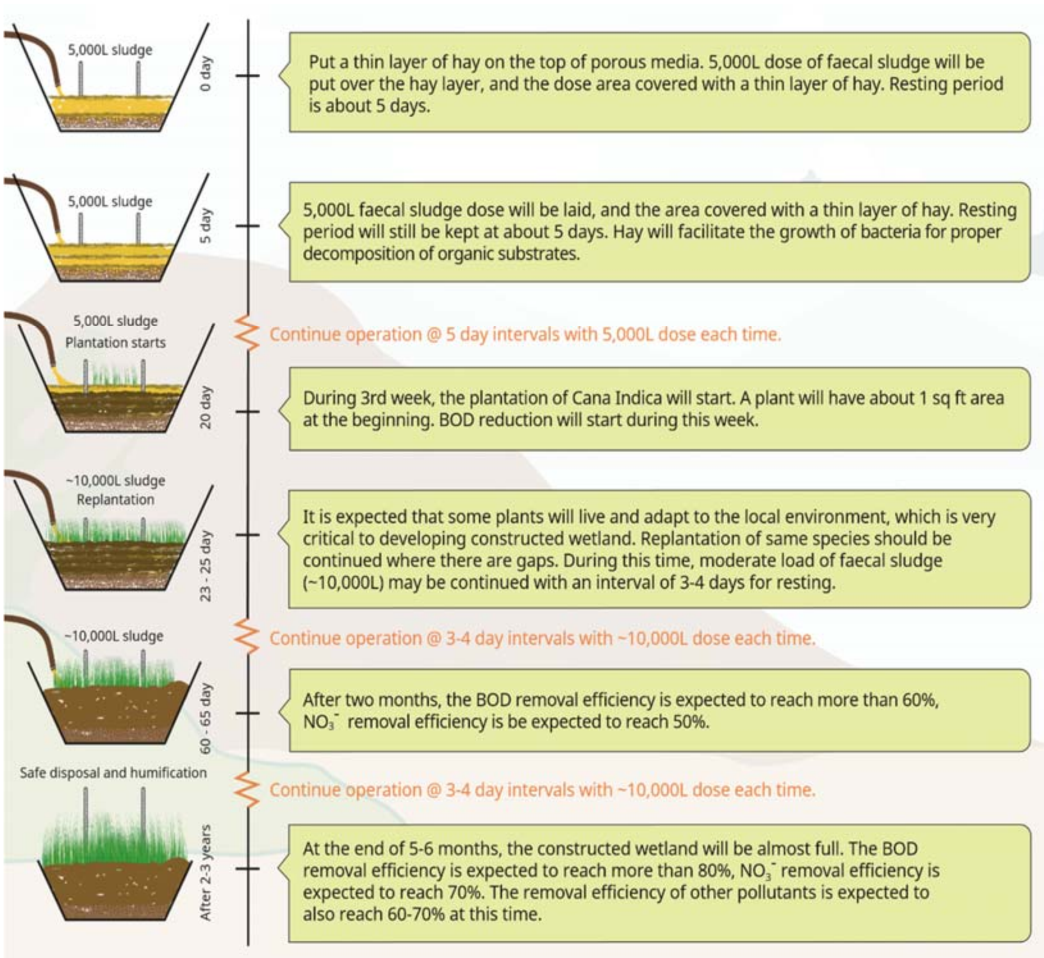

Figure 2: Gradual Development of Biological Treatment Unit

Biological treatment unit is composed of two part (Figure *1*). One is constructed wetlands where sludge comes from transfer station in gravity flow and another is filtration chamber where liquid part is treated finally (secondary treatment) for disposal to environment. There is an underground pipe to connect construction wetland part and sand filtration chamber. After primary treatment liquid passes to filtration chamber from constructed wetland part through this pipe. Constructed wetland is made of clay lining, Stone chips and plants for biological treatment. Two perforated pipes are being used to ensure oxygen availability in root zone of plant, which is the basic requirement for aerobic bacteria. As the decomposition process is done automatically with root zone aerobic bacteria, no extra care or technical people is required regularly which makes this system easily operate able and maintainable. As this is a biological system, it requires proper time and gradual development to be fully functional (Figure *2*). 30 mm compacted clay layer is used to prevent infiltration of untreated liquid part to the ground. Generally, lily, Cana Indica, P. Australis are used as plant (Figure *3*)

Figure 3: Different types of plants are used in FSM treatment plant (constructed wetland unit)

Figure 4: FSM plants from outside

Plants plays a very important role in this treatment process. Plant evapotranspiration reduce the volume of sludge, its root zone supports aerobic bacteria which involves with different process of sludge and water treatment. In aerobic treatment process nutrients are break down in two or three steps. Involvement of bacteria is very important here. The processes are but not limited to:

Organic matter + O_2 + nutrients$\rightarrow$ CO_2 + H_2O + $C_5H_7NO_2$ + other products

Where $C_5H_7NO_2$ are the newly synthesized cells.

$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3$ + energy

Again, in nitrification process nitrosomonas and nitrobacter produced nitrate which become gaseous nitrogen in denitrification bacteria. Pathogen is removed in different part of constructed wetland system by its process and through predation of root zone bacteria and protozoa. A number of physical and biological process are involved with pathogen removal. Natural die off is also a part of pathogen removal in planted dyeing bed.

SOME DATA AND EXPERIENCES

From September 2017 to 2019 total thirty faecal sludge management unit are constructed in different camps to keep operating the toilets and ensure healthy sanitation system. Total about 4 million liters of fecal sludge from 4 camps are treated with 30 FSM unit from the beginning (*Table 1*). One FSM system can cover about 150 Latrines that means total 30 FSMs are capable to serve total 4500 toilets. Now total 30 FSMs are serving about 2500 toilets of five camps. There are total about 48000 operational toilets in Rohingya camps which requires FSM support. (ISCG-WASH, SITUATION REPORT ROHINGYA REFUGEE CRISIS-January,2019, January, 2019)

Table 1: Amount of Sludge Treated in Different Camps with Different Number of Treatment Unit

Sl. No	Camp	Number of treatment unit	Average Volume of treatment unit in cum.	Total Sludge volume treated
1.	1	6	30	879225
2.	2	4	35	558450
3.	3	10	55	1238700
4.	5	1	51	115050
5.	6	9	50	1215150
			Total Sludge Volume Treated	**4006575**

Other than 30 FSM Plant of WaterAid 150 more FSM plants are constructed (ISCG-WASH, ISCG WASH Sector, 2018) by different organizations to serve the increasing demand. Out of 47923 Latrines only 9055 are (as per December 2018) under FSM coverage. Only 18.8% toilets are under coverage of FSM plant (ISCG-WASH, ISCG WASH Sector, 2018) and most of the remaining toilets are desludging directly to lake or free lands or sometimes they are kept nonfunctional due to proper desludging. In camp 1E and 1W WaterAid has total six (6) FSM plants and total 14 FSM plants including other organizations which are supporting total about 730 toilets out of 3013 toilets. Total FSM coverage is about 24.23% (1E 47% & 1W 13%). (ISCG, WASH Sector FSM Site Mapping, 2018). In camp 2E and 2W WaterAid has total four (4) FSM plants and total 28 FSM plants including other organizations which are supporting total about 886 toilets out of 1288 toilets. (ISCG, WASH Sector FSM Site Mapping, 2018) Total FSM coverage is about 68.79% (2E 71% & 2W 68%). In camp 3 WaterAid has total ten (10) FSM plants and total 12 FSM plants including other organizations which are supporting total about 1037 toilets out of 1935 toilets. Total FSM coverage is about 54%. In camp 5 WaterAid has only one (1) FSM plants and total 12 FSM plants including other organizations which are supporting total about 1148 toilets out of 1880 toilets. Total FSM coverage is about 61%. In camp 6 WaterAid has total nine (9) FSM plants and there are no other FSM plants of other organizations. Only nine FSMs are supporting total about 726 toilets out of 1535 toilets. Total FSM coverage is about 47.29% A list of FSM coverage in camps where WaterAid has fecal sludge management plant are given bellow in *Table 2*:

Table 2: FSM coverage in different camp

Sl. No	Camp	Number of total FSM	Number of Toilets	Number of Toilets Under FSM coverage	Percentage of toilet coved by FSM
1.	1	14	3013	730	24.23%
2.	2	28	1288	886	68.79%
3.	3	12	1935	1037	54%
4.	5	12	1880	1148	61%
5.	6	9	1535	726	47.29%

Out of 180 FSM plants 43 FSM plants are using constructed wetlands technology to treat fecal sludge. Oher than that lime stabilization, up flow filtration, solid separation unit, anaerobic digestion etc. are popular methods there for fecal sludge management.

Compared to other system constructed wetland-based FSM system is totally biological and environment friendly and required very less land with high amount of sludge treatment capacity (about 2.6 million liter) in full lifetime (about 5 to seven years). The operation maintenance and treatment cost are also very low and estimated about 5 USD for each cubic meter sludge including infrastructure construction and yearly renovation cost.

CONCLUSION

About 44 organizations are working on WASH in different camps and 20 of them are working actively (ISCG, Operational Presence in WASH Sector, 2019). Among them 12 organizations are implementing FSM plant (ISCG, Operational Presence in WASH Sector, 2019) and managing fecal sludge with those. Only about 19% toilets are covered by FSM plants in Rohingya camps and about 2% are covered by bio gas plants. WaterAid is covering about 4% toilets of total camps which is not enough but the context specific, low cost, biological sludge treatment process can be replicate in different camps to ensure easy and handy Fecal Sludge Management solution. With further research and exploration this system can be a scenario changing agent of sanitation system in emergency response.

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Paper ID: 127

Faecal Sludge and Municipality Solid Waste Co-Composting Plant, Jamalpur

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ABSTRACT

BRAC WASH programme initiated a pilot faecal sludge management (FSM) operation in Jamalpur municipality. Upon approval from the municipality authority, BRAC WASH renovated the municipality owned FSM treatment plant. It formed a pit emptier group and trained them for safe emptying and transportation. It built a country made vacutug and started emptying of the filled pits/septic tanks of the households inside the municipality. It also included the municipality solid waste emptying and reuse service through collection from the households and reuse them for co-composting with faecal sludge. At present BRAC WASH is operating solid and faecal waste collection through five waste collecting vans and one motorized vacutug. Along with this advocacy, meetings with municipality and promotional activities among the community people also carried out regarding FSM.

MAIN TEXT

Jamalpur municipality was established in 1869. It is the second largest A "class municipality with an area of 53 square kilometers. Municipal ward quantity 12, the total number of households 35375, the total population 148219.
Jamalpur municipal waste management system has received 110 dustbins. Municipal workers assigned to clean those dustbins through the municipal waste collection vehicle to its reserved dumping site. Municipality has 35 cleaning staff and one waste collection truck for this purpose. This waste collection chain covers six of the twelve wards. Remaining wards' households manage their waste at individual level. No waste treatment facility is currently operational in Jamalpur. A partially completed waste treatment plant is there but no operation has been carried out on that.

There was no operational FS treatment plant in Jamalpur. Both the City Authority and informal groups dump the collected sludge indiscriminately, polluting the environment. The present sludge management service is neither effective nor sustainable. As a result, many consumers illegally connect their toilet outlets to storm drainage. Some disadvantaged groups have no access to storm drainage or pit emptying services, so their toilets simply overflow with feces leading to filthy and very unhygienic conditions. This drives them to abandon their toilets, ultimately leading back to open defecation, further polluting the environment and deteriorating public health.

Upon successful completion of 6 months pilot FSM operation in Jamalpur, BRAC WASH has started full scale implementation in order to carry out the success gained in the pilot phase. The duration for FSM operation in Jamalpur is January 2017 to December 2020.

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Figure 1: Formation of pit emptier and waste collector group

Activities completed

- Formation of skilled pit/septic tank emptiers
- Health and occupational safety training of the emptiers
- Repair and activation of the treatment plant
- Emptying of pits/tanks in a hygienic way
- Safe transportation of sludge and solid waste to treatment plant
- Treatment and reuse of faecal sludge and solid waste
- Development of organic fertilizer and marketing

Process Description

The technical operation of the plant follows a process cycle. It starts with collection of faecal sludge from the pits/tanks. The emptiers use a customized vacutug and pump to collect the sludge from the pits/tanks. They use safety gears such as gloves, coverall and goggles during collection. The transportation of the sludge to the treatment plant is done by the customized vacutug.

The sludge is disposed to the mixing chamber of the treatment plant. The sludge contains a liquid: solid ratio of 90:10. Thus the solid is subjected to be mixed with the liquid manually.

After proper mixing the sludge is disposed to the next chamber, the drying chamber. This chamber has sand bed which separates the liquid from the solid. The solid remains on the top of the sand bed for drying. The liquid is passed through the sand bed to a soak pit for being discharged to the soil.

The solid is subjected to be dried for 15 days. The dried sludge (sludge cake) is collected, weighted and subjected to co-composting. Municipal solid waste (MSW) is being collected from the households and municipality dumping spot. The MSW is sorted and shredded before weighing. Then the weighted MSW is subjected for co-composting with the sludge.

The MSW is being mixed with the sludge in 2:1 ratio. That means 2 kg of MSW is mixed with 1 kg of sludge cake. The sludge cake contains inherent moisture of 10%-15 %. The MSW contains a moisture of 20%-25%. The co-composting continues for 45 days. The co-composted fertilizer is dry, odorless and granular in shape.

The co-compost is graded through strainer and weighted for packaging. The dry compost has a moisture value of 10%-15% and contains no pathogens (Dey, 2016).

The process of the treatment and co-composting is illustrated below through a flowchart.

Figure 2: Stages of producing organic fertilizer in the FSM co-composting plant

<u>Achievements of FSM co-composting plant up to December 2018</u>

- Emptied and transported 135,156 liters of sludge (140 pits and 22 septic tanks)
- Treated 10,730 kg of dry faecal sludge
- Treated 22,225 kg of municipal solid waste
- Produced 4,011 kg of organic fertilizer

Figure 3: Advocacy and promotional activities regarding environmental FSM

CONCLUSION

However, practice of using faecal sludge as organic fertilizer yet new in Bangladesh. Advocacy with the local community and concerned authorities is therefore required to promote such activities.

The programme is facing challenges in the following areas to operate the FSM co-composting plant. These are:

- Acquiring suitable Vacutug at low cost
- Poor acceptance of organic fertilizer produced from faecal sludge
- No regulation available on pit emptying tariff, thus households show tendency to negotiate on tariff
- Unwillingness of the pit emptiers to work for FSM plant

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STUDY ON BIOCONVERSION OF HOUSEHOLD WASTE AND FAECAL SLUDGE THROUGH VARIOUS COMPOSTING PROCESS

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ABSTRACT

The aim of this research work was to prepare, analyze and compare different properties of three types of compost [(a) organic solid waste compost, (b) co-compost of faecal sludge and organic solid waste and (c) vermicompost of faecal sludge and organic solid waste] ensuring SRDI standard. In this purpose solid waste and faecal sludge were collected at the waste management plant of KUET campus. Dried faecal sludge and organic solid waste were mixed at 1:3 ratio to prepare co-compost. For vermicompost Eisenia fetida earthworm species was used. A 56 days cycle of composting period was considered for maturation. The prepared composts were slightly alkaline. Moisture content, total organic carbon and TVS decreased during composting process. A reverse scenario was observed in case of fixed solids and total kjeldhal nitrogen content. The C/N ratio and total phosphorus content was within the recommended range for all type of compost. But only faecal sludge vermicompost satisfied the SRDI standard value for total potassium content. At maturation stage the number of faecal coliforms decreased by 50 times with respect to the initial condition.

INTRODUCTION

The population explosion causes more and more production of different types of waste. This bang in waste production leads to inappropriate damping. Stabilization of these waste before damping is a fruitful way to reduce the health and environmental risk associated with improper damping. There is various process for the biological stabilization of solid waste products. Among those process composting, co-composting and vermicomposting are well known and effective for a large variety of waste (Domínguez & Edwards, 2010). Composting has gained its importance in municipal solid waste management process. Composting can be done both for organic solid waste and to a mixture of biodegradable fraction of solid waste with faecal sludge which is termed as co-composting (Alamin *et al*., 2017). Vermicomposting is a special type of composting in which, biodegradable fraction of waste is converted into a better end product by using certain species of earthworm. It is quite similar to the composting process. In this process, aerobic transformation of organic by product takes place. This transformed organic product can be used in crop production without any detrimental effects (Baca *et al.*, 1992). The conventional concept of compost involves the management of decomposable organic solid waste. Sometimes it may include cow dang, saw dust etc.

The idea of co-composting faecal sludge (FS) with organic solid waste (OSW) has become a positive solution to many problems including the management of faecal sludge in an efficient and environment friendly manner. Faecal sludge contains a large content of nutrition. Co-composting of faecal sludge and organic solid waste allows recycling of nutrients into agriculture thereby closing the nutrient loop (Alamin *et al*.,2017).

Vermicompost is a naturally rich soil conditioner. It slowly releases the nutrients into the soil to improve the physicochemical and biological characteristics of the soil. Through this process it provides beneficial impact on plants. Similarly, composts provide nutrients in a readily available form which enhances the uptake of nutrients by plants. This improves the growth and yielding of crop products (Sreenivas *et al.*, 2000). In recent years, vermicomposts is largely used in different parts of the world. The main reason behind this is its low cost and large amount of waste conversion capacity. It is also remarkable that it can convert a variety of wastes *i.e.* sewage sludge, paper industry wastes, food and animal waste as well as residues from cultivars (reviewed in Domínguez, 2004). The final end product of vermicompost is finely divided peat like materials which shows high porosity and water holding capacity. It also contains many nutrients in a form that can be readily uptaken by plants.

The present study aims to prepare compost from organic household wastes, co-compost with faecal sludge and organic waste and vermicompost with earthworms. Analyzing the quality of produced compost, co-compost and vermicompost will be a major part of this study. This analysis will include the physical and chemical properties of the composts. This study will also focus on the comparison of the analyzed properties of prepared composts.

The main objectives of this study are:

- To prepare (a) compost from organic household wastes, (b)co-compost with faecal sludge and organic waste (c) vermicompost with earthworm.
- To analyze different properties (i.e. pH, moisture content, total organic carbon, total nitrogen, total phosphorus, total potassium, TC, FC, Fixed Solids, Volatile Solids, Color and Odor) of the prepared composts.
- To compare the quality of three different types of compost [i.e. (a) compost from organic household wastes, (b)co-compost with faecal sludge and organic waste (c) vermicompost with earthworms] ensuring compost standard provided by Soil Resource and Development Institute (SRDI).

MATERIALS AND METHODS

Research Location and Raw Materials

The research work was conducted in Khulna University of Engineering & Technology (KUET) campus. The sludge samples were collected from a septic tank located in the premises of KUET. The organic solid waste samples were collected from the waste management plant of KUET. The research work was carried out at the waste management plant of the KUET campus. The laboratory works were performed in the Environmental Engineering laboratory of the Civil Engineering department of KUET.

The FS was first pre-treated by dewatering in drying bed before co-composting. A Faecal Sludge drying bed was prepared beside the waste management plant. The bed is of 12.5X12.5 size having a sloppy bed surface with maximum depuration at the middle. The least depth of the bed 6in. was at the edges of the bed and maximum depth was at the middle 8in. The bed was constructed with gravel-sand filter material of different layers, thickness, and particle sizes. The dewatering unit is used is to produce sludge of suitable water content, before composting with SW. The dewatering process was continued for 15 days.

Solid wastes were collected from the waste management plant of KUET campus. This management plant collects waste from the 7 residential halls and all the teachers and officer quarters daily basis. The solid wastes were collected at the same date of faecal sludge collection. Co-compost quality greatly depends on the quality of input material. Substances which are not biodegradable are being separated from the biodegradable fractions. Sorting is especially crucial with regard to hazardous waste.

In case of vermicomposts earthworms were collected with the help of a private collector of the locality. For this experiment *Eisenia foetida* type of earthworms were collected. They are typically 2.5-3inch long. July-August are their breeding time. But at favorable condition they can breed throughout the year. Generally, one kilogram of worm contains approximately 1000 number of worms. Around 500 numbers of worms can be collected in one-liter container. Worms should be applied within 5-6 hours of the collection. In this experiment the collected worms were applied immediately after collection.

Faecal Sludge and Solid Waste Mixing Ratio for Co-compost

For the better quality of co-compost, the faecal sludge and solid waste mixing ratio should be carefully maintained. In this case the ratio was kept 1:3. In previously conducted research work Hafiz *et. al.,*2017 this ratio shows the better result than others. Based on that in this research 1:3 ratio is taken. Faecal sludge and sloid waste should be mixed thoroughly.

Experimental Process

Total process involved in this research work is presented by a flow chart given in Figure 1

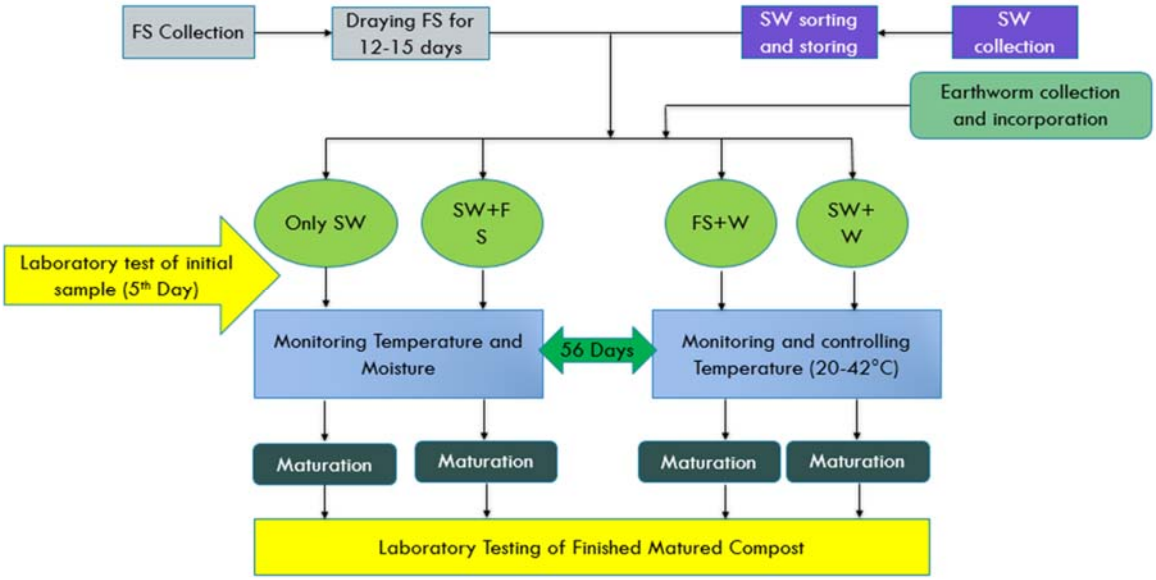

Figure 1: Experimental Process Flow Chart

Here, SW= Solid Waste
SW+FS= Solid Waste + Faecal Sludge Co-compost
FS+W= Faecal Sludge + Earthworm
SW+W= Solid Waste + Earthworm

At first raw faecal sludge samples were collected from the septic tanks of the KUET campus. Then they were dewatered for 12-15 days in the prepared drying bed. At the same time solid waste samples were collected from the waste management plant of KUET campus. The collected solid waste samples were sorted for inorganic, harmful and toxic elements. Than the composting process was started. Vermicomposting process is slightly more complicated than the other types of composting process due to the presence of vermiworms. Vermiworms are very much sensitive to the heat, temperature and light. So, the whole process was done in a cold and damp place. Temperature was maintained very carefully. In this experiment, the highest temperature of solid waste vermicompost was recorded as 40°C. Then the temperature decreased and merges with the ambient. In case of faecal sludge vermicompost highest temperature was 38°C. The compost heap was covered with a piece of black cloth to avoid the effect of light. This also produce a damp condition inside the heap chamber.

Maturation

Total composting operation continued about 50 days. During this time the compost mass turned into soil type color. The absence of foul odor is also an indication of compost maturation.

Vermicomposting is a continuous process. It also depends on the amount and type of feedstock. The first cycle of maturation takes longer time then the next cycles. It takes roughly about 50-55 day to mature the first cycle.

Laboratory Testing

Laboratory tests of various samples is the most important part of the research work. It involves from collection to sampling for various parameters as per standard methods. Different types of tests (physiochemical, microbial) have been performed for different samples that were collected. The whole experiment was carried out in the Environmental Laboratory in KUET campus, except total Phosphorus (P) and total Potassium (K) tests. Total Phosphorus (P) and total Potassium (K) parameters were experimented at Soil Research and Development Institute (SRDI) in Dhaka.

RESULTS AND DISCUSSIONS

Mainly three types of composts were prepared in this research work. These were compost from organic solid waste, co-compost of faecal sludge and organic solid waste and vermicompost with *Eisenia foetida* earthworm. Prepared vermicompost were of two kinds *i.e.* faecal sludge vermicompost and organic solid waste vermicompost.

Color and Odor
From the final condition result it is seen that, color, odor and moisture that was observed is satisfactory which depend on the local climate, constituents of the OSW, local human nature, etc. prototype compost was dark gray in color, absence of foul odor, and dry in combination. Physically there is no significant difference between three types of co-compost. Although particle size analysis was not carried out, there was no significant difference in texture of finished compost.

pH
pH is an important indication of compost maturity. It can be seen that the pH values are within the recommended values 3-11 for compostable substance (De Bertoldi *et al*., 1983). Figure 2 shows the variation of pH value at initial and final condition.

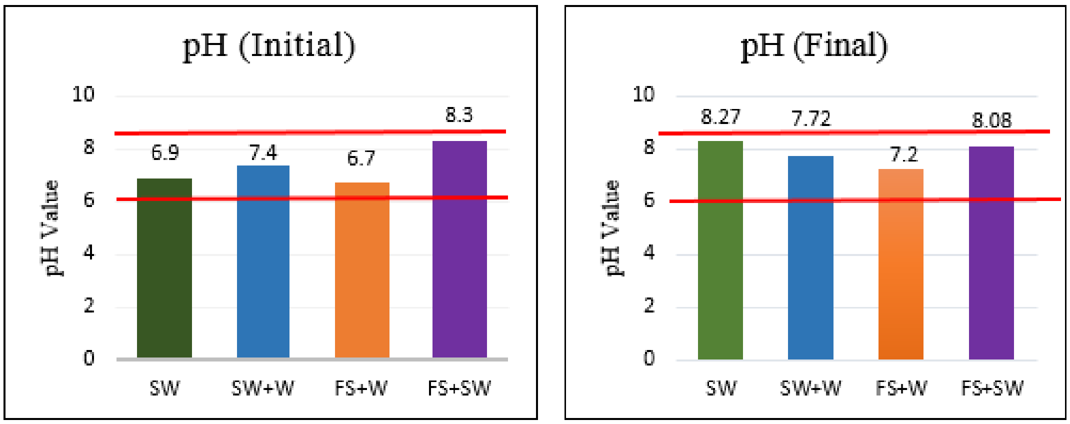

Figure 2: pH content at initial and final stage of composting

In this experiment initially, pH values of different composts were*.* 6.9 for solid waste sample, 7.4 for solid waste vermicompost, 6.7 for vermiculture of faecal sludge and 8.3 for faecal sludge and solid waste co-compost. Finally, these values were found as 8.27, 7.72, 7.2 and 8.08 respectively. At finished condition pH values for the prepared composts are within the pH range of 7.1-8.6 reported by Bernal *et al*.,1998 for composts of various organic waste sources like sewage sludge, animal manure, city refuse, industrial and plant refuses. Earthworms and microorganisms are able to change the soil pH (Suthar *et al.,* 2015). Low pH at initial period is due to the formation of carbon dioxide and volatile fatty acids. But in case of co-compost of faecal sludge and organic solid waste initially the pH value was high. It can be explained by solubilization of ammonia leading to ammonium formation (Omrani *et al.,* 2005, Suthar *et al.,* 2015). In later stages of the experiment, the action of aerobic microorganisms increases the decomposition. Which leads to formation of alkaline materials in presence of sufficient moisture (Yousefi *et al.,* 2012, Parvaresh *et al.,* 2004). If compost is highly alkaline or acidic then it will harm the soil condition and even adversely affect the fertility of soil resulting in a decrease in crop production. It may also cause immature destruction of crops. Thus, the pH of compost should be within the desirable level for the soil. According to the SRDI standard the pH of compost should be within 6 to 8.5. The marked red lines show the SRDI standard range.

Moisture Content
Moisture content is an important indication of maturation. In normal and co-compost, the microorganisms take up nutrients in a thin film of water. In case of vermicompost it is essential to maintain a certain moisture in the compost to provide favourable condition for the vermiworms to breed. Also, to maintain the temperature level in vermicompost the moisture content can be modified. The moisture contents in the composts were initially high *i.e.* 52.73% for solid waste sample, 55.67% for vermiculture of solid waste, 27.97% for vermiculture of faecal sludge and 44.09% for faecal sludge and solid waste co-compost. At final stage the moisture content dropped to the following 21.52%, 19.86%, 18.60% and 18.98% respectively. The marked red lines show the SRDI standard range. Figure 3 shows moisture content at initial and final condition.

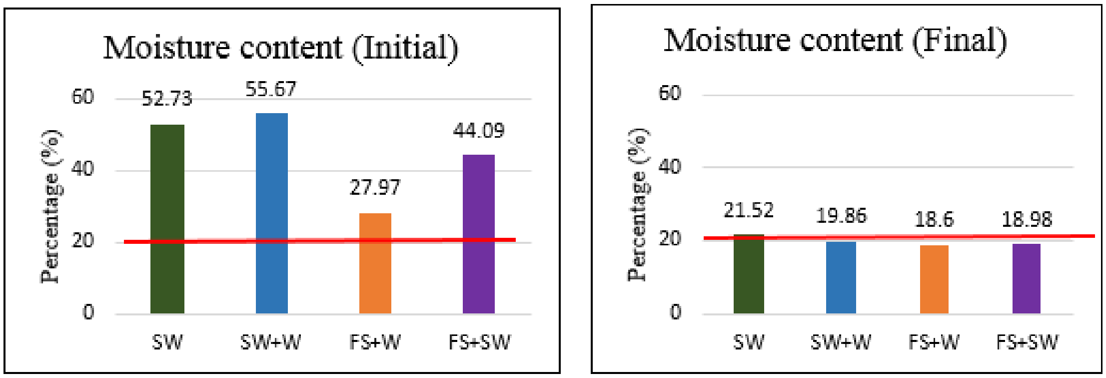

Figure 3: Moisture content at initial and final stage of composting

Total Volatile Solids (TVS) and Fixed Solids (FS)

At initial condition total volatile solid content was found as 62.4% for solid waste sample, 56.08% for vermiculture of solid waste, 40.22% for vermiculture of faecal sludge and 53.08% for faecal sludge and solid waste co-compost. As in final condition these values decrease to 27.24%, 23.11%, 20.37% and 25.25% respectively. The degradation of organic material is the reason behind this drop in TVS value (Bernal *et al*., 1998). Figure 4 shows TVS at initial and final condition.

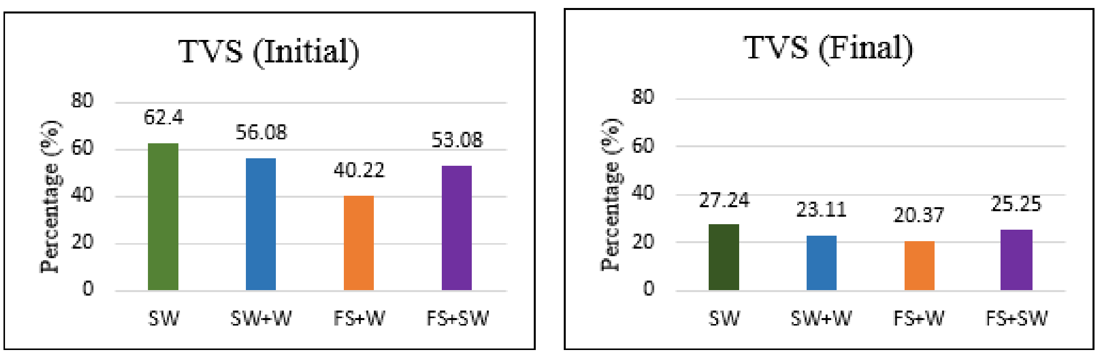

Figure 4: Total Volatile Solid (TVS) content at initial and final stage of composting

In case of fixed solids (Figure 5) at initial condition obtained values were 37.6% for solid waste sample, 43.92% for vermiculture of solid waste, 59.78% for vermiculture of faecal sludge and 46.92% for faecal sludge and solid waste co-compost. At final conditions these values increased considerably and found as 72.76%, 76.89%, 79.63% and 74.75% respectively. This increase in fixed solids content is due to the moisture decrease in the composting process. The marked red lines show the SRDI standard range.

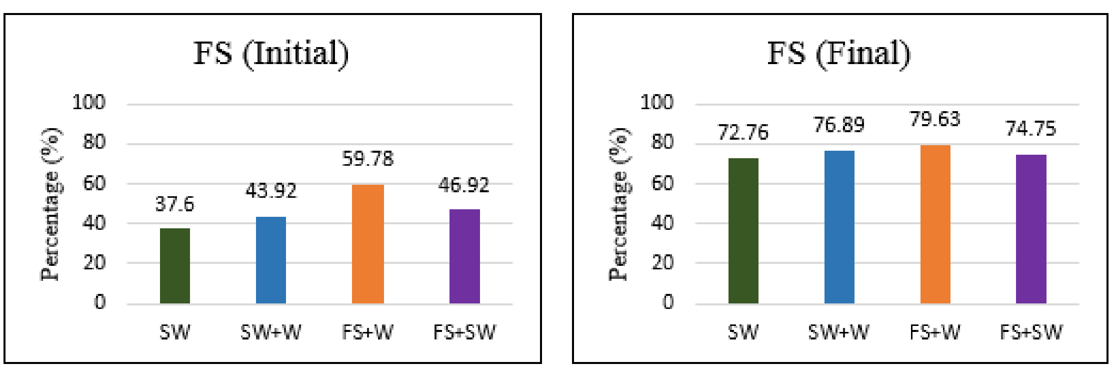

Figure 5: Fixed solid (FS) content at initial and final stage of composting

Total Organic Carbon

Total carbon content (%) of co-compost was determined as a direct function of total volatile solid (TVS) (Adams *et al*., 1951). Figure 6 shows total carbon content at initial and final condition.

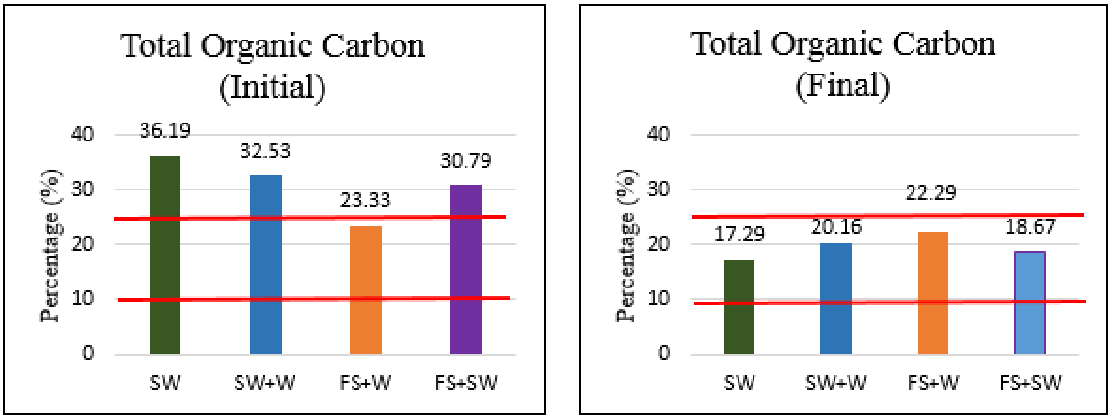

Figure 6: Total Organic Carbon content at initial and final stage of composting

Total carbon content values for the final stage of compost falls within the standard range of the SRDI compost standard. It also falls within the value range provided by Gotaas (1956). A decrease in total carbon content was observed in the initial and final values of co-compost. This may be explained as the decomposition of starting material and mainly transformation into carbon dioxide. The marked red lines show the SRDI standard range.

In case of vermicompost, the earthworms mineralize and decomposes the organic compounds into substrate material. Carbon compounds are lost in the form of CO_2. The number of earthworms also decreases slightly with the decrease of C/N ratio. this decrease in C/N ratio increases the oxidation of organic matter and thus total organic carbon.

Total Kjeldahl Nitrogen

An increase is observed of the values of nitrogen content. From the Figure 7 it is seen that initially total kjeldahl nitrogen content was 1.75% for solid waste sample, 1.49% for vermiculture of solid waste, 1.60% for vermiculture of faecal sludge and 1.65% for faecal sludge and solid waste co-compost. Finally, these value increases as 1.68%, 2.1%, 1.82% and 1.75% respectively. The marked red lines show the SRDI standard range.

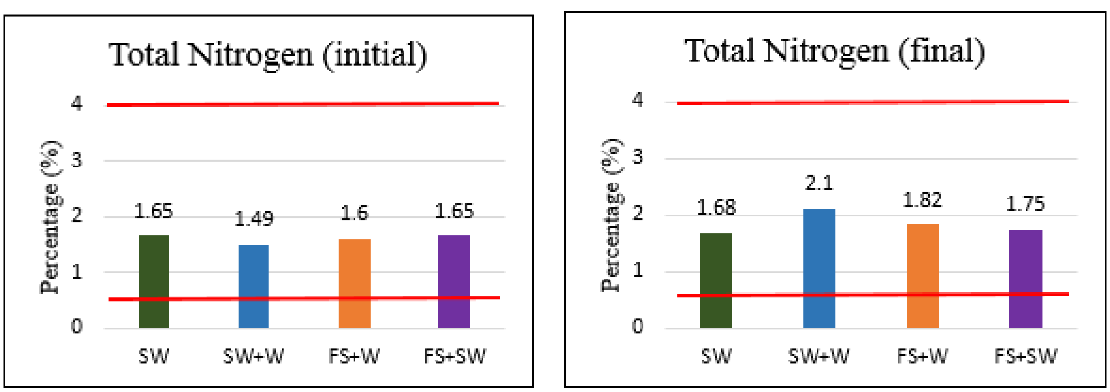

Figure 7: Total Kjeldahl Nitrogen content at initial and final stage of composting

From the analysis it is evident that the nitrogen content of composts rises at maturation. This is due to the concentration effect caused by the decomposition of organic compound which leads to weight loss (Bernal *et al*.,1998; Sa´nchez-Monedero *et al*., 2001). In case of vermicompost, the nitrogen level increases due to the secretion of enzyme by earthworms.

Carbon to Nitrogen (C/N) Ratio
Carbon to nitrogen ratio (C/N) is an important indication of compost maturity. It represents the decomposition of organic matter and the stability obtained during composting period. C/N ratio decreases in every sample with time. The C/N ratio during composting is shown in Figure 8.

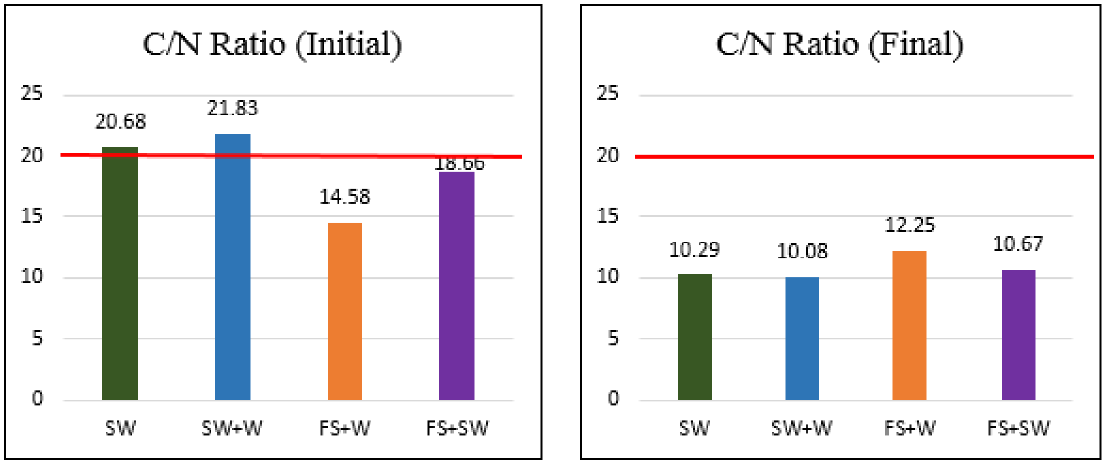

Figure 8: Carbon to Nitrogen Ratio (C/N) at initial and final stage of composting

Many authors have used C/N ratio as an indicator of compost maturity. But due to its large variation and dependency on input material it cannot be used as absolute standard. However, a value below 20 may be considered as satisfactory (Wong *et al*, 2001). According to Fuchs *et al.,* (2001) a value around 16 is satisfactory. It also ensures compost to avoid nitrogen blockade. Allison (1973) recommended that, for a well humified compost C/N ratio value should be around 10. In case of mixed material, he recommended the value to be below 15. This value will not alter the microbial equilibrium of soil. From the above results and discussions, it is clear that the vermiculture of faecal sludge shows better result (C/N ratio 12.25) than others. The marked red lines show the SRDI standard range.

Total Coliform (TC), Faecal Coliform (FC)
While implementing resource recovery technique it should be ensured that the system is not harmful for the users. For this purpose the amount of pathogens should be monitored carefully. Figure 9 shows total coliform content.

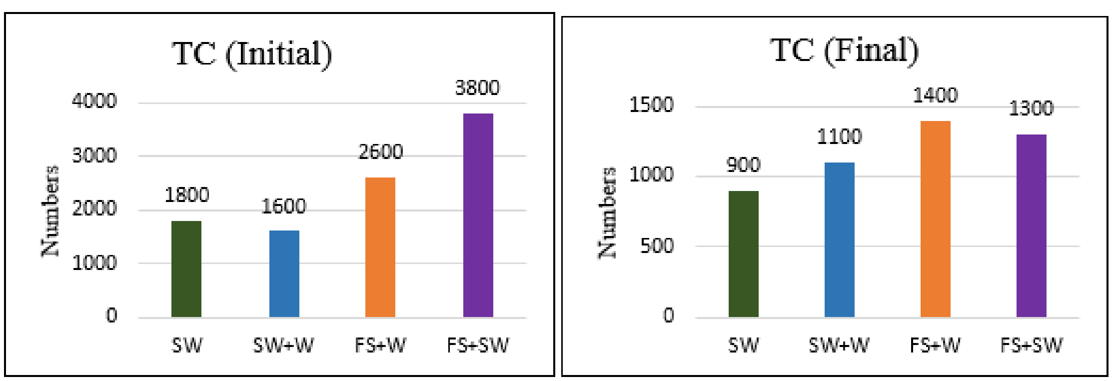

Figure 9: Total Coliform (TC) content at initial and final condition of composting

presence of faecal coliform in compost indicates pathogenic contamination, which is harmful for the user and the environment. Raw faecal sludge contains considerable amount of faecal coliform. It is important to ensure that compost prepared from faecal sludge contains FC within standard. In this case, maturated compost sample of all type contains less faecal sludge then the WHO guideline provided standard. The marked red lines show the SRDI standard range. Figure 10 shows faecal coliform content at initial and final condition.

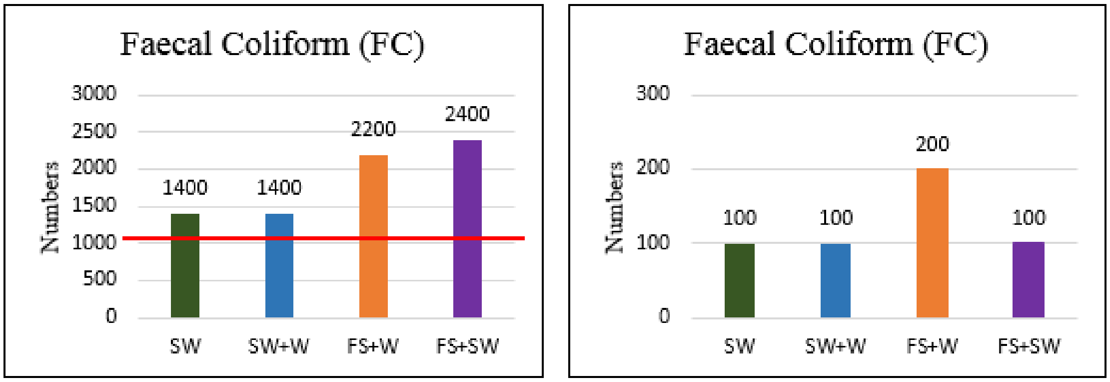

Figure 10: Faecal Coliform (FC) content at initial and final condition of composting

Phosphorus (P)

Phosphorus is an important constituent of organic fertilizer. During composting period phosphorus content increases. The enzymes in the intestines of the earthworms and action of microorganisms mineralize and mobilize the amount of phosphorus. This is the reason behind the increase in phosphorus content (Suthar & Singh, 2008). In different experiment, it has been found that the phosphorus content normally increases during composting period (Jadia *et al.,* 2008). The following Figure 11 shows the Phosphorus content of prepared compost.

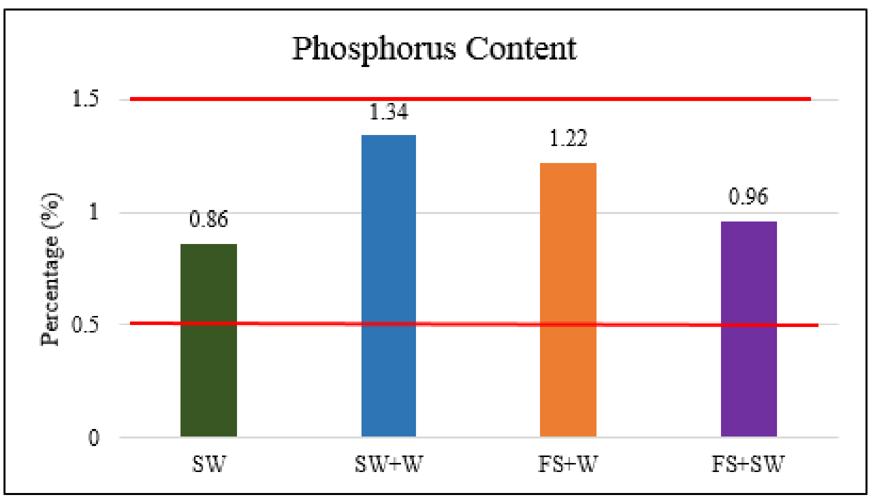

Figure 11: Total Phosphorus content of different types of compost at final condition

In this experiment, total phosphorus content is found as 0.86% for solid waste compost 1.34% for vermiculture of solid waste, 1.22% for vermiculture of faecal sludge and 0.96% for faecal sludge and solid waste co-compost. These values are within the standard (0.5-1.5%) provided by the Soil Resource and Development Institute (SRDI). The marked red lines show the SRDI standard range.

Potassium (K)

Potassium is also an important constituent of organic fertilizer. It is essential for proper growth of plants and essential nutrient for crops. In this experiment, total phosphorus content (shown in Figure 12) is found as 0.86% for solid waste compost 1.34% for vermiculture of solid waste, 1.22% for vermiculture of faecal sludge and 0.96% for faecal sludge and solid waste co-compost. These values are within the standard (0.5-1.5%) provided by the Soil Resource and Development Institute (SRDI). The marked red lines show the SRDI standard range.

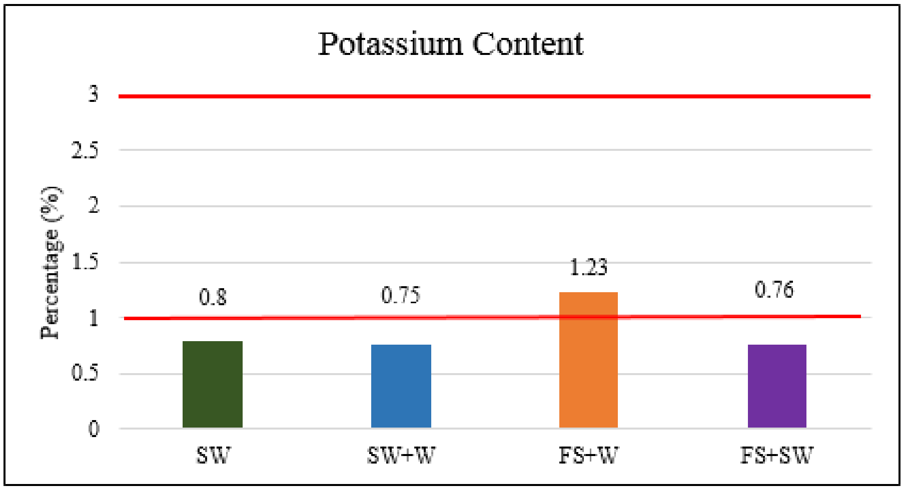

Figure 12: Total Potassium content of different types of compost final condition

Acid production during organic matter decomposition by the microorganisms is the major mechanism for solubilisation of insoluble phosphorus and potassium. Also, the presence of large number of microflorae in the gut of earthworm might play an important role in increasing P and K content in the process of vermicomposting (Pramanik *et al.,* 2006).

Temperature Variation During Composting Process

To ensure the compost quality monitoring and maintaining temperature is very important. Because the rates of organic degradation are temperature dependent and increases at wormer temperature. Composting is a controlled process of biodegradation of organic waste. The microorganisms involved in this process are same as responsible for the organic degradation of soil. The resulting end product is a dark, rich, humus-like matter that can be used as a soil amendment. That's why, during composting period, regular temperature was monitored and recorded.

Considering a 55 days cycle of composting a temperature vs days graph has been prepared for each type of sample. The graph for normal organic compost and co-compost of faecal sludge and solid waste are more or less similar. This is due to the same type of biodegradation process. The microorganisms of compost rapidly go through a series of bioreaction with the biodegradable organic compound and raise temperature at a considerable level. The temperature variation of solidwaste compost is shown in the Figure 13.

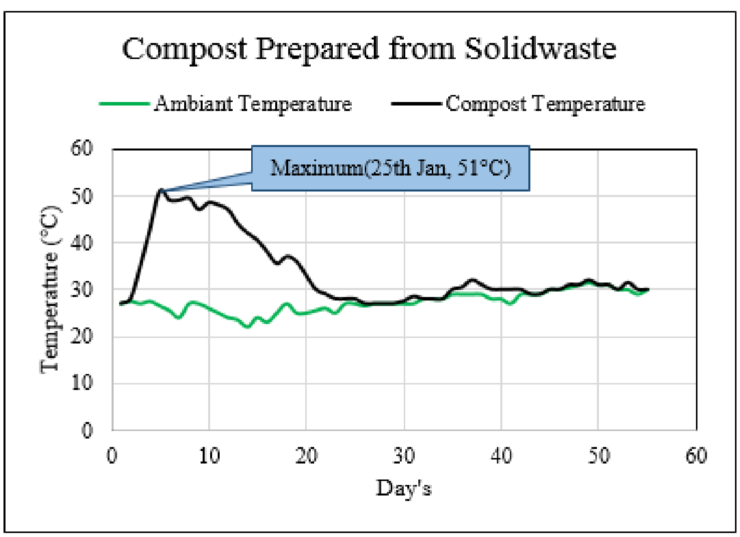

Figure 13: Temperature Curve of Compost prepared from Solid waste

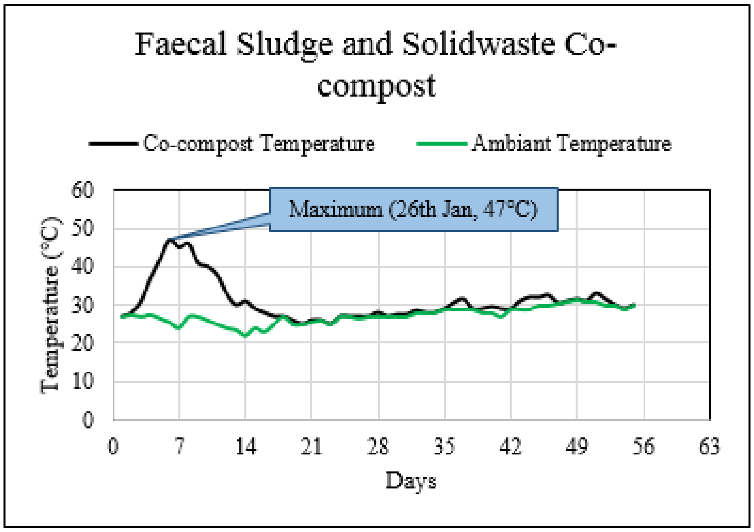

Figure 14: Temperature Curve of Faecal Sludge and Solid waste Co-compost

Highest temperature for normal organic compost was observed 51°C at the 6th day (25th January, 2018). Then it started to decrease and gradually nearly coincide with the ambient temperature. Same type of fluctuation was observed in the case of co-compost (shown in Figure 14). The temperature of co-compost was highest at 7th day of composting cycle (26th January, 2018) and it was 47°C. This temperature also decreases with time and finally come near to the ambient temperature.

But in case of vermiculture samples *i.e.* vermicompost of organic solid waste and vermicompost of faecal sludge, the temperature variation is different. This is because of the use of vermiworms or earthworms. The earthworms cannot sustain higher temperature above 45°C. Temperature below 20°C is also unsuitable for their breeding. The best temperature for earthworm is 35-20°C. But for the reaction of microorganism compost temperature may increase. That's why certain temperature controlling measures (*i.e.* turning of compost, using water sprinkle etc.) were adapted. The variation of temperature of vermicompost is represented graphically in the Figure 15 for faecal sludge vermicompost and in Figure 16 for solid waste vermicompost.

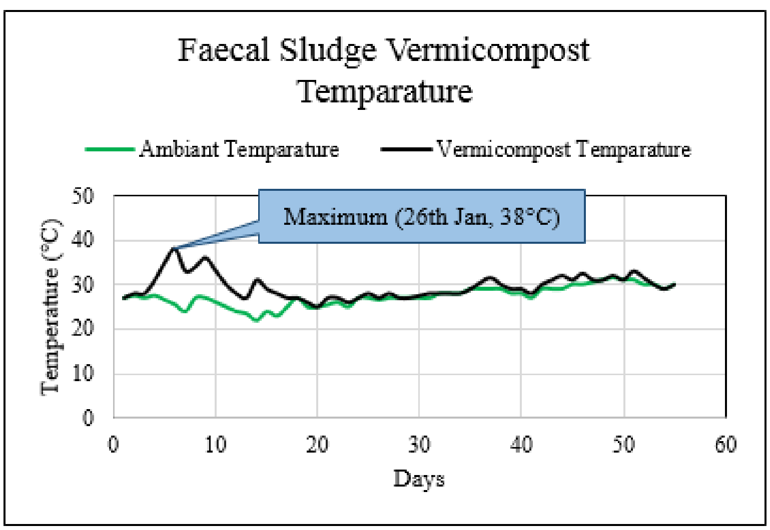

Figure 15: Temperature Curve of Faecal Sludge Vermicompost

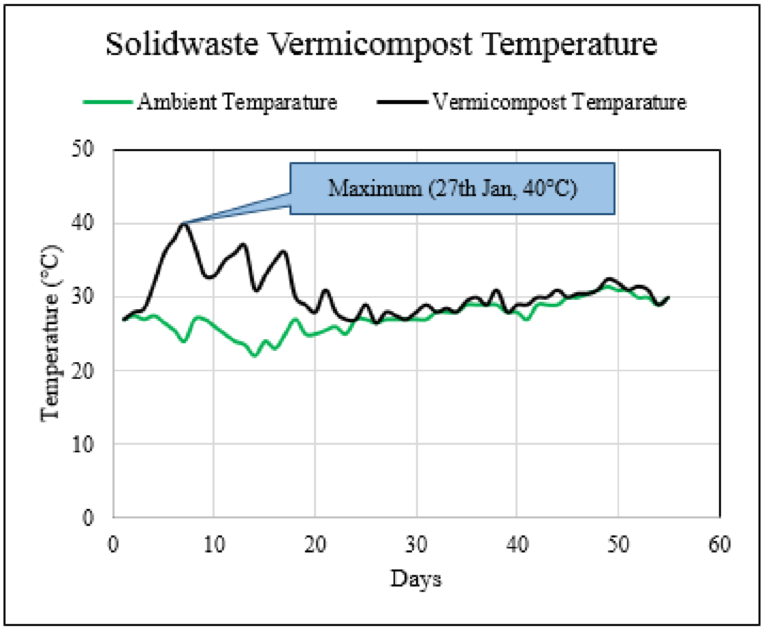

Figure 16: Temperature Curve of Solid Waste Vermicompost

From the above data and descriptions, it is clear that, the physical condition of all types of composts were more or less same. Color of composts varied from dark grey to black. Absence of odor was an indication of good maturation. From the pH values it is evident that the composts were slightly alkaline in nature. This may be due to the formation of alkaline compound during composting process. The pH values were within the recommended standard of SRDI. The moisture content of solid waste compost was a little higher than the SRDI recommended value. In other composts moisture content was within the standard. The percentage of total organic carbon considerably decreased during composting process. At maturation stage the final carbon content were within the SRDI standard value. But the carbon content of vermicomposts were little higher than the solid waste compost and co-compost. This may be due to the reduction of microorganisms by earthworm's guts action. Similar scenario was observed in case of nitrogen content. Although the nitrogen content of all composts was within the standard range, the nitrogen percentage of vermicomposts were slightly higher than the solid waste compost and co-compost. The C/N ratio for all composts were within the recommended value. So, the proportion of raw materials at initial period was optimum. The number of pathogenic microorganisms decreased considerably during composting process. The number of faecal coliforms decreased by 50 times with respect to the initial condition. This indicates that the prepared composts were safe for handling, transport and processing. The percentage of Phosphorus content was within the standard limit. But in case of Potassium only faecal sludge vermicompost satisfies the standard limit.

CONCLUSION

The findings of the conducted research works can be concluded as the followings:

- The physical condition of all prepared compost was more or less same. The color of the composts varies from black to dark gray. Absence of bad odor represents the acceptable stage of maturation.
- All parameters of the prepared composts satisfied the SRDI provided standard values except potassium. However, only the vermicompost prepared from faecal sludge satisfied the potassium standard value.
- The values of moisture content, volatile solids, total organic carbon and C/N ratio have decreased during composting process.
- The pH, fixed solids and total Kjheldhal nitrogen increased during composting process.
- The number of pathogenic microorganisms decreased considerably during composting process. The number of faecal coliforms decreased by 50 times with respect to the initial condition.

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