M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.5 (1-7)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Mathematical Model Showing The Benefit-Cost Ratio Per Unit Trip for the Solid Waste Management of Dhaka City

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ABSTRACT

Dhaka, the capital of Bangladesh, is generating more than 5000 tons of solid wastes per day. The Dhaka City Corporation, the responsible authority, is only dumping these wastes or simply burning it down without treating them further as a very useful source of energy. The research objective is to bring an engineering solution of the present problem. A Massive Integrated Bio-plant is designed, based on that a mathematical model showing benefit-cost ratio of it. The method has been formulated using an integer linear problem. The proposed model includes: trucks for transportation of waste, replacement trucks and their depots, incineration with energy recovery, dumping site, plastic plant, bio-gas plant, fertilizer plant etc. The obtained result is the benefit-cost ratio per trip derived from the cost owing to investment and management cost, operational costs from the use of replacement trucks, benefit from energy generation from various plants.

INTRODUCTION

The protection of the environment and natural resources is increasingly becoming very important through environmentally sustainable waste management program. Therefore following the part of waste managers, a sustainable approach to the waste management and to integrate strategies that will produce the best practicable option becomes necessary. This is a very challenging task since it involves taking into account economic, technical, regulatory, and environmental issues. Waste management can become more complex if social and political considerations are also into account.

It is not very ago, Dhaka, the capital of Bangladesh possessed an image as a city of green and water bodies. Within last few decades this serene and tranquil city has been transformed into one the most polluted and crowded cities in the world. Dhaka City Corporation (DCC) is responsible for managing the city. The juristic of DCC area is 360 km^2 and accommodates over 15 million people. It is projected that the population would be more than 20 million by the year 2015. Right now it is the 9th largest cities in the world and 28th among the mostly densely populated cities in the world (23029/km^2).

People around Dhaka city gathered here for better jobs and livelihood because Dhaka is called the city of opportunity for the people of Bangladesh. This huge amount of population is generating massive amount of wastes which DCC is dealing with. Unfortunately most of these wastes are dumped in the landfill areas and then burnt. If utilized in the engineering way with proper technology under the supervision of experts, these wastes can be recycled, reused and can be used to generate electricity, biogases and various different products.

This is the high time to plan a massive project that can stand parallel and uphold the gas and electricity scarcity. The developed countries like ANNEX countries which include UK, Germany, and USA etc. have already developed the technology of building massive integrated bio-gas plant which is used for multiple ways of generating various products and useful energy. Unfortunately the people of Bangladesh are being deprived of enjoying such facilitations even though they are producing massive wastes and uselessly throwing them away. People of Dhaka city largely depends on gas and

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electricity for cooking and other activities. As the population increases the problem will also rise and it can be easily predicted that one day there will be nothing to spare for these poor citizens of Dhaka!

RESEARCH OBJECTIVES

The establishment of the mathematical model is on a massive integrated bio-plant. The work focuses on the construction and design of a schematic of one such plant. The study will also illustrate a detailed description of the mathematical model that can be used as tools for decision makers in the day to day planning and management of integrated program of solid waste collection, incineration, recycling, treatment and disposal.

METHODOLOGY

SCHEMATIC DIAGRAM OF THE MASSIVE INTEGRATED BIO-PLANT

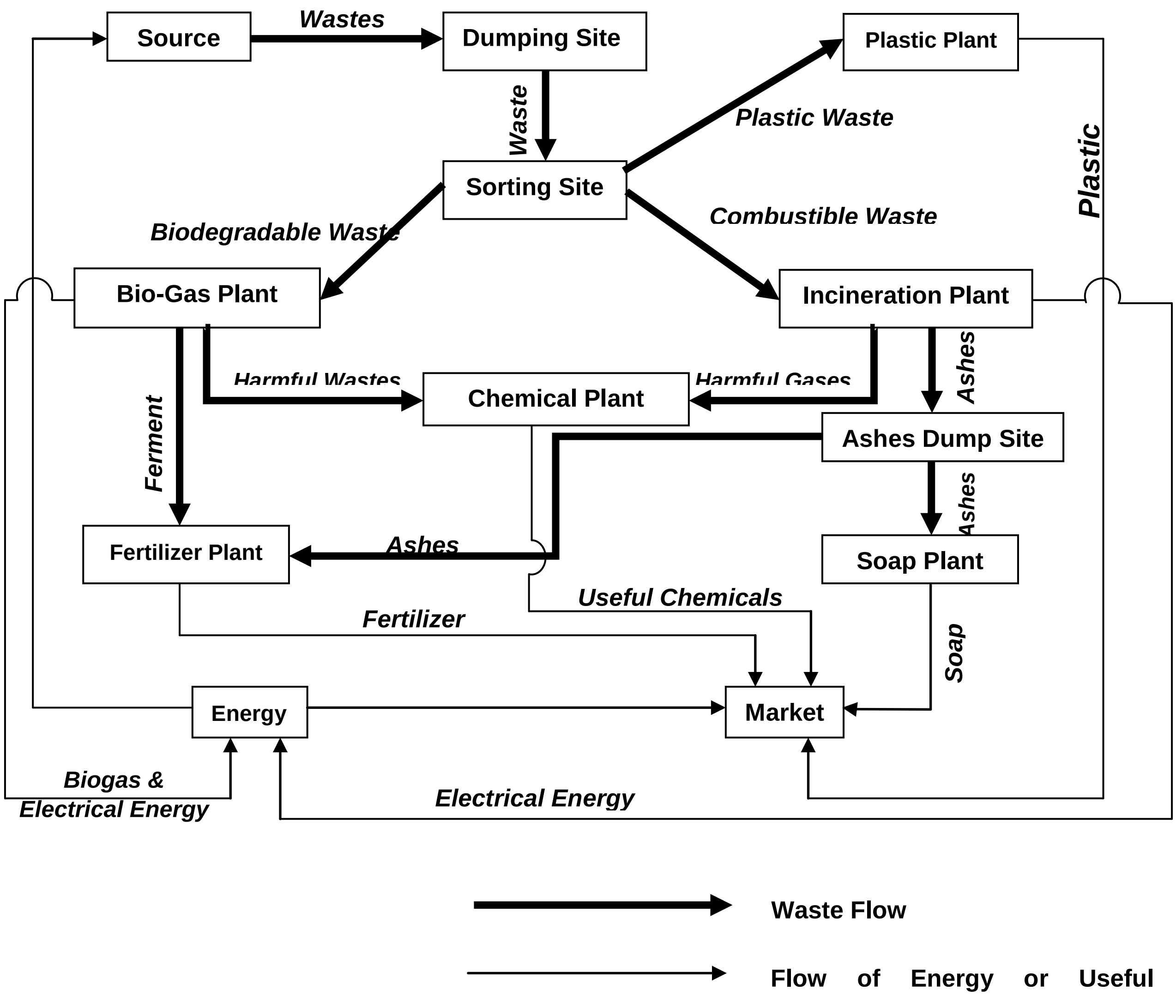

Figure 01: Schematic Design of a Massive Integrated Bio Plant

Working Principle of the Massive Integrated Bio-plant

Wastes generated by the sources are dumped in the dumping sites. These wastes after some treatment are sent to the sorting sites where three categories of wastes are separted; namely the biodegradable wastes, combustible wastes and plastic wastes.

Biodegradable wastes are those wastes which has got the putrefying ability like garbage. Therefore these wastes are transferred to Bio Plant. Combustible wastes are the wastes which have high heating value, low humidity, moderate activation energy and which are easily burnt; like paper, leaves, bits of wood, straw etc. are taken to the incineration plant for combustion or burning. Plastic Wastes like ployvinyl chloride (PVC), low-density polyethene (LDPE), polypropylene (PP), polystyrene (PS) are taken to the plastic plants, mainly for recycling after series of treatments.

Biogas plant produces bio methane and electrical energy as the useful products, which are directly or indirectly passed back to the source or market. This plant also produces harmful wastes especially gases which are treated in the chemical plant before it is released to the environment or send back to the market.The ferments produced in the biogas plants are transported to the fertilizer plant where they are converted to low priced fertilizer which is back to the market.

The purpose of incineration plant is to treat combustible waste. The electrical energy produced is back to the source directly or indirectly. The harmful gases produced are treated in the nearby chemical plant before it is released to the environment and useful chemical to the market. The ashes produced are dumped to the ash dump sites where the types of ashes are classified. One part ashes are transported to the fertilizer plant and the other part is transported to the soap plant.

Plastic plants take care of the plastics wastes most of which are recycled back to the market. The soap plants are plants where different soaps are manufactured. There may be different brands of soaps that can be manufactured by certain specific type of ashes. The chemical plants are those where harmful wastes are converted to useful product and human friendly chemicals so that there would be no adverse effect of these chemicals on the environment.

MATHEMATICAL MODEL FORMATION

The model is formulated as an integer linear program. It has been presented as a decision making tool for solid waste planners in decisions concerning the overall management of solid waste. Several treatment plants and facilities along with the waste collection component has been considered within the proposed model: trucks for the transportation of waste; replacement trucks and their depots; incinerators with energy recovery; dumping site; several plants for recycling useful products and energy etc. The user may prefer to measure the transportation costs in terms of costs per trip made from the waste source; in that case the model is more appropriate.

The objective function of the model describes tipping fees, total investment and maintenance costs, costs for buying or hiring trucks, transportation costs as well as operational costs from the use of replacement trucks. The benefits from energy generation, compost, and recycling are also incorporated in the objective function. Apart from the transportation costs, installation and operational costs for plants and landfills, and benefits from different plants, the objective function also includes truck purchase costs as well as costs due to the presence of replacement trucks depots. Special attention has been given to deciding the number and the type of trucks that are used to transport a given type of waste from the waste collection points to the plants or landfills. Replacement trucks are also considered with the observation of possible breakdowns of the operational trucks. Moreover, instead of measuring the amount of waste using the number of trucks used multiplied by their capacities, continuous variables can be introduced to measure directly the amount of waste that goes to the plants and landfills.

ASSUMPTIONS

The mathematical model is based on the following assumptions:

1. The waste handling operations in the mathematical model are to be executed daily.

2. Each plant or site is considered to have the benefit-cost ratio more than 1 and is justified to invest for the proposed model.

3. It is assumed that each plant or site is giving more rate of return than minimum acceptable rate of return (MARR).

4. Waste source and the dumping site are located at the centers of the waste generating areas.
5. The dumping site and the sorting site is considered to be at the same location.
6. The incinerator and the ash dump site is also considered at the same location.

Schematic Model for Mathematical Formation

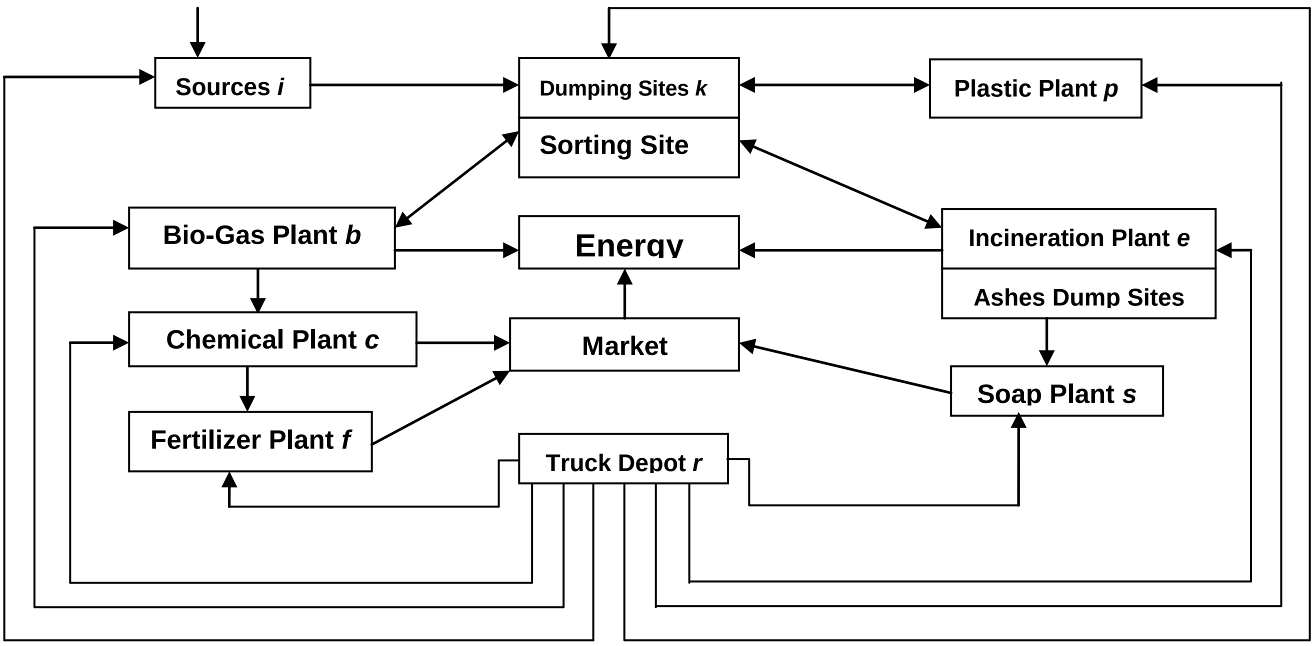

Figure 02: A Schematic Diagram of the Massive Integrated Bio plant according to the assumptions

Indices

i = 1, 2…	I: location of waste source
b = 1, 2…	B: location of biogas plant
c = 1, 2…	C: location of chemical plant
e = 1, 2…	E: location of incineration plant
f = 1, 2…	F: location of fertilization plant
k = 1, 2…	K: location of dumping site
p = 1, 2…	P: location of plastic plant
r = 1, 2…	R: location of truck depot
s = 1, 2…	S: location of soap plant
l = 1, 2…	L: truck type
g = 1, 2…	G: waste Type

VARIABLES

X_{kbg}, X_{kpg}, X_{keg}: respectively the total number of trips made by trucks of type *l* used every day to carry waste of type *g* from dumping site *k* to a biogas plant at *b*, to a Plastic Plant *p* and to an incinerator at *e*.

x_{kbg}, x_{kpg}, x_{keg}: respectively the number of trucks of type *l* used every day to carry waste of type *g* dumping site *k* to a biogas plant at *b*, to a Plastic Plant *p* and to an incinerator at *e*.

Y_{ikg}, $Y_{bkg,}$ Y_{ekg}, Y_{pkg} : the total number of trips made by trucks of type *l* used every day to carry waste of type *g* from a source *i*, biogas plant at *b*, an incinerator at *e*, to a plastic plant *p* to a dumping site *k*.

y_{ikg}, $y_{bkg,}$ y_{ekg}, y_{pkg}: the number of trucks of type *l* used every day to carry waste of type *g* from a source *i*, biogas plant at *b*, an incinerator at *e*, to a plastic plant *p* to a dumping site *k*.

n_{rb}, n_{rc}, n_{re}, n_{rf}, n_{rk}, n_{rp}, $n_{rs:}$ respectively number of trucks of type *l* used every day from a replacement trucks depot at *r* to a biogas plant at *b*, to a chemical plant at *c*, to an incinerator at *e*, to a fertilizer plant at *f*, to a dumping site at *k*, to a plastic plant *p* and to a soap plant at *s*.

z_b, z_c, z_e, z_f, z_k, z_p, z_{rs}, z_r : 0-1 variables indicating respectively, the presence of biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, to a plastic plant *p*, a soap plant at *s* and a truck depot at *r*.

w_b, w_c, w_e, w_f, w_k, w_p, w_s : amount of waste transported everyday respectively, to a biogas plant at *b*, to a chemical plant at *c*, to an incinerator at *e*, to a fertilizer plant at *f*, to a dumping site at *k*, to a plastic plant *p* and to a soap plant at *s*.

T_l: The number of trucks of type *l* used every day.

$(RT)_l$: The number of replacement trucks of type *l* required every day.

Input Data/Parameter
α_l : capacity (in tons) of a truck of type *l*.

m_{rb}, m_{rc}, m_{re}, m_{rf}, m_{rk}, m_{rp}, m_{rs}, m_{ri}: respectively the cost of moving a truck of type *l* from a replacement trucks depot at *r* to a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, a plastic plant *p*, a soap plant at *s* and a waste source at *i*.

u_{kb}, u_{kp}, u_{ke}: respectively transportation cost per unit of waste carried by a truck of type *l* from a dumping site at *k* to biogas plant at *b*, to a plastic plant *p* and to an incinerator at *e*.

d_{ik},d_{bk}, d_{ek}, d_{pk} : respectively transportation cost per unit of waste carried by a truck of type *l* from a waste source at *i*, a biogas plant at *b*, an incinerator at *e* and a plastic plant at *p* to a dumping site at *k*.

β_b, β_c, β_e, β_f, β_p, β_s : revenue respectively, per unit of waste at bio-gas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f* , a plastic plant at *p* and a soap plant at *s*.

f_l: the cost of buying a new truck of type *l*, *l* = 1 ..., *L*.

d_i: amount of waste at Source *i*.

ρ_b, ρ_c, ρ_e, ρ_f, ρ_p, ρ_s : fraction (%) of unrecovered waste respectively, at biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, to a plastic plant *p* and a soap plant at *s*.

δ_b, δ_c, δ_e, δ_f, δ_k, δ_p, δ_s, δ_r : respectively installation cost incurred in opening a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, to a plastic plant *p*, a soap plant at *s* and a replacement trucks depot at *r*.

γ_b, γ_c, γ_e, γ_f, γ_k, γ_p, γ_s : respectively variable cost incurred in handling a unit of waste at a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, a plastic plant at *p* and a soap plant at *s*.

RESULTS/FINDINGS

The objective function represents the overall daily waste management costs. The first component, V_1 *(z, w, X, Y)*, gives the investment and waste handling expenses as well as transportation costs. The second component, $V_2(n,z)$, gives expenses owing to the use of replacement trucks. The third component, $V_3(x,y,n)$, is the total cost incurred for buying all the trucks of various kinds and capacities. In this function we have the installation cost parameters δ, and the variable cost parameters γ. The variables *X* and *Y* have been defined before. The component *Bn (w)* is the income and revenues earned from per unit waste from different plants. The benefit-cost ratio per unit trip can then be derived dividing the benefit by the total cost, *V*, which is the summation of all the cost components V_1, V_2 and V_3. The model works on daily basis.

The component V_1 will show the overall cost for installation, transportations and other variable cost (e.g. maintenance).

$$V_1(z, w, X, Y) = [\Sigma_b(\delta_b z_b + \gamma_b w_b) + \Sigma_c(\delta_c z_c + \gamma_c w_c) + \Sigma_e(\delta_e z_e + \gamma_e w_e) + \Sigma_f(\delta_f z_f + \gamma_f w_f) + \Sigma_k(\delta_k z_k + \gamma_k w_k) + \Sigma_s(\delta_s z_s + \gamma_s w_s) + \Sigma_p(\delta_p z_p + \gamma_p w_p)] + \alpha_l [\Sigma_{glkb} u_{kb} X_{kbg} + \Sigma_{glkp} u_{kp} X_{kpg} + \Sigma_{glke} u_{ke} X_{keg} + \Sigma_{glik} d_{ik} Y_{ikg} + \Sigma_{glbk} d_{bk} Y_{bkg} + \Sigma_{glek} d_{ek} Y_{ekg} + \Sigma_{glpk} d_{pk} Y_{pkg}] \quad (1)$$

The component V_2 concerns the total costs owing to the presence of replacement trucks (or standby trucks).

$$V_2(n,z) = \Sigma_{ril}(m_{ri} n_{ri}) + \Sigma_{rbl}(m_{rb} n_{rb}) + \Sigma_{rcl}(m_{rc} n_{rc}) + \Sigma_{rel}(m_{re} n_{re}) + \Sigma_{rfl}(m_{rf} n_{rf}) + \Sigma_{rkl}(m_{rk} n_{rk}) + \Sigma_{rsl}(m_{rs} n_{rs}) + \Sigma_{rpl}(m_{rp} n_{rp}) + \Sigma_r(\delta_r z_r) \quad (2)$$

The component V_3 gives the total cost for buying all trucks required in the daily management of waste.

$$V_3(x,y,n) = \Sigma_l f_l [T_l + (RT)_l] \quad (3)$$

The component Bn gives the benefits at the plants owing to the production of electric energy, compost, recycled materials and other revenues of the useful part per unit waste.

$$Bn(w) = \Sigma_b \beta_b (1 - \rho_b) w_b + \Sigma_c \beta_c (1 - \rho_c) w_c + \Sigma_e \beta_e (1 - \rho_e) w_e + \Sigma_f \beta_f (1 - \rho_f) w_f + \Sigma_p \beta_p (1 - \rho_p) w_p + \Sigma_s \beta_s (1 - \rho_s) w_s \quad (4)$$

Total Cost:

$$V = V_1 + V_2 + V_3 \quad (5)$$

The benefit-cost ratio per unit trip:

$$\text{Benefit: Total Cost} = Bn/V \quad (6)$$

DISCUSSIONS

Limitations of the Mathematical Model

Some of the limitations of the model are as follows:

1. Although regulatory, technical, and environmental constraints are not comprehensively considered in these models, it is assumed that they can be handled in details without affecting the results of the model.

2. In our model we neglect the traffic jam in Dhaka city. If this would be considered the model would be more realistic.

3. In reality the united sites like the dumping site, sorting site, incinerator, and the ash dumping site may not exists at the same place. In that case the mathematical models need to be modified.

4. As this is a massive project design and requires a huge amount of money to start with. As it needs time to construct, time to time modification of the design might result a better benefit. This means it is not the final model and has a lot of scopes to be modified.

5. Selection of suitable locations for such a massive project might give a bit of trouble for the investors. They may not risk their money on the basis of these models only.

6. Some of the plant in the design might give lesser benefit-cost ratio and should be discarded. But in our model we assume the individual plant has got the benefit cost ratio more than one, so that the mathematical models could be established.

7. During transportation there is some loss of the waste due to littering or scattering.

Application of the Mathematical Model

1. The mathematical model can be simulated in AMPL modeling system with a compatible solver CPLEX. This powerful algebraic modeling language solves problems in linear, non-linear, and integer programming etc.
2. The model can be used as important tools for planners in solid waste management in an urban environment.
3. The model may as well be adapted for use in other areas of application like industrial warehouse location and product distributions among industry agents.

CONCLUSIONS

The study illustrates a schematic design of a massive integrated bio plant. The plant concerns with following plants: biogas plants, plastic plants, incinerators, fertilizer plants, soap plants and chemical plants. These plants work in parallel with dumping sites, truck depots and the waste source. The model works on daily basis and the revenues from these plants are considered as benefit; the total cost includes the installation cost, variable cost, maintenance cost, tipping cost, transportation cost and the cost for buying trucks. Based on the devise a mathematical model is developed showing the benefit-cost ratio per unit trip. The mathematical formula is derived applying the linear integer program.

The formula only works under certain assumptions and limitations. The performance can be further studied using a powerful algebraic programming AMPL and CPLEX. In that case the overall management of solid waste may be more easily accessible to solid waste planner in decision making. Although implementation of this mathematical model is expensive, risky and time consuming; there are various ways this model can be modified and made suitable in real life.

ACKNOWLEDGEMENTS

My special thanks to all the Professors of my university, officers working in Dhaka City Corporation (DCC) and Local Government Engineering Department (LGED). Finally I thank my family whose love has kept me going through the project; my friends in IUT and colleagues in my office deserve thanks too.

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Solid Waste Management in the Developing Countries
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Development of an Interactive Solid Waste Management System in a Territory

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ABSTRACT

Solid Waste Management is a prime concern in present days regarding the environmental impact. Unattended domestic solid wastes within a specified boundary gradually place a serious problem with increased population. In this case an efficient management system within a well-specified boundary can play a vital role in environmental risk reduction that was the main objective of this task to develop such a procedure. The paper ends with the proposal of an optimal design of solid waste management network including waste dumping, collection, transmission, processing and final disposal. It also portrays the scenario of the prevailing system. Chittagong University of Engineering and Technology (CUET) campus has selected for this study to evaluate this interactive methodology. In this methodology, the waste production nodes and their waste production rates were specified. The locations of waste source and dumping sites were precisely specified in a GIS based map of the campus and the waste transportation network was identified. The best collection to dumping route was designated using shortest and efficient path selection from various alternative road networks. Thus, concluding remarks were made on development of the interactive solid waste management (SWM) system within CUET campus. It is expected that the proposed interactive SWM would provide useful information for residential university campus to aid future decision making process.

INTRODUCTION

Solid Waste Management (SWM) becomes urgency in parallel to increased industrialization and consumer based society. In this connection modern life often face severe problem with handling the generated solid wastes than the rural fringes (Leao, Bishop et al. 2001; Guerrero, Maas et al. In press). Compare to the industrialized countries, unfortunately developing country experiencing poor SWM, and thus placing serious threat to human health (by disturbing food chain), environmental pollution (air pollution, fire risk as well as contaminated water) and overall economy (Arukwe, Eggen et al. 2012). Recently Guerrero *et al.*(Guerrero, Maas et al. In press) studied 22 developing countries from 4 continent, this study attempted to indicate the six responsible factors (i.e. technical, environmental, financial/economical, socio-culture, institutional/organizational, political/legal) influence the SWM performances. Similarly, for a well specified boundary with modern life style improper solid waste management provide a threat to environment. However, to sustain the SWM in this context Geographical Information System (GIS) based interactive system needs to be developed. In this study the spatial dynamisms were studied among total urban system including population, infrastructure, human behaviour and the produced waste. The aim of this paper is to develop a sustainable GIS based interactive system applicable for a specified boundary and thus to a municipality area in Bangladesh context.

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SWM IN CUET CAMPUS

Chittagong University of Engineering & Technology (CUET) is located about 25 km away from the center of Chittagong city, Bangladesh and it covers about 161 acres of land area. The total population of the area was approximately 6700 in the year 2007.

The area mainly comprises of academic, administrative, residential, agricultural, open spaces and water bodies. Most of its land areas (76% of the total area) are mainly hilly area, forests and bare lands which ensure the opportunity for future development. The land use composition of the area is shown in the Figure 1 (based on Field Survey, 2012).

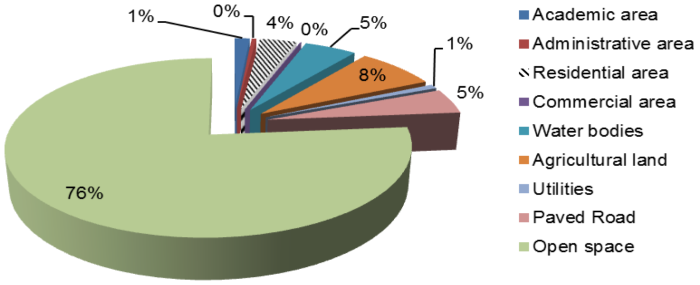

Figure1: Land use distribution of CUET Campus

Due to its topographic variance the area experiences gradual high and low land coverage. The low-lying areas are mainly acting as the solid waste dumping sites in this locality. Due to lack of knowledge on long term adverse effects on the unplanned waste dumping, inhabitants of the study area usually dumps these wastes in the depressed areas (Fig 2a). The authority has made some dustbins (Fig 2b) that are far below the adequacy that's why lot of open dumping places has been recognized. The existing dustbins also suffer from space limitation and in most cases it remains unused. People throw the dusts mainly outside the bin. Presently there are 10 dustbins distributed in different locations within the campus. Besides, 9 open dumping points were identified (Fig 3).Thus Solid Waste Management (SWM) in CUET is a burning issue due to the associated public health risks and environmental concern.

(a) Open dumping (b) Typical dustbin

Figure 2: SWM in the study area

The existing SWM scenario in CUET is as follows:

- No bin exists throughout the campus main road as well as in common places of interest (e.g. academic area) (Fig 3);
- Individual initiatives on kitchen wastes (from five students' Halls, Teachers' residential area and Staffs' residential area) dumping practiced in nearby open ditch/lands (Fig 3);
- Although a huge amount of organic wastes generated in the study area (Fig 4), there is no arrangement for proper dumping of them. Laboratory test showed the average p^H and moisture contents of these wastes are of 12% and 21% respectively, there is a need to discover any possibilities of composts from them;
- Similarly absence of specific dumping location for inorganic waste (e.g. plastic, papers, glass, electronics etc.) (Fig 3 and 4); and
- No separation/processing facilities for recycling/reusing the wastes.

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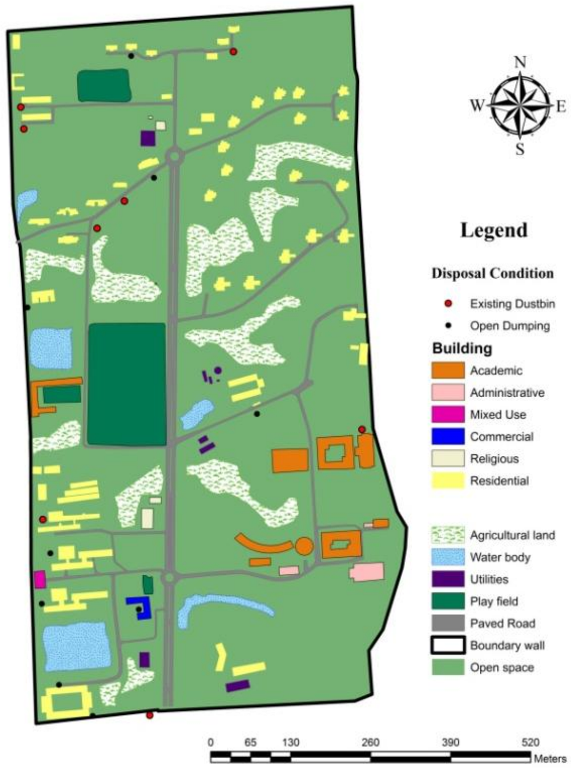

Figure 3: Existing condition of solid waste management system in the study area (based on field survey, 2007 and 2012)

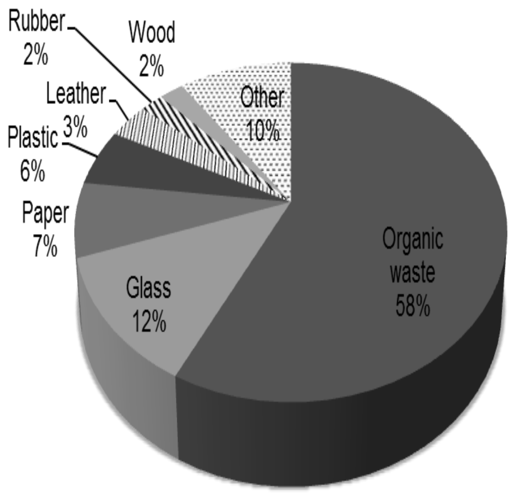

Figure 4: Composition of wastes (based on field survey, 2007)

METHODOLOGY

Based on survey data during 2007 and also considering some on-going developments, to achieve an interactive SWM system, this research adopted a GIS based study (Fig 5). Data preparation on waste characteristics was followed by a first-hand waste collection from specific locations and then the laboratory tests for the organic wastes were carried out.

With identification of existing and proposed location of dustbins for waste dumping, the collection route has been demarked and transmission network to the final dumping point has defined using Network Analyst tool in ARC GIS software. Finally, a proper SWM system has proposed covering waste collection to disposal in a systematic way.

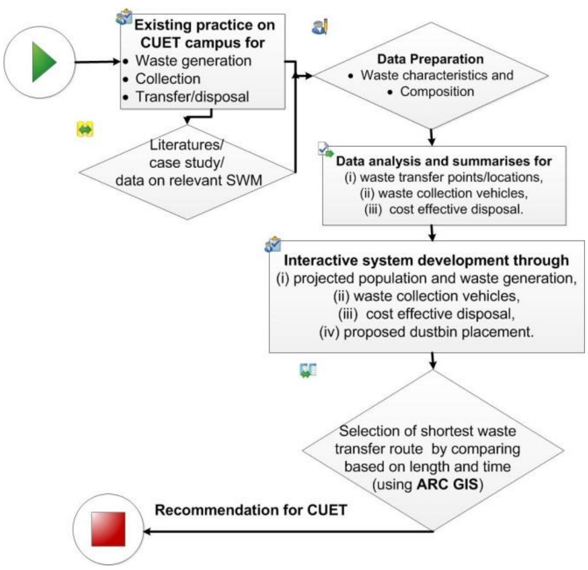

Figure 5: Flow chart of the adopted methodology

GIS BASED INTERACTIVE SWM

There are 9.5 km of Pucca, 5 km of HBB and 3.17 km of Katcha road in CUET campus (Fig 3). Most of the existing dustbins are well connected by roads. New dustbins are proposed in the open dumping sites and along the buildings lacking dustbin facility. These proposed locations (18 numbers) also have accessibility by roads. Here to propose an interactive solid waste management system, the following assumptions are taken:

- The waste should be collected from the point sources of dustbin using a mini truck once per dayand the minimum speed has considered 25 mile/h following IIHS (IIHS 2012);
- One labour and one truck driver is sufficient to maintain the collection and dumping work considering the quantity of the waste because most of the waste material is organic and naturally it decomposes in the ground;
- The maintenance of truck and salary of the engaged persons will be recruited by the university authority. The residents of the community can invest a minimum amount like 30 BDT[1] per month which can ease the solid waste management system function smoothly and also ensure cost effectiveness of the program.

The GIS based map of the campus is available showing the land use, road network, location of existing and proposed dustbins and so on. Based on the present population in CUET, among the proposed dumping locations the busiest points in week days are the dustbin ID #20 and #21 (Fig 8). Similarly, other dumping points besides the academic or commercial areas might have different peak times compare to the residential area. So, to find out suitable route for collection and transporting the waste within the campus Network Analyst tool in ARC GIS software was utilized and the shortest path was found based on two criteria as major constraints i.e., (a) distance and (b) time. In both cases, the waste will be collected chronologically from the numbered dustbins following the chain shown in Fig 7:

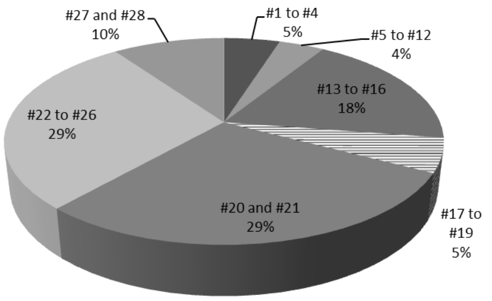

Figure 6: Proposed dustbin ID wise population coverage

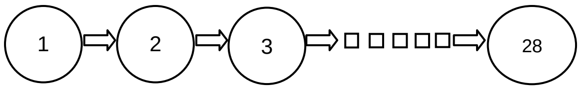

Figure 7: Chronological numbers for waste collection route (should be read with Fig 8 and 9)

When time is the main consideration, the total route covered in minimum 766.47 sec with a distance of 4.67 mile (Figure 8). While minimum distance coverage is the target then the route found was about 4.71 mile and time required to cover the distance is 770.71 sec (Figure 9). Comparing the two routes, though the routes are almost same, it is found that the route considering time factor is more convenient than the other and should be considered as best route for collection, transmission and disposal to the final dustbin point no 29 outside the campus beside the main gate. There is adequate space surrounding that dumping position which ensures uninterrupted collection of the waste by municipal vans. The collected materials will ultimately be disposed in the identified land fill sites of the municipality and will be processed there environmentally and scientifically.

[1] 1 Bangladesh Taka (BDT) = US$80 (As per December 2012)

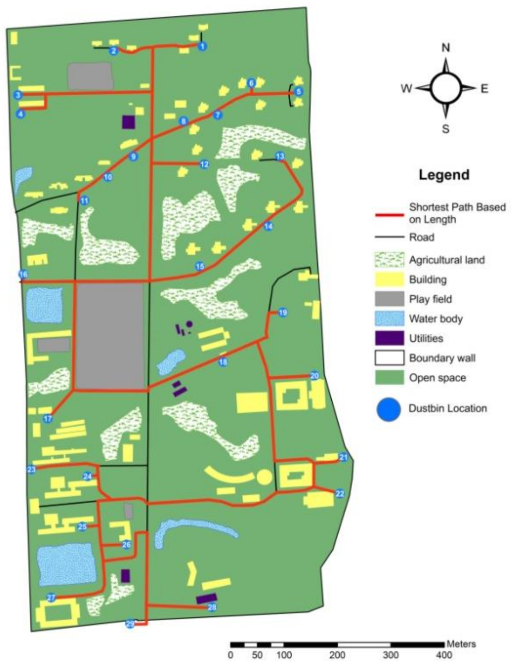

Figure 8: Shortest route based on length.

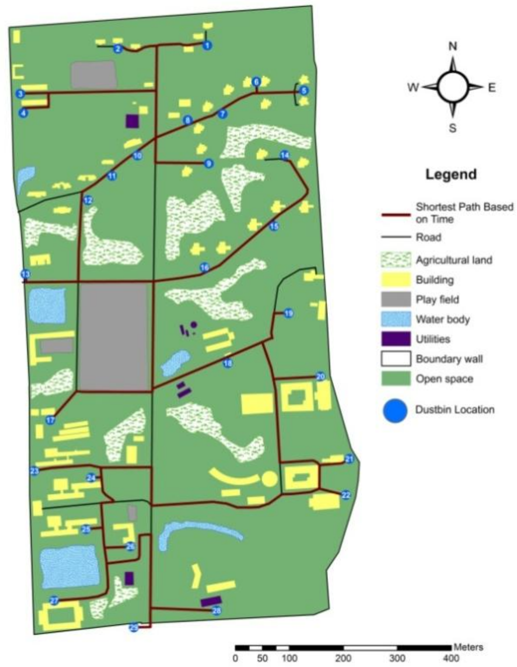

Figure 9: Shortest route based on time.

CONCLUDING REMARKS

The reported study aimed to acquire knowledge on solid waste management in a specified area using the GIS facilities. The primary data collection was done using first hand waste collection and field survey. To date the survey and the characterisation of wastes provided a guidance to the possibility of some resources from the wastes if there is any advancement on 3R's (reduce, reuse and recycle) can be established. This study duration is 2007 to 2012, during this period wastes shifting to the dumping location outside the campus has considered as the best option. However, the on-going research works are considering the possibilities of on campus recycling points.

ACKNOWLEDGEMENT

At first all praises belong to the Almighty Allah, the most merciful, the most beneficent to man and his actions. The authors wish to express their sincere gratitude to the undergraduate students of the batch 2002, Department of Civil Engineering, CUET for conducting the survey, waste characterization and laboratory tests. The authors also owe their profound gratitude to Md. Ahsan Habib, undergraduate student of the Department of Urban & Regional Planning, CUET for analyzing data and finding best transmission route.

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Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Solid Waste Management in Gaza Strip: System Analysis, Challenges and Opportunities

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ABSTRACT

Solid waste management is a concerning issue for both public health and the environment in Gaza Strip. Its high population density, still raising, heavily loads an already exposed system. Nevertheless almost all the solid waste is collected (90-95%). It is directly transported to landfill, or temporary stocked in transfer stations, for a time frame depending on funds availability and other factors, like security and vehicles conditions. International support is fundamental, but service providers developed appropriate solutions with available resources. Estimations suggest a MSW production of 1,717 ton/day, including healthcare waste, as only a very limited part is incinerated. Industrial activities are negligible, while farmers manage their own refuse. Considerable actions are required to prevent system collapse and find disposal alternatives.
Authors suggest solutions considering local conditions, with particular attention to system robustness and sustainability, like increasing population involvement, alternative collection methods for rural areas, and recycling introduction into public institutions.

INTRODUCTION

Solid waste collection and management is the most expensive service a municipality should provide to citizens, with high costs that are progressively increasing, with particularly heavy effects for developing Countries budget (Collivignarelli et al., 2011; Hoornweg and Bhada-Tata, 2012). Also in Palestine, although the service coverage rate is generally very high, a large percentage of residents do not pay fee, and the service quality is therefore affected (Al-Khatib et al., 2007). Also Gaza Strip, a part of Palestinian Territories where more than 1.6 million inhabitants are affected by a blockade imposed by Israeli Government since 2007 (UN OCHA, 2009), has to face severe budget challenges, with further constraints like insecurity, difficulties to import equipment and spare parts, impossibility to access areas close to borders and a very high population density (UN OCHA, 2011). In such conditions, not all the population can be covered by the service and, though it is in large majority quite satisfied by the service, waste piles on the streets are frequent and open burning is a common practice (UNICEF and PHG, 2010).

Municipal Solid Waste (MSW) collection service is supposed to be provided either by municipality or Joint Service Council (JSC), a group of local government authorities (LGA) which is delegated to provide one or more specific services to communities (Jabr, 2004). In Gaza Strip two JSCs are present, one in the North governorate and one in the Middle governorate, called Solid Waste Management Councils (SWMCs), while in the other three governorates, which Gaza Strip is administratively divided into, municipalities directly provide the service; also United Nations Relief and Works Agency for Palestine Refugees (UNRWA) is involved, as it covers all the refugee camps.

However MSW management has been critical for more than 10 years, both in terms of operation and economic sustainability (Afifi and Barhum, 2009), and also public health and the environment are clearly exposed. In fact from one side waste piles on the streets and open burning have direct and clear impacts, on the other improper management and disposal affect soil and underground water (Alslaibi et al., 2010). Currently out of the three disposal sites in use, only the one placed in Deir Al Balah is a sanitary landfill (Allen and Taylor, 2006), though it will be close soon, as it is already operating over designed capacity. However even the remaining sites (Johr Al Deek and Sofa) can be called landfills, as they have a certain level of management (e.g. siting considered geology and water table depth, incoming waste is accounted and compacted, site is guarded), unlike transfer stations which are mainly accumulations without any control.

Due to such critical situation, a Feasibility Study and Detailed Design for Solid Waste Management In the Gaza Strip (FS) (DHV et al., 2012) was developed by a group of consultancy firms contracted by United Nations Development Program (UNDP). After a literature review, they collected data from service providers and field activities (e.g. waste sampling and analysis, demand assessment and willingness to pay survey, topographic and geotechnical investigations), and they developed scenarios which were discussed with stakeholders. The final version, dated January 2012, can be considered as the most reliable source of data about waste management in Gaza Strip, as well as the official planning document to take into consideration while programming any possible action in such sector.

COOPI, an Italian NGO operating in Gaza Strip since 2006, has supported for years MSW service providers introducing the use of donkey carts for collection, through cash for work scheme. In order to get a clear picture of the situation, in particular about challenges and possible way forward, it requested CeTAmb, Research Centre on Appropriate Technologies for Environmental Management in Developing Countries, to assess MSW and health care waste (HCW) management systems. Such article describes the main reported findings and recommendations.

MATERIAL AND METHODS

The assessment started with a deep literature review, with documents available on internet or locally collected by COOPI. Then, during field missions, more documents were found, from local experts, local and international organizations, and service providers.

Two field missions were arranged: the first one, in October – November 2011, was more focused on collecting the majority of information, while the second, in February 2012, was useful to collect missing data and to check some aspects directly with service providers. Moreover, considering both the fluid situation and a number of unclear and conflicting information, due to the large number of stakeholders and personal opinion referred as actual situation, it was very important to crosscheck collected data. Field visits, interviews of different stakeholders as well as staff of the same organization, data analysis and discussion with expert were all very important to get a whole, clear and consistent picture of the MSW management system. COOPI support, and in particular its cooperation with the local technical staff, was very important: in fact they have worked with almost all the service providers for years, developing practical experience, personal relationships with staff, and collection good amount of data and documents. Their opinion was precious also to discuss and closely analyze feasibility and potential sustainability of possible actions.

In fact, not only technical and economical aspects should be considered to identify appropriateness of a certain solution, but also other determinants like impact on health and the environment, social influence, organization and institutions (Zurbrugg et al., 2012). Such holistic approach is even more required for a place like Gaza Strip, under such constrained and unstable conditions. Therefore during assessment activities a list of required information (Table 1) was used to address visits and interviews for each service provider, but then remaining aspects were discussed. In particular case studies, related to projects concerning introduction of separate collection, recycling and composting activities, were analyzed, considering weakness and challenges, as well as potentialities.

Finally, part of the data were elaborated in order to develop maps and flowcharts to facilitate both MSW management system comprehension and discussion with stakeholders. Coordinates of important waypoints (e.g. landfill, transfer station, garage, composting facility) were collected with a GPS device, while other locations (e.g. communities, health care facilities) had already been georeferenced, and they were only converted from Palestine 1923 / Palestine Grid to WGS 84 / UTM projection with DNR Garmin. Google Earth and QGIS were used for GIS elaboration and maps development, while flowcharts were drown with Inspiration 7.6.

RESULTS

Almost all the solid waste from all the sources goes into MSW flow: industrial activities are very limited, and produced waste does not have a dedicated flow, while health care facilities practically separate sharps only, which are incinerated. Agricultural waste is directly managed by farmers, and eventually a small quantity is disposed in either landfill or dumpsite. Globally in 2012 production is estimated to be 1,718 ton/day, raising up to 2,230 ton/day in 2020. Agricultural waste cannot increase, as the available land is already completely cultivated. Recycling activities are very limited and almost completely linked to informal market; in fact blockade obstructs any export, while few internal industrial activities prefer using raw material illegally imported through tunnels (UNEP, 2010).

Therefore only composting could have, and it is expected to have in the future, an effective impact to reduce waste quantity to landfill. However currently composting covers only about the 1% of produced MSW (Table 2). Construction waste and debris are not considered, as they have their own dumpsites, where they are temporary stored and slowly recovered, thanks to some projects funded by international actors (Hassan and El-Essy, 2012). Only a certain part is collected with MSW, in particular with street sweeping, and therefore already included in the previous estimation.

Table 1 List of topics for specific questions for each MSW management system assessment.

Topic	Description
General data	General information about the system and stakeholders
Population and area	Characteristics of population and the covered area
Laws/regulations	Regulation about the environment and waste management
Finance and economy	Financial and economic aspects of the system
Waste production and composition	Waste characterization
Waste collection	Description of waste collection, including equipment and modality and informal sector
Waste landfilling	Description of waste disposal including equipment and modality and informal sector
Personnel	Detail of involved personnel
Fuel	Cost and use of fuel
Waste treatment/recycling	Description of treatment and recycking activities, including informal sector
Organization and capacity building	Description of organization and available capacity
Awareness campaigns	Description and impact of previous awareness campaigns

Table 2 MSW generation per source, and volume required for landfilling (DHV et al., 2012)

Year	Household (ton/day)	Commercial (ton/day)	Market (ton/day)	TOT MSW (ton/day)	Compostin g rate	MSW to landfill (m^3/year)	Agricultural (ton/day)
2007	1,306	68	72	1,446	1%	435,336	1,200
2011	1,506	78	83	1,667	1%	501,825	1,200
2012	1,552	80	85	1,718	1%	517,303	1,200
2015	1,711	88	94	1,893	2%	564,272	1,200
2020	2,019	102	109	2,230	6%	637,709	1,200
2030	2,874	128	137	3,139	15%	811,511	1,200
2040	3,383	147	157	3,687	18%	919,599	1,200

Landfilling and composting are hence the only 2 available final possibilities for disposal of waste, but several routes can lead there. In fact 7 main service providers (UNRWA, SWMC-North, SWMC-Middle Area, Jabalia municipality – now included into SWMC-North, Gaza City municipality, Khan Younis municipality, and Rafah municipality) have different schemes for waste collection (street containers, kerbside collection with tractors, trucks or donkey carts), haulage (direct transportation, transfer station using small containers, roll-on roll-off containers, or temporary dumpsites), and equipment (containers of different capacity and loading mechanism, skips, tractors, trucks and compactors). Then a part of waste is not collected by service providers, but introduced later into the flow, or illegally dumped into street accumulation or remote areas, and thus occasionally cleared (Figure 1). Area not covered by the 7 main service providers are poorly served by small municipalities, of left without service.

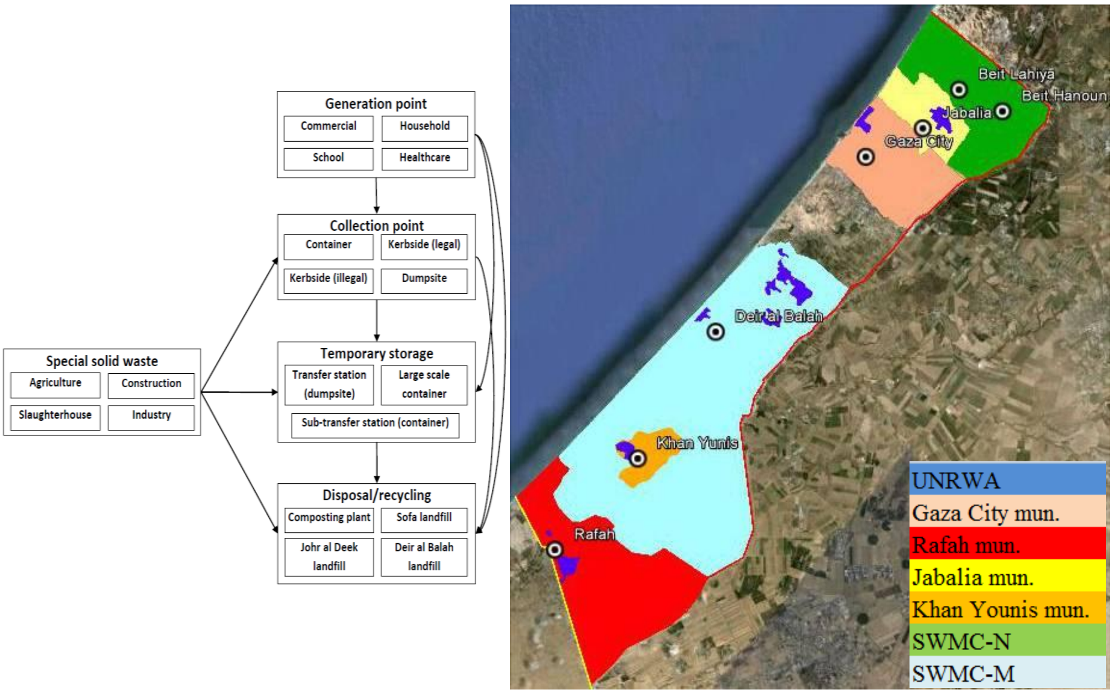

Figure 1 MSW general flowchart and coverage by main service providers.

It is important to underline that not all the areas can benefit from the same service, in terms of both quality and frequency. Waste accumulations are more frequent where service is poor due to lack of containers and vehicles, irregular collection, unpaved roads or simply because considered less important. In fact almost all service providers' assets share bad conditions, need of maintenance, and a life span exceeded by long time. Due to such situation, service does not cover all the population, and people living in peri-urban or recently built areas are not served. Table 3, reporting data directly collected from service providers and their estimations, generally confirms it, suggesting that about the 91% of the waste produced in serviced areas is disposed of in landfill. Considering a total population living in Gaza Strip of 1,657,155, it is possible to estimate a generation rate of 0.84 kg/per/day, and a disposal rate of 0.76 kg/per/day. Such values are only slightly underestimated, as municipalities whose data were not available are not very populated.

About waste composition, some weighing campaigns were carried out in the past, but methodology was either unclear or disputable. Then it is clear that composition has been affected by blockade and security. However organic should cover the 50-60%, sand and fine material 10-15%, while packaging is an important component (paper 7%, plastic 14%), as it is required to protect goods coming through tunnels (DHV et al., 2012).

DISCUSSION

The FS was able to set a picture of the situation shared by almost all the service providers, and it addresses solutions to face final waste sanitary disposal, probably the main challenge in Gaza Strip, due to land scarcity. Haulage, with logistics optimization, was included, as well as costs for improving collection. However it is a middle-long term approach, and it will be obviously affected by conditions both external, like security, blockade ceasing or at least easing, and large support from international donors, and internal, like a significative increase of fee and payment rate, road quality improvement, large raise of composting activities and trustful use of produced compost by farmers.

However at short term, and in case of endurance of instability and current constraints, it is possible to identify solutions to at least ease the heavy waste load on the system, and to improve situation in currently poorly served areas. Obviously they will have neither to overlap with the development plan at Gaza Strip level nor to conflict with it; they should support recycling and reuse practices, and tackle specific waste flows not considered, instead. Moreover, considering the current low level of fee payment rate, and waste dumping, it is important to work to raise awareness about the environment, and to increase people direct involvement. Waste management can also create good job opportunities or income generating activities. Supporting recycling and small scale activities could have also an important impact on Gaza Strip economy (Wilson et al., 2006).

M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.26 (1-10)

Table 3 Breakdown of disposed solid waste per source and landfill and estimated generation.

Municipality	Governorate	Disposed waste (ton/day)	Disposal Site	Collection rate	Waste generation (ton/day)
Um Al -Nasser	North Gaza	n.a.	Johr al Deek	95%	n.a.
Beit Hanoun*	North Gaza	27	Johr al Deek	95%	29
Beit Lahia*	North Gaza	42	Johr al Deek	95%	44
Jabalya*	North Gaza	119	Johr al Deek	95%	125
El-Zahra*	Gaza City	3	Johr al Deek	95%	3
Al-Moghraqa*	Gaza City	3	Johr al Deek	95%	3
Gaza City*	Gaza City	535	Johr al Deek	95%	564
Wadi Gaza	Gaza City	n.a.	Johr al Deek	95%	n.a.
Al-Breej**	Middle Area	10	Deir al Balah	90%	11
El-Zawaida**	Middle Area	10	Deir al Balah	90%	11
Al-Musadar**	Middle Area	1	Deir al Balah	90%	1
Al-Maghazi**	Middle Area	9	Deir al Balah	90%	10
Al-Nusirat**	Middle Area	29	Deir al Balah	90%	32
Deer Al-Balah**	Middle Area	47	Deir al Balah	90%	52
Wadi El-Salqa**	Middle Area	1	Deir al Balah	90%	2
Al-Fokhari	Khan Younis	n.a.	Sofa	80%	n.a.
El-Qarara**	Khan Younis	12	Deir al Balah	80%	16
Bane Sehela**	Khan Younis	17	Deir al Balah	80%	22
Khan Younis**	Khan Younis	93	Deir al Balah	80%	116
Khuza'a**	Khan Younis	7	Deir al Balah	80%	8
Abasan Al-Jadedah**	Khan Younis	5	Deir al Balah	80%	6
Absan Al-Kabera**	Khan Younis	13	Deir al Balah	80%	17
Al-Shoka	Rafah	n.a.	Sofa	70%	n.a.
Al-Nasser	Rafah	n.a.	Sofa	70%	n.a.
Rafah***	Rafah	100	Sofa	70%	143
2 camps*	UNRWA North	50	Johr al Deek	100%	50
5 camps**	UNRWA Middle	97	Deir al Balah	100%	97
1 camp***	UNRWA South	30	Sofa	100%	30
TOTAL	**Disposal**	**1,261**	**ton/day**	**Generation**	**1,391**

**: source: municipality of Gaza, Johr al Deek landfill registry for September 2011.*

***: source: Financial Statements and Independent Auditor's' Report for the Year Ended December 31, 2010 - SWMC Deir al Balah-Palestine.*

****: source: interview with municipality of Rafah, Environment and Health Department.*

Table 4 offers a list of actions and approaches to tackle specific challenges. Generally they start from the concept of intermediate technology (Schumacher, 1973), particularly appropriate to meet Gaza Strip constraints: small systems, not very depended on external materials, technologies or capacity, hence quite robust in a fluid situation. Several solutions were suggested, but in this paper only few will be discussed: approaches to improve population involvement, solutions for peri-urban areas and sustainable introduction of separate collection.

Table 4 Challenges identification, and solutions proposal.

Challenges		**Way forward**
Topic	**Specific challenge**	**Solution**
Vehicles conditions	Scarcity of vehicles	Solutions to reduce vehicle use, through **reduction of waste disposal of in landfill** (separate collection of recyclables): - Separate primary collection with locally designed system - Separate collection in schools and public offices - Separate collection of specific fractions in commercial area
	Vehicles are old and in need of maintenance → frequent breakages	
	Scarcity of spare parts	
	Impossibility to regularly apply a daily action plan for vehicles due to previous reasons	
	Difficulties to transport all the waste from TS to landfill due to previous reasons	
Separate collection and recycling	High content of organic matter	**Composting** (starting from specific areas, like market, rural and scarcely covered ones) **Anaerobic digestion** (with direct use of produced biogas)
	How to effectively introduce separate collection	Progressive introduction of door to door or kerbside collection in small and not to crowded areas (pilot project with **participatory design** and previous agreement about recyclable selling)
	Waste volume increasing (with density decreasing) due to higher content of packaging (in particular carton in commercial area)	**Packaging to be collected separately**, in particular in commercial area
	Instability of plastic as secondary raw material due to import through tunnel of better quality, affecting separate collection activity	**Increasing quality** of collected material, availability of **storing place**, **contracts with fixed price** for a certain period, support craft made local reuse and recycling activities
	Presence of informal waste collectors and scavengers at transfer stations and landfills	**Integration of informal waste sector** into formal activities
	Service providers are understaffed (in particular for labor intensive work like primary collection with donkey carts)	In particular for primary collection workers, find **other forms of payment** (integrating separate collection with existing recycling opportunities) and **MSW fee collection** (direct fee collection from households)
Improper disposal	Several sites with improper waste disposal (limited quantities), probably due to scarce environmental attention and poor collection system	**Cleaning campaign**, possibly with school involvement. **Awareness campaign** and **participatory solution designing and planning** at local level (some households provide street cleaning as payment for unique bill, as actually they already do)
	Several areas scarcely/not covered by MSW collection (no kerbside collection, street containers are very far and often undersized, service infrequent and irregular); such areas are peri-urban or rural, usually with unpaved roads	**Locally designed solutions**, introducing organic recovery directly on site (composting or anaerobic digestion) and recyclable storing

Approaches about population involvement, facing staff scarcity and improper waste disposal

MSW service is expensive and current budget is not able to cover all the costs without external support. Fee collection rate is low and currently no sign is present about a trend changing. Moreover future scenarios consider to increase such fee in order to achieve economical sustainability, as well as a very high collection rate is required. If it could be possible at medium – long term, after application of specific policies and regulations, at short term no solutions to increase direct payment look feasible. Therefore it is suggested to change the approach, at least in certain areas where service is already lacking and improper disposal is frequent.

The main point is to get a money saving, through a practical work, that could be considered an alternative payment for public service fee. For example, part of people involved in primary collection could be exempted from the unique bill (usually water supply and MSW collection fees are requested together), as partial payment for their work. It is important to include not only MSW service, but also others like water distribution, potentially easier to cut off, or healthcare; otherwise people will not be attracted, as currently fee is not commonly paid. Another possibility is to contract out waste collection for specific areas, for example small communities, allowing contractor to directly collect MSW fee. In fact operative costs are higher for certain areas, where roads are in bad conditions, people more scattered and vehicles in use not appropriate. Therefore a more customized service could be more effective and efficient. A private contractor would be more flexible and could use more appropriate vehicles, even simple donkey carts, at least for collection phase; haulage could be still managed by official service provider, but from a more convenient spot. It is similar to primary collection currently in use in some governorates, but in this case contractor will pay service provider for haulage and disposal phase, if he cannot provide them directly. However the important point would be to allow contractor to directly collect fee, as a private subject is usually much more effective than a public actor due to its own interest. This system is already in place between SWMC-Middle Area and municipalities, but with the important difference that primary collection is up to public actors, not private.

Obviously such approaches are strongly related to local situation: people living conditions, service providers, public services. Therefore it should be accepted by all the parts, with a participatory design in order to be attractive for people, effective for service quality and convenient for municipal budget.

Solutions for poorly/non-covered rural/peri-urban areas

Several areas are very poorly covered, so waste are often scattered around or improperly accumulated. Collection is difficult and expensive for service provider and, if present, it is irregular. Tailor-made solutions should be implemented, arranging groups of people collecting waste, separating (possibly at the source) and properly storing them. Organic should be segregated at the source and locally recovered, with either composting or anaerobic digestion. Then recyclables should be stored aside, ready for collection by recycling company. When remaining material reaches a certain quantity, formal service provider should be called in order to provide haulage and disposal, with logistic optimization as waste quantity will be clear. With an effective preliminary organic removal, waste should be stored with little smell, reducing need of open burning and presence of scavenging animals. With the same criteria, recyclers can be called when enough material is available.

The main point is organic recovery, very important to strongly reduce quantity of waste to haulage and landfill. Then, another aspect is how to make such system economically sustainable, as recyclables do not have enough value. Organic recovery has to be carried out locally, otherwise cost of haulage will make it uneconomic; moreover no centralized medium – large capacity plants are present in Gaza Strip, therefore currently this material has no economic value.

Composting is a possible solution, quite simple from a technical point of view, but challenging and troublesome from others. In fact if starting material is not contaminated and processing works properly, resulting compost will be of good quality, ready for use or selling. However it is not so easy to produce a compost good enough for selling and, according to FS, market has to slowly accept it. In case of introduction of low quality compost, all the market could look warily at Gaza made production. Moreover if we consider rural / peri-urban area, agricultural waste and manure are usually available, and they are easier to compost with good results. For previous reasons, at least at short term and at low capacity scale, composting cannot guarantee a stable income generation, but only a domestic use. Therefore it could interest only specific people, very committed and with the possibility to directly utilize it.

Anaerobic digestion looks more applicable, but under specific conditions. It should be at very small scale, with simple technology and low capacity; at the beginning it could be a pilot project at household level. It could be eventually extended later, after first operational results, when process data are available to design digesters of larger capacity. In fact, according to documents and visits, anaerobic digestion is a technology currently not in use in Gaza Strip. Therefore it should be tested, as well as local capacity and knowledge should be developed. Moreover at the present moment large digesters, with high biogas production, look not feasible also from a political - strategic point of view: import of required material and equipment would not be probably allowed and construction and operations will be endangered by Israeli in case of instability.

Anaerobic digestion at household level has been practiced for decades in several Countries (e.g. China, India, Nepal, Tanzania), with millions households (Voegeli and Zurbrugg, 2008) receiving energy from small scale digesters. Technology is consolidated, while several models and set-ups are available, with different capacities. It is important to identify the most appropriate for Gaza Strip, but required materials are very simple and available at local market, while local technicians are already highly skilled; moreover local university could follow the testing phase, also for an academic interest, in order to enlarge their expertise.

Biogas can be used in different ways (Bond and Templeton, 2011): it can be connected and directly used by a cooking stove (Kurchania et al., 2011); it can be directly burnt for energy production and/or heating purposes; it can be stocked for transportation, selling and different uses. Actually last point would be more problematic if immediately applied in Gaza Strip, because it is more complicated and requires advanced technical capacity; moreover, as gas should be particularly clean, some treatments, not appropriate for a domestic scale digester, would be required. Therefore the recommendation is to start introducing and testing such technology with very small capacity (domestic) plants, and then to increase progressively the level of complexity (community scale).

Practically some households could be supplied with domestic digesters, whose operations will be regularly monitored with also local university support. These people will collect waste from the surroundings, as previously agreed with MSW service provider. Organic waste will be used as feeding material for anaerobic digestion, recyclables (plastic and metal, eventually paper) and remaining waste will be stocked in specific containers. Such containers will be distributed by service provider and located in a suitable place to both favourite haulage and prevent scavenging, especially for recyclables. Concerning these aspects, it would be better to involve for this activity people already working in recyclable collection, like scavengers and road collectors; from one side they will be moved from informal to formal sector, from the other a "market competitor" will be avoided. Previously explained approaches should be considered for this solution application.

Benefits will be several, and in particular:

- for workers: they will be involved in a formal activity, earning some money from recyclable selling (point to be discussed and agreed with service provider: it is better they receive at least a percentage on quantitative base, in order to be stimulated to collect more) and anaerobic digestion. First of all, they will save money for cooking fuel, as they will produce it autonomously; then they could be paid a certain amount from other households for feeding their digesters;
- for other people: they will receive at least a better service, while some households will save money using digesters (cooking fuel is imported, price fluctuates and it is a relevant domestic expenditure);
- for service providers: waste quantity to manage is minimized, removing both organic and recyclables. Moreover haulage can be optimized and carried out only when it is really required;
- for local economy: in general people will be formally employed, with the possibility to develop other income generating activities. If the system is successful, other people will be involved in digester production, as well as in related activities (e.g. cooking stove, maintenance) and developments (e.g. for energy production).

Last but not least, production of biogas out of organic solid waste effectively replaces fossil fuel, making energy locally available. From one side Gaza Strip will be less depended on imported fuel and potentially for electricity, from the other greenhouse emissions are reduced. In fact working with anaerobic digestion allows to access to CDM (clean development mechanism) funding of the carbon trading system. Moreover, compared to current unsafe disposal site, impact on natural compounds (air, soil, water) is greatly reduced, as well as related external costs (Muller, 2007).

Practically this solution needs anaerobic digester model adaptation/development, material supply, construction activities (digesters and biogas users, like gas cooking stove), training, capacity building and monitoring activities, plus a good coordination with MSW service provider. It is suggested to involve a local university as technical partner.

Solution for sustainable introduction of separate collection and education activities

Several public institutions are present in Gaza Strips, in particular schools and offices, where thousands of people daily spend several hours. Such places produce a large quantity of good quality paper, plastic and metal, all that could be easily separated at the source. Scholastic canteen produces organic, it can be segregated for composting or simply disposed with general MSW. Contracts can be signed with private companies (e.g. small recyclers, scrap yards) to directly collect recyclables when container of a specific material is full. In this way logistics can be optimized (material volume will be known), with clear economic agreements and material of good quality regularly available for recycler. School and public office have no additional cost, besides containers, while material separation will be a source of income. It will be important to fix a unit price to avoid dispute and market fluctuations; considering lack of costs for waste producer, unit selling price could be even quite low at the beginning. Eventually later, when recyclers recognize material quality and activity profitability, an open tender can be arranged to get a better contract.

Such activity in schools can be very important also for educative purpose, in order to raise environmental attention in the youth, the largest part of Gaza population. A specific awareness campaign can be arranged, and daily separation practice will provide an effective learning-by-doing approach. Eventually organic waste could be composted, possibly with a composter as it is particularly simple and requiring little space. Compost could be used for gardens inside the scholastic area, or outside for public green caring. In fact students could be involved in cleaning campaign for certain areas, sharing scholastic activity and experience with community. Such activity could eventually include other topics connected to sanitation, but it is important to organize practical activities and decide a limited numbers of messages to convey. Some CBOs and local NGOs have already experience in both waste management and awareness campaign, showing both good technical capacity and close relations with university world. Such kind of cooperation could be strategic to properly monitor activities, regularly data collection and analysis, and to eventually rectify some aspects.

Finally it is suggested to support local entrepreneurs and companies introducing other possible recycling activities, in particular for paper/carton and plastic recovery. In fact, the internal market is potentially attractive, but according to current recycling practices, it is more profitable to process imported secondary raw material; moreover in general factories are closing. However several alternative actions with the aim to close the whole recyclables life cycle in Gaza Strip are possible, with different levels of complexity, like production of fuel briquette, insulating panels (Ayrilmis et al., 2008), and decorative sheets and items.

CONCLUSIONS

Gaza Strip situation is highly constrained by internal and external drivers, and MSW management is an heavy load, with impact on both public health and the environment. Although service providers have been able to somehow face the situation, thanks to great struggle and external support, challenges are increasing more and more, and system could collapse soon. A middle and long term program to improve haulage and landfilling has just been developed, but collection, in particular in some areas, and material recovery activities look still challenging. Most of all, at short term, and in case of duration of instability and the blockade, it looks important to introduce good practices and approaches to decrease the load on the system, with locally sustainable solutions, and appropriate technologies not conflicting with future system development program. Community involvement approaches, alternative fee payment systems, anaerobic digestion at domestic scale, and separate collection in public institutions look to be the most promising actions recommended by authors. Moreover paper and plastic recycling activities, at small scale and not requiring particular equipment nor capacities, should be introduced, in order to boost recycling potential in Gaza Strip.

ACKNOWLEDGEMENT

This study has been developed within the activities of the “Support to vulnerable households affected by limited livelihood opportunities in West Bank and Gaza Strip, Occupied Palestinian Territories” project, funded by DG ECHO, implemented by COOPI. The authors wish to thank all the COOPI staff, both in Italy and in oPt, for the support in the research activities. Marco Caniato is a Ph.D. trainee in “Appropriate Methods and Technologies for International Development Co-operation” of the University of Brescia, supported by the Alberto Archetti Fund.

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ISBN: 978-984-33-7045-7 PI. 36 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Integrated and Eco-Friendly Approach of Waste Management: An Environmental Case Study of Dhaka City in Bangladesh

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ABSTRACT

Waste is an unavoidable by product of human activities and Improper management of this waste is one of the main causes of environmental pollution. Waste generation increases with population expansion and economic development. The sight of a dustbin overflowing and the stench rising from it are all too familiar sights of the old part of the Dhaka city. The municipal agencies are unable to handle the increasing amount of municipal solid waste, which into the uncollected waste being spread on roads and in other public areas leading to tremendous pollution and destruction of land and negative impact on human health. In this paper we will try to come up with acceptable integrated approach to solve the environmental problems and to reduce the quantity of solid waste disposed off on land. This paper will also highlight the present status of municipal solid waste management in Dhaka city including environmental issues. It is also envisaged to expose the solid waste generation rate, its composition, collection systems, and areas of responsibilities (public / private sector), transfer and treatment sites and waste disposal systems used.

INTRODUCTION

The generation of solid waste has become an increasingly important global issue over the last decade due to the escalating growth in world population and large increase in waste production (M. A. Warith,2003). Improper management of solid waste is one of the main causes of environmental pollution and degradation in Dhaka city, which is our main concern. Waste Management has emerged as one of the greatest challenges faced by Dhaka city corporation authority. DCC is facing serious problems in providing a satisfactory service to the city dwellers with its limited resources and a poor management plan. An inadequate information base (regarding quantity, type and characteristics of wastes), poor operation and maintenance of service facilities and above all lack of civic awareness on the part of a section of the population are adding up to the deteriorating environmental situation(Faisal Ibney Hai,2004). Waste generation increases with population expansion and economic development. Improperly managed solid waste poses a risk to human health and the environment. Uncontrolled dumping and improper waste handling causes a variety of problems, including contaminating water, attracting insects and rodents, and increasing flooding due to blocked drainage canals or gullies. In addition, it may result in safety hazards from fires or explosions. Improper waste management also increases greenhouse gas (GHG) emissions, which contribute to climate change. So, it is important to assess the pollution level for the protection of environment and natural resources that requires sustainable interventions in the Dhaka city. Therefore, a study on the environmental impact assessment in the surroundings of Dhaka city on the basis of relevant environmental parameters and made an EIA report based on it. So, the overall objectives of this study were:

1. To evaluate the existing environmental condition in Dhaka city.
2. To gather information regarding waste generation, collection, handling, hauling, treatment and disposal of waste.
3. To adapt/undertake the protective measures to reduce the adverse impact of waste on human environment and natural ecosystem.
4. To build up the awareness program for strengthen the waste management system.

Figure 1: the location map of the Waste dumping site

A REVIEW ON EXISTING ENVIRONMENTAL CONDITIONS IN DHAKA CITY

Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the developing world. Dhaka is one of the most polluted cities in the world (according to an UNFPA report'2001). Municipal waste is one of the major issues but air and water pollution are also responsible to make the city pollute.

Solid wastes are basically of two types (a) organic wastes, which include vegetables, fruits, food staff from households, hotels and restaurants, and (b) hard wastes, such as pieces of wood, metals, glass, plastics and polythene materials, paper, rubber, cloths and textile factory waste and construction materials. Household waste is an aggregate of all substance from a household ready for disposal, which is about 1718 tons /day at a percentage of 49.08 %. There are over 1,000 small and large industries in the Dhaka metropolitan area generating a significant amount of toxic and hazardous wastes and contributing to environmental degradation in and around Dhaka City. These industries include chemicals, textiles, dyeing, printing, tannery, iron and steel, metal, plastic, rubber, and tobacco. A total of about 722 tons and 835 tons of Commercial & Industrial Waste generated per day from Dhaka city. It is estimated that 20 percent of the whole hospital wastes (255 tons, 7.29 % of total solid waste generated per day) generated in the city is infectious and hazardous. Waste is collected from small bowls (plastic or metal) or plastic bins provided for each bed and emptied into larger containers. These containers are then conveyed by pushcart to the nearest municipal bin for dumping. (Reza 2005)

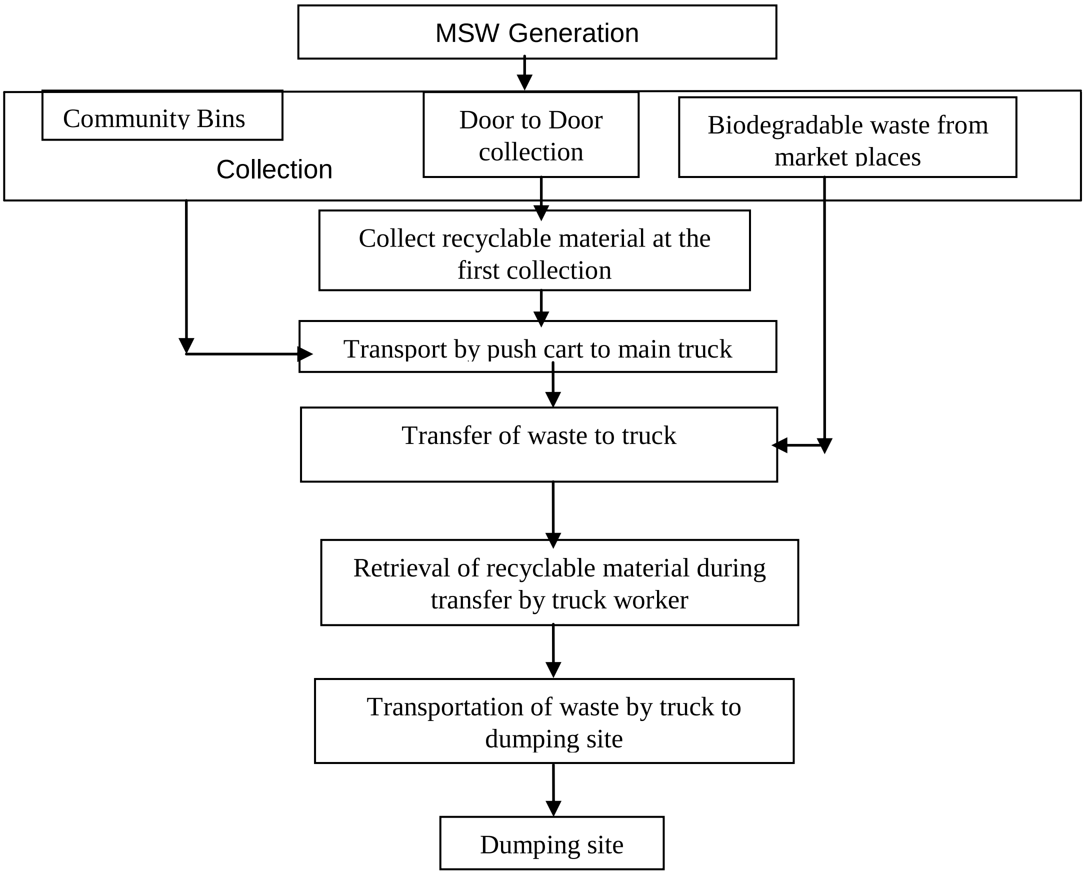
More than 3 million people do not have legal access to water supply in Dhaka City. Quality of water is poor and the incidence of water-borne diseases such as diarrhea, cholera, dysentery, jaundice, typhoid etc. is very high. Due to indiscriminate discharge of wastewater the water bodies within Dhaka City are polluted. About 45 % of populations are connected to separate or combined sewerage system and 11% of populations are connected to septic tank. Rest of the population discharges wastewater directly or indirectly to water bodies (Report on SWM; DCC' 2005). The river of Buriganga contains soluble chromium, which causes cancer and for that leather industries in Hazaribagh are mainly responsible, most of which are situated along the river. The water bodies often are loaded with human excreta, decomposable kitchen wastes, other non-decomposable wastes and industrial effluents.

STUDY METHODOLOGY

The study used both primary and secondary data. Primary data collected from officials and general people of Dhaka City Corporation. The methods used for this study are a combination of observation by case studies and questionnaire survey. Relevant data for this study were collected directly from the field by using a questionnaire and depthinterview. The sample size was 100 respondents (Residential respondents 50, Commercial 25, Service Sector 25) for the questionnaire survey. The key part of the questionnaire inquires the perception on the general people who received the service. The methods adopted for the present study also make extensive use of secondary material analysis to build up and support the objectives of the study. The data obtained through the field survey was analysed as input for EIA. The relative importance among various environmental parametes was conducted by pairwise comparison. The pairwise comparison method is applied to reduce individual judgment errors by requiring multiple pairwise comparisons of relative values. An

Environmental Impact Value (EIV) was calculated based on the weightage and maginitude of the concerened parameter and an EIA report was prepared.

Figure 2: Current Solid waste management practice in Dhaka city



ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

An environmental impact assessment (EIA) is an assessment of the possible positive or negative impact that a current situation may have on the environment, together consisting of the environmental, social and economic aspects. The purpose of EIA is to ensure the protection and conservation of the environment and natural resources including human health aspects against uncontrolled development. The long-term objective is to ensure a sustainable economic development that meets present needs without compromising future generation's ability to meet their own needs. EIA is an important tool in the integrated environmental management approach.

METHODOLOGY FOR EIA

Considering the situation of our country, a simple methodology was taken for Environmental Impact Assessment of the environment of the Dhaka city. The methodology used for EIA in Dhaka city is Environmental Evaluation System (EES). Relative importance of the parameters is selected based on 'LGED guideline, 1992'. The environmental parameters are grouped into four categories which are: Physical resources, Ecological resources, Human use values and Quality of life values. The environmental impact was assessed by Environmental Impact Values (EIVs) which may be defined mathematically as equation (1):

$$\mathrm{EIV} = \sum_{i=1}^{n} Vi\ Wi \qquad (1)$$

Where V_i is the relative change in the value of environmental quality of parameter i with respect to existing situation. W_i is the relative importance or weight of parameter i, and n is the total number of environmental parameter related to the project. The computation of EIV of solid waste needs determination of V_i, the value representing the magnitude of alteration of the environmental parameters, and W_i, the value representing relative weight or importance of the respective parameters.

Table 1: Environmental Impact value of Dhaka city

Environmental Parameters	Relative importance value	Degree of impact	Relative impact		EIV
			POSITIVE	NEGETIVE	
Physical resources					**-55**
Dust pollution Obstruction to water flow Regional hydrology/Flooding Drainage congestion/ water logging Land use	6 6 4 5 5	-3 -3 -1 -4 +1	+1	-3 -4 -1 -5	-18 -18 -4 -20 +5
Ecological Resources					**-62**
Fisheries Flora & Fauna Wetland habitant Forest Eutrophication Aquatic biology Sewerage	6 4 4 2 1 4 4	-4 -2 -2 -1 0 -3 -2	0	-4 -2 -2 -1 -3 -3	-24 -8 -8 -2 0 -12 -8
Human use value					**+48**
Employment opportunity Commercial and service facilities Industrial activities Landscape Navigation Irrigation facilities Flood control	8 6 3 2 3 3 3	+4 +3 +2 -1 0 0 -2	+4 +3 +2 0 0	-1 -2	+32 +18 +6 -2 0 0 -6
Quality of life values					**+11**
Public health Disposal of garbage	6 7	-4 +5	+5	-4	-24 +35
Total Environmental Impact Value (EIV)					**-58**

MAGNITUDE OF ENVIRONMENTAL PARAMETERS

The beneficial and adverse changes in environmental parameters resulting from solid waste, usually expressed in qualitative terms are plotted in a scale to quantify the environmental alterations in Table 1. The changes of environmental parameters are measured with respect to background conditions. The adverse changes have been given values -1, -2,-3,-4,-5 to represent very low, low, modarate, high and very high negative impacts respectively. Similarly +1, +2, +3, +4, +5 represent very low, low, modarate,high and very high positive impacts respectively. A value from the scale representing effect of the project on each parameter was taken to compute the EIV of the Dhaka city for solid waste.

IMPORTANCE OF THE RELATIVE ENVIRONMENTAL PARAMETERS

The importance of a parameter varies from country to country depending on the environmental concerns of the country. All environmental parameters influenced by the solid waste are not of equal importance or weight. EES methodology is based on the assignment of an importance unit to each parameter by judgment of professional experts consists of chemists, biologists, civil engineers, environmental engineers, agricultural scientists, social scientists and urban planners. The judgments complete the pair wise comparisons that are needed at this stage, and are entered in a pair wise comparison matrix. The data in the matrix can be used to generate a good estimate of the criteria weights (Nydick et al. 1992). The weights provide a measure of the relative importance of each criterion.

RESULT AND DISCUSSION

Values are indicating the magnitude of environmental changes influenced by the solid waste. All these impacts were summed up to obtain the total EIV of -58. Despite of some human interest related factors as positive impacts on physico-ecological environment made the total EIV negative. Based on the interviews it was found that the environmental parameters gave the highest negative value of -62. Employment opportunities earned positive degree of impact because people living here are so poor that they are satisfied to earn rather than remaining unemployed although the working condition is totally adverse.

RECOMMENDATIONS

The concerned authority like RAJUK, DCC, DWASA etc. should take the immediate and long term measures to overcome the existing problems.
Following recommendations should be taken into considerations:

- Preparation of legislation, (by laws, rules, regulations) should be involved for Waste reduction
- There have to be provision for involving interested NGO’s, private sector and general public to participate in waste management
- Formulate the policy for community-based program for strong awareness creation undertaking to win the commitments
- Involvement of the community in the system of safe household waste management
- Composting plant should be installed
- Institutional strengthening should be built for recycling sector where it is a way of managing household waste
- Informal recyclers have to be encouraged by providing them space to produce their materials
- Sustainable solid waste management should be assisted through generation of electricity, gas, fertilizer, ceramic product etc
- Landfill should be designed in such a way that it can sustain for long time and manage waste properly
- Public awareness program where attention have to be given for reusable household waste

CONCLUSION

Urban solid waste issues represent major problems in developing countries, so infrastructure and technology should be improved to overcome barriers to the safe collection and disposal of urban waste. Effective solid management system is needed to ensure better human health and safety of workers involving in the process of waste disposal. So NGOs can contribute for initiating a environment friendly system, demonstrating new concepts, providing technical training and knowledge to others. In addition to these prerequisites, an effective system of solid waste management must be economically sustainable also.

A community based projects have a demonstrated effect for managing solid wastes and the success of this approach depends largely on identifying and addressing the community’s needs. Although Dhaka is a capital city, in spite of being a large number of residences are not completely aware of the health hazard and solid waste related problems. The households are not disposing their waste in bins or a recommended place. Therefore, it is important to launch a long-term awareness program that people can be motivated for enhancing their existing environmental conditions willingly where media can play an integral role for building up this program. Apart from the media, Government Should has taken the policy as soft and hard measures for implementing the system which is environmentally sustainable.

ACKNOWLEDGMENT

The authors would like to thank the authority and workers of DCC and the local people of Uttara area.

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ISBN: 978-984-33-7045-7 PI. 38 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Study the Household Solid Waste Generation in Rajshahi City

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ABSTRACT

Data on solid waste generation rates and waste composition are the basic information to plan and implement the solid waste management system. The main objective of this study is therefore to identify the compositions of household waste and analyze its generation rate and assess solid waste management systems in Rajshahi city. The study was conducted on randomly selected 138 households which are expected to represent all categories of income level (Low, Middle and High income levels). This study reveals that, the household solid waste generation rate in Rajshahi city is 0.378 Kg per capita per day which makes the total daily, monthly and annual generation are 170, 5100 and 62050 tons respectively. The physical composition of the solid waste of the city is mainly organic which constituents 60.3% and recyclable waste is 7.3% which assures that 67.6% of the total waste is a resource to generate more income for employment.

INTRODUCTION

Solid waste management (SWM) is one of the critical concerns facing the developing countries because of the social, economic and environmental implementations once not properly managed. Studies shows that only 30-50% of the waste generated in developing countries is collected and managed properly (Dawit and Alebel, 2003). The rest is either burnt or left to decompose in open space or dumped in unregulated landfills which are damaging the environment. The base of the municipal slid waste management system is reliable information about the quantity and type of material being generated. The quantity and type of waste generation determines the decisions for managing them (Tchobanoglous et al., 1977). It is thus a prerequisite for collection program managers to have detailed information about the nature and quantity solid waste generation in order to set appropriate management systems.

In Bangladesh, alike developing countries, the increase of solid waste generation is resulted from rapid urbanization and population booming. According to Dawit and Alebel (2003), the amount of solid waste in Rajshahi City Corporation (RCC) and other fast growing areas in the country has been increasing over time, largely attribute to rapid population growth rate. The same authors indicated that from the total solid waste released by the population in the city about 50-60% was collected and rest was unattended. Recently the municipality has increased its coverage to about 85% (AACG-SPBA, 2003).

RCC, as being one of the fast growing towns of the country, has increasing solid waste generation. The average per capita rate, according to estimation of Ministry of Health, aperson generates 0.378 Kg/day solid waste (Ministry of Health, 1996). According to CSA population projection of 2006, RCC has a population of 800000 (CSA, RCC, 2006). Based on the data, 170 tones of residential solid waste is being generated every day in the town. Inadequate solid waste management in RCC has resulted in the accumulation of waste on open lands, in drains and in the residential areas, causing a nuisance and foul smelling pools, environmental pollution through leachate from piles (water and soil pollution) and burning of waste (air pollution), clogging of drains. This situation is believed to result in poor environmental conditions, which in turn present a formidable threat to health. There is thus a need for improved waste management system in the town.

Therefore, it was planned to conduct a study on solid waste quantity and composition of household in RCC. The prime objectives in this study are to determine the household solid waste generation rate as well as to determine the physical composition of household solid waste in RCC. It is hoped that this study will have paramount importance in providing relevant information that is basic to design appropriate solid waste management system.

HOUSEHOLD WASTE

Household waste is an aggregate of all substances from a house hold ready for disposal. These include paper, vegetable peelings, onion seed coats, broken plastic and festal, spider net, soil and dust, pieces of cloth, small bottles, soot, used car parts, etc. The waste aggregate more frequent and most abundant in the whole mass of household waste is house sweeping, which is composed of soil and dust followed by pieces of paper and vegetable peelings.

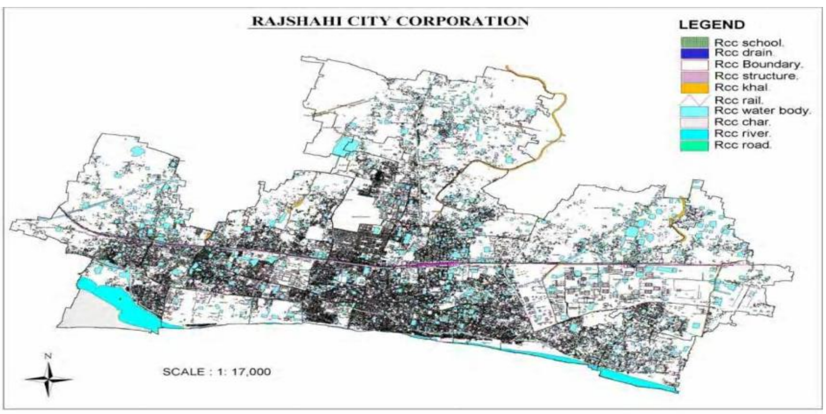
SOURCES AND COMPONENTS OF RESIDENTIAL SOLID WASTE

The sources of solid wastes are residential, commercial, institutional, construction and demolish municipal services, industrial treatment plants sites and agricultural wastes (Tchonoglous et al., 1977). Various industrial plants generate wastes, which are mainly hazardous wastes during their raw material preparation, production or transportation processes. The waste generated from such sources is not only hazardous but also inorganic requiring special treatment before final disposal (Bilitewski et al., 1977). In this regard, in RCC small scale manufacturing activities are found to significant amount of wastes. Solid waste sources are mainly municipal services in RCC.

The composition of a municipal solid waste (MSW) stream is important for designing material recovery facilities and developing other waste minimization programs. Successful characterization depends on obtaining representative samples of the collected solid waste and making statistically precise and accurate estimates of components weights (Zeng et al., 2005). The percentage of residential solid waste (RSW) components varies with location, season, economic condition and many other factors (Tchonoglous et al., 1977). Components that typically make up most MSW include food wastes, paper, ash, plastic, metals, textiles, glass and ceramics etc.

DESCRIPTION OF STUDY AREA

Rajshai is one of the oldest city is northwestern part of Bangladesh. The river Padma or Ganges, one of the major rivers of the Indian subcontinent, flows beside the city. It was promoted to a district headquarter in 1825, a municipality in 1876, a city corporation in 1987 and a metropolitan city in 1992. the climate of Rajshahi is generally marked with a typically tropical monsoon climate with high temperature, considerable humidity and moderate rainfall. The hot season commences early in March and continues till the middle of July. The maximum mean temperature observed is about 32°C to 36°C during the month of April, May, June and July on the other hand the minimum temperature recorded in January is about 7°C to 16°C. The highest rainfall is observed during the months of monsoon. The annual rainfall in the district is about 1,448 mm. The city is divided into 30 wards. In 2001, the population was estimated to be 350,000. Rajshahi city is now producing about 300M tones of solid every day. The city corporation is unable to manage this amount of solid waste. Expansion of city boundary as well as human settlement enhances the solid waste generation. The solid waste management will be a big problem for Rajshahi city in future. The present management system of solid waste is unhygienic. The RCC is now collecting and dumping both biodegradable and non-biodegradable waste together in landfill. The landfill at Nawdapara was started in 1963 but it is still traditional. There is no sanitary landfill in RCC area. Figure 1 showing the study area.



Source: RCC 2006

Figure 1. Study area

IDENTIFICATION OF HOUSEHOLDS

To identify participatory households, all households were stratified into three income level groups; low, middle and high income groups. Since there was lack of data on income level of the households, grouping was actually done in discussion with RCC administration, officials and some individuals who are expected to know about residents. Moreover, some information collected from different surveys and at country level by the Central Statistics Authority and other researchers was taken into consideration for comparison. Based on their life standards, housing and other facilities, households were categorized into low income groups, middle and higher income groups. Households which were categorized under low income level were those who are lining in slum areas and congested living rooms. To determine the no. of households those to participate in this study, a sample technique which was developed by Cochran (1977) showing in equation (1) to determine sample size with the desired degree of precision for general population was used. Equation (1) indicates that the minimum no. of households required for analysis of physical composition of solid waste is 138. After determining the total no. of households, 46 households (33%) from low income group, 69 households (50%) from middle income group and 23 households (17%) from high income groups were selected.

Systematic random sampling technique was employed to sort out sample residential houses to each of the three income groups (Agresty and Finlay, 1986). In doing this, effort was made to represent all corner of the town.

$$n = \frac{NZ^2PQ}{d^2(N-1)+Z^2PQ} \qquad (1)$$

Where, n= minimum no. of households required, P= Housing unit variable, Q= (1 – P), N= Total no. of housing unit, Z= Standardized normal variable and value that corresponds to 95% confidence interval equal to 1.96 and d= Allowable error (0.05)

COLLECTION AND SORTING OF WASTES

To obtain adequate information for the study, different types of data collection tools were employed. These were questionnaire, a focus group discussion and field observation. The questionnaire was set for selected households to have information about their socio economic status, housing condition, onsite solid waste handling and solid waste disposal practices.

Actual collection and sorting of wastes from the participating households has been conducted for eight consecutive days, but the first day data were discarded to be confident enough. In order to have an average result of the whole days of the week, in case of differences in waste generation between days, each household was given a plastic bag labeled with its house number. Next day during collection, another bag with the same label was given for the next day collection and this process continues for seven days. Finally, components of the solid wastes were separated, weighted and were recorded. Figure 2 shows the different stages of collection and sorting of household wastes.

DATA ANALYSIS

Primary data regarding the solid waste generation rate, percentage composition of RSW components, socio-economic status, housing condition, onsite solid waste handling, and currently existing RSWM practices of the residents of RCC were determined at the household level from a survey of 138 residential houses. The secondary data have been the main resources of information for the study. The secondary sources of data included books, published articles both from Internet and journals, various research papers that are published or unpublished, government publications, etc. The primary data obtained from sample residential houses through direct measurement (solid waste generated), questionnaire and focus group discussion were analyzed basically using averages, ratios and percentages as a major summarizing tool. Excel program was used for the analyses of data obtained from solid waste measurements and questionnaire. The average waste generated by the different households was calculated for low, medium and high-income levels. Results were compared whether the average waste generation rate was the same for each socioeconomic level or not. Moreover, the household waste components were analyzed and compared based on socio-economic levels. The percentage composition of fractions by household income is presented using tables Charts and graphs. To carry out the analysis a number of items of equipment like hand protective plastic gloves for handling, hand push and horse drown carts for transport of waste, scales of different ranges, wood containers for volume measurements, wire mesh or Sieve / to separate waste, 10 mm thick plastic sheets to cover the floor, plastic bag for collection and sorting of solid wastes, trash bag for collection of already processed wastes, photo cameras to record the research process were used.

Figure 2. Collection and Sorting of wastes

WASTE GENERATION RATE AND ITS COMPOSITION

Daily solid waste generation of the town as well as per capita per day solid waste generation rate at household level can be calculated from equation (2). According to our survey at 138 households, the average family size and total solid waste was 4.54 and 243.11 Kg/day respectively. The composition of household solid waste for different income level shown in Table. 1. The generation rate was ranged from 0.32 to 0.40 kg/cap/day, while highest generation rate was 0.40 kg/cap/day at high income family, lowest generation rate was 0.32 kg/cap/day at low income family and the weighted average was 0.388 kg/capita/day for Rajshahi city. Figures 3, 4 and 5 shows that household's solid waste composition (% by weight) for different income level family.

$$\text{Per capita per day waste generation} = \frac{\text{Total waste gerenation within } 7 \text{ days}}{7 \text{ days} \times \text{Total family size of } 138 \text{ survey household}} \quad (2)$$

Table 1. Component weight of household waste generation in Rajshahi city

Waste category	Household waste generation (Kg/day)		
	High income family	Middle income family	Low income family
Organic matter	29.74	85.95	51.52
Paper	3.92	10.65	5.89
Plastic	1.97	4.97	3.45
Textiles and Wood	0.99	2.12	1.54
Leather and Rubber	0.50	1. 42	0.81
Metal	0.50	1. 42	0.81
Glass	0.50	1. 42	0.81
Other	3.31	12.77	8.77
Per capita (Kg/day)	0.40	0.388	0.32

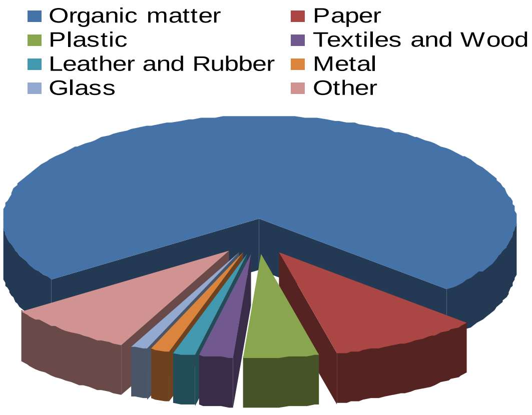


Figure 3. Household waste generated at high income family

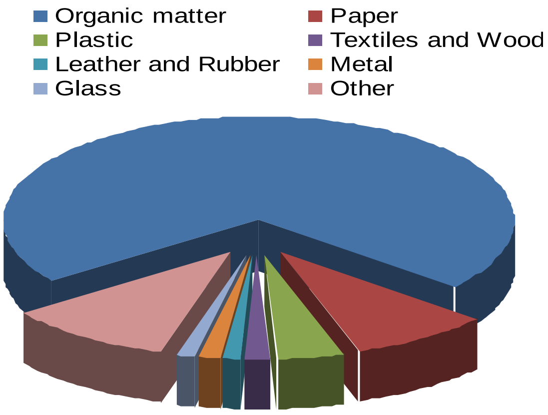


Figure 4. Household waste generated at middle income family

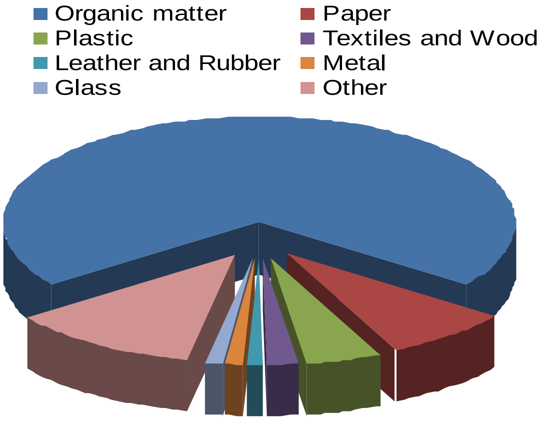


Figure 5. Household waste generated at low income family

DISCUSSIONS

In high socio-economic family, daily waste generation rates were generally higher that the other lower socio-economic families. According to our survey at 138 households in RCC, the per capita solid waste generation rate is ranged from 0.32 to 0.40 kg/cap/day, while the average rate is 0.388 Kg/cap/day. It is observed that organic matters are usually the predominant component in the waste stream, which ranged from 70 to 71.83% due to the common habit of fresh food consumption, while paper and plastics are about 8 to 9.47% and 4 to 4.5% respectively. The glass, leather and rubber were the smallest composition in each city. Statistical analysis indicates that the waste characteristics are slightly different with respect to geographical regions and the influence of seasonal variation is insignificant. There is a little variation of other waste characterization studies with compared to the present study due to different local conditions, methodologies, scope and waste component definitions. Composition of MSW is also positively related to other several influencing factors which are changed with time. The important factors are public attitude, population density, habits and custom of living, life styles, economic conditions, fruit seasons, climate, recycling and waste management program, all have a great impact on the waste composition. It is highly recognized that the existing solid waste collection and disposal services are inadequate both in terms of coverage and sanitary treatment of the waste. The solid waste collection service coverage is very low which means the major portion of the solid waste generated with in the city is uncontrolled and improperly disposed which creates unhealthy environment to live and work in. No condition is available for community and Private sector involvement in re-use, recycle and composting of the waste. But it can create job opportunity for the unemployed citizens of the town. In general waste management is not considered as important development sector to meet the goals set in the national and regional policies and strategies for sustainable development.

CONCLUSION

The study showed that, the household solid waste generation rate of RCC is 0.388 Kg/cap/day. For the total population, 170 tones domestic solid waste is generated from the town in a day. Based on this figure, the daily, weekly, monthly and yearly generation rate of RCC will be 170, 1190, 5100 and 620509 tones respectively. This does not include other municipal solid waste streams. To have a complete picture on generation rate similar studied should be conducted on the other waste streams. From this study it is also concluded that the waste collection system of the municipality is weak. Particularly door to door collection is insufficient. The truck assigned to this purpose is only one and is very old so that the coverage is very limited. There were no awareness raising education and provision to proper training of residents with regard to residential solid waste management methods in the town. This has aggravated the waste management problems and challenges thus leading to public health, aesthetic and ecological concerns. From the study results, large proportion of the waste (more than 74.4%) is decomposable organic matter, which might be efficiently recycled or composted.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7 PI. 46 (1-8)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Life Cycle Assessment of Solid Wastes in a University Campus in Bangladesh

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ABSTRACT

Waste is a by-product of our daily activities, which poses a serious threat to societies all over the world. Life cycle assessment (LCA) methodology was used to determine the optimum municipal solid waste (MSW) management strategy for Khulna University of Engineering and Technology (KUET). In this study, Life cycle assessment (LCA) of four different solid waste management scenarios was developed. Therefore, four different scenarios were developed as alternatives to the current waste management system. Collection and transportation of waste, a material recovery facility (MRF), recycling, composting, incineration and landfilling processes were considered in these scenarios. The total waste generation rate in KUET campus was found to be in the range of 0.41 kg/person/day. In accordance with the results obtained from this study, scenario four was found to be the option with the minimum environmental impact. Therefore, LCA should be implemented for waste management activities in developing and developed countries. In this study waste management alternatives were investigated only on an environmental point of view.

INTRODUCTION

The development of waste management started with the collection and transportation of waste to the disposal facilities, which in the majority of cases were local dumps or landfills. Solid waste management is a multifaceted and multidisciplinary problem that should be considered from technical, economic and social aspects on a sustainability root. For this purpose, different techniques can be used. Stu dies on modeling of solid waste management systems were started in the 1970s and were increased with the development of computer models in 1980s. While models in the 1980s were generally based on an economic perspective (Gottinger, 19880) models that included recycling and other waste management methods were developed for planning of municipal solid waste management systems in the 1990s (MacDonald, 1996). One of the main problems associated with these activities is that they may not have an immediate effect and some may have a more global impact on the environment. Life Cycle Assessment (LCA) is an environmental management tool that enables quantification of environmental burdens and their potential impacts over the whole life cycle of a product, process or activity. Increased biological treatment of organic waste is an explicit goal within the Swedish national solid waste management strategy (SEPA, 2005). The national environmental objectives state that 35%of all organic household waste should be treated biologically by2010 (SEPA, 2007). In the present study, three treatment alternatives for organic household waste are compared: decentralised composting centralised anaerobic treatment and incineration. Models have included linear programming with Excel-Visual Basic (Abou Najm and El-Fadel , 2004), Decision Support t Systems (Fiorucci et al., 2003; Haastrup et al., 1998), fuzzy logic (Changand Wang, 1997) and Multi Criteria Decision- Making techniques (Hokkanen and Salminen , 1997). It is accepted that life cycle assessment (LCA) concepts and techniques provide solid waste planners and decision makers with an excellent framework to evaluate MSW management strategies (Obersteiner et al., 2007).Environmental LCA is a system analysis tool. It was developed rapidly during the 1990s and has reached a certain level of management and consistency. LCA studies the environmental aspects and potential impacts throughout a ‘product’ life (i.e., c radle-to- grave) from raw material acquisition through production, use and disposal.). So, in the study obtainable in this paper, LCA methodology was used to analyze and to evaluate different alternatives that can be implement to enable the targets required by University campus Landfill and casing and Packaging Waste Directives for solid waste management in KUET campus .University campus Landfill Directive (1999) and the

Packaging and Pack aging Waste Directive (2004) aim to reduce the amount of environmental municipal wastes going to landfill.

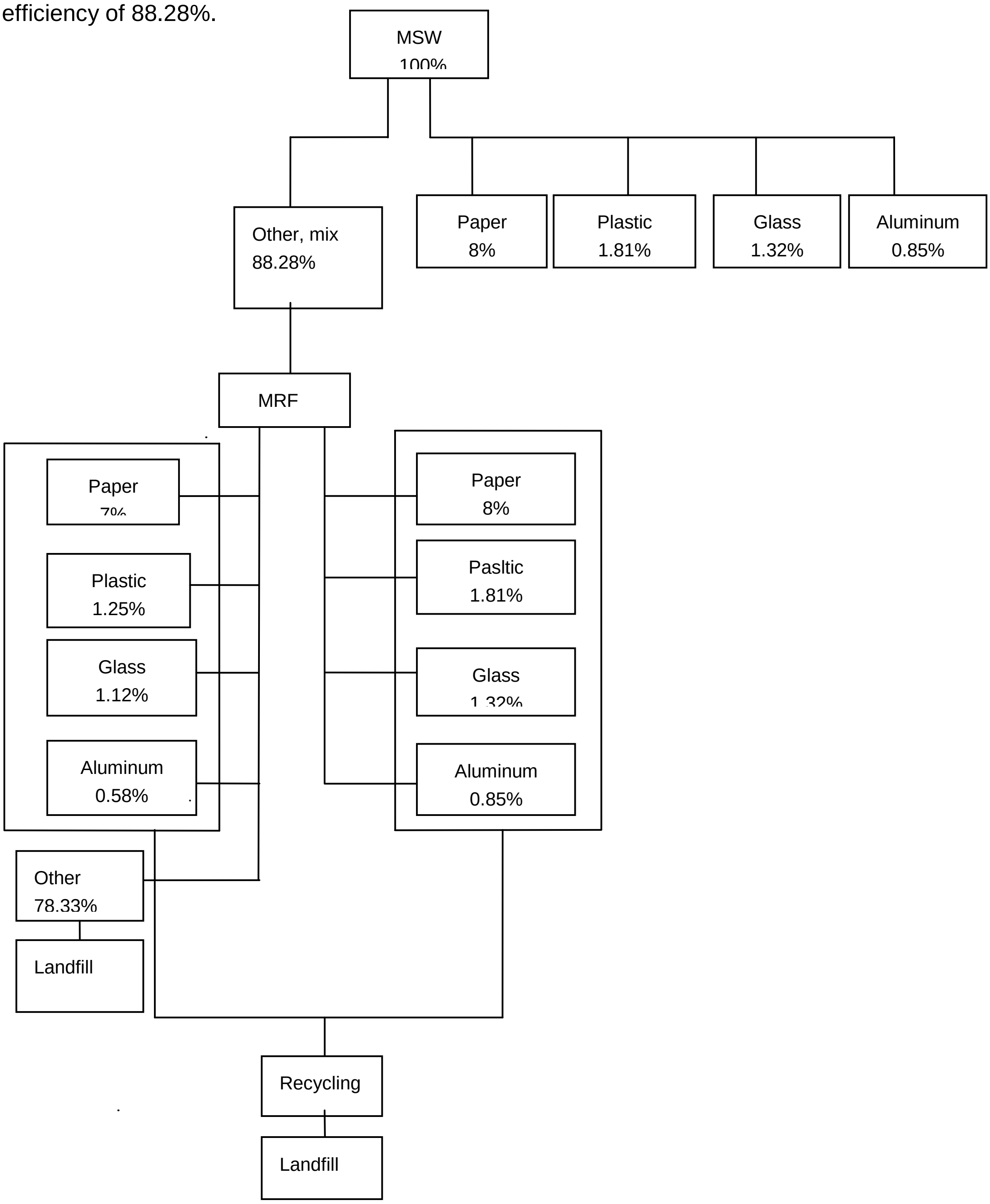
METHODOLOGY

The LCA methodology has been used to conduct an environmental comparison of the alternative scenarios to the current waste management system. Life Cycle Assessment aims to evaluate the environmental effects from a product or service along the whole life cycle, i.e. from the extraction of raw materials to production, use phase, recycling and disposal (“cradle to grave”).

Description of the scenarios

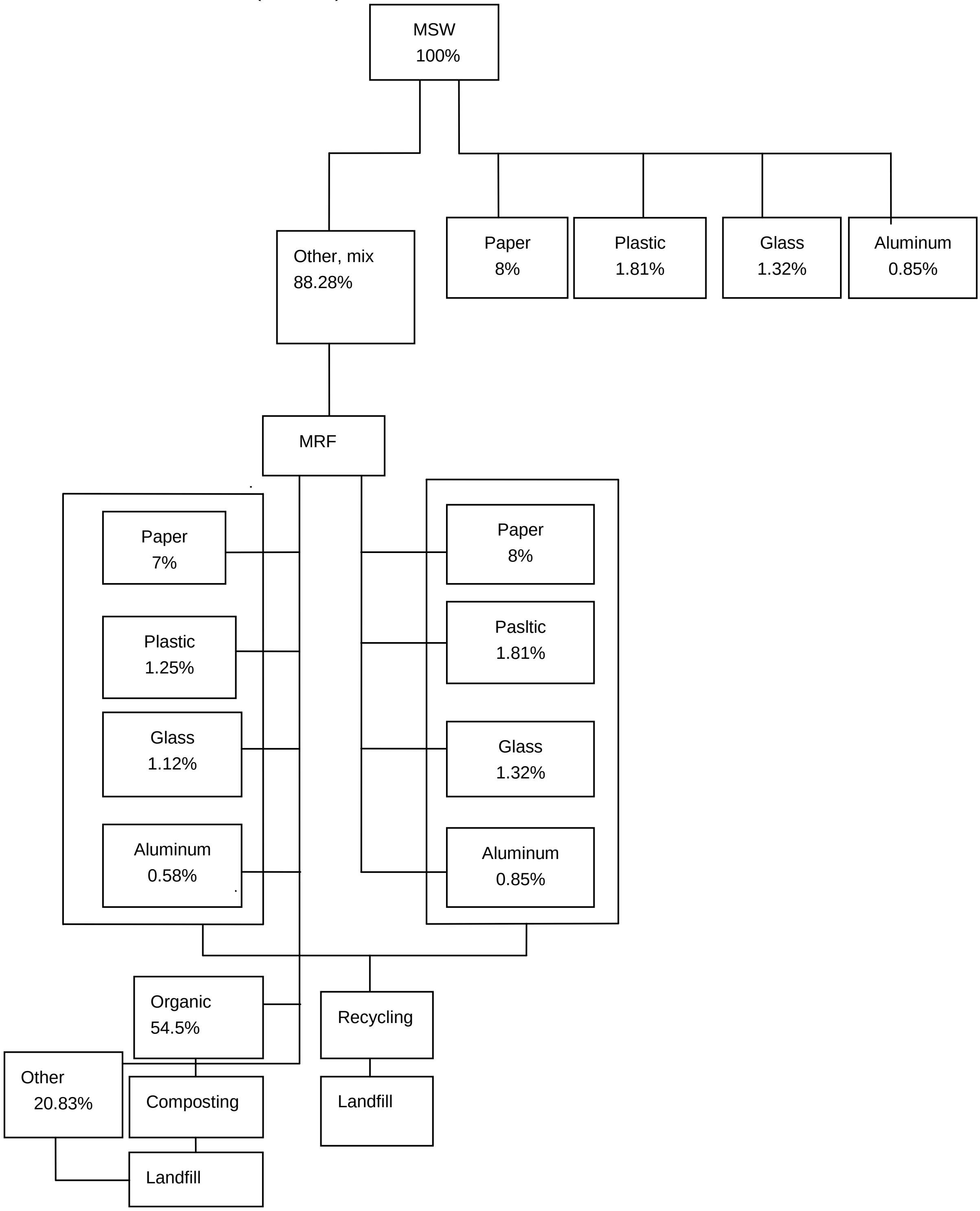
(a) Scenario 1 (S1): 20.00% recycling + 80.00% landfilling.

Scenario 1: The recyclables obtained from source separation (11.72%) were sent to the MRF, and after processing they were sent to the recycling facilities in other cities to recycle, at an efficiency of 88.28%.



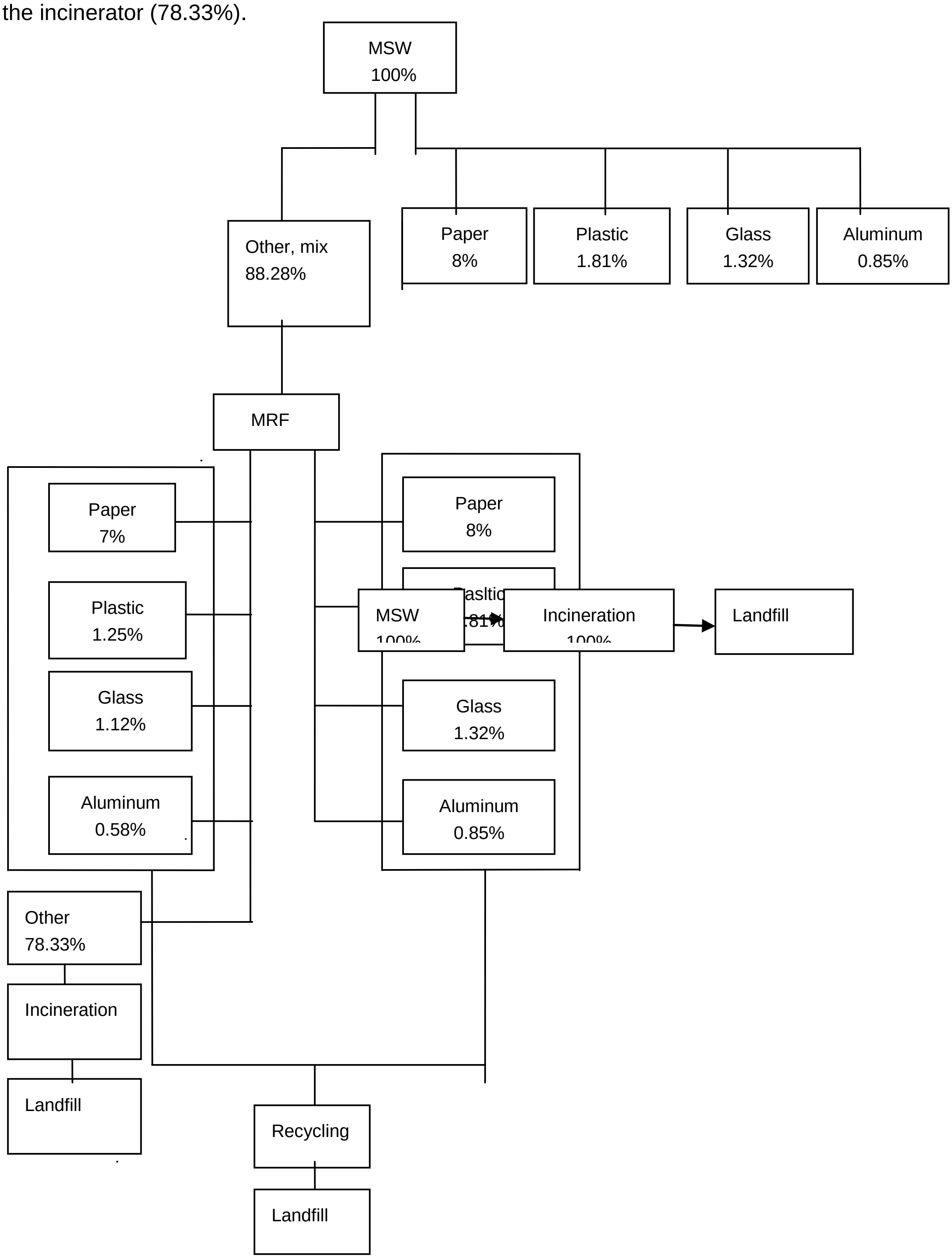
(b) Scenario 2 (S2): 21.67% recycling + 54.5% composting + 23.83% landfilling.

Scenario 2: The flow of the system is similar to Scenario 1 for recyclable materials, while organic fraction (54.5%) from the MRF is transported to the composting facility. The residue from the MRF is sent to the landfill (20.83%).

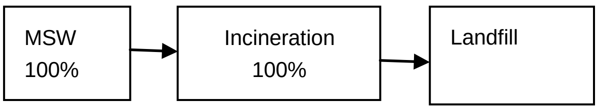


(C) Scenario 3 (S3): 21.67% recycling + 78.33% incineration

Scenario 3: All organic wastes and the wastes from the separated recyclables are transported to the incinerator (78.33%).



d) Scenario 4(S4): 100% incineration.



Scenario 4: In this scenario it was considered that all MSW is sent to the incineration facility (100%).

Figure.1. Flowcharts of the scenarios (after efficiency). The percentages represent the proportion of the total municipal solid waste stream.

Table 1:Composition of solid waste in KUET
Total=1722Kg/day

Component	Composition (wt%)
paper	45
Cloth	4
Plastic	5
Glass	1
Food	39
Wood	2
Metal	1
Other	3
Total	100

Goal and scope Definition

In this phase of an LCA study, the aim of this study is to select an optimum waste management system for KUET by evaluating, from an environmental point of view, alternatives to the existing system .The alternatives compared and the system boundaries (e.g. the geographic region).

Life cycle inventory

For a recycling scheme this can be e.g. the transport for collection, sorting of the material and processing in a recycling plant. For each of the processes, the input (energy and other resources) and the output (emissions) are calculated or estimated. Then, for the whole system the emissions in term of single parameters are summed up Critical points in LCI are: to consider all relevant processes, which include also upstream processes (e.g. fuel, which is used in waste collection, has caused additional emissions while being produced).

Collection and transport

Generally speaking, significant amount of the solid waste generated in KUET campus are uncollected and either dumped in the open space or end up in water bodies. Waste that is collected is mainly disposed off in open dump-sites, many of which are not properly operated and maintained, thereby posing a serious threat to public health .The study includes kerb-side systems and brings systems. The collection rate varies from hall to office and collection facilities are either inadequate or inefficient in almost all of the university. Each transport stage is assigned a 'utility' which reflects whether the vehicles make their journeys fully laden or empty.

Figure 2. Waste collection scenario

Recycling

Recycling is generally carried out by the informal sector. Recycling of materials such as waste paper is considered to reduce environmental effects of waste management. But, by more complex waste collection schemes with higher transportation effort, this positive effect can be reduced. To evaluate the effect of transportation in waste management, we conducted an LCA study. In the landfill scenario, paper is disposed of by landfilling, new paper and energy has to be produced. There are no policies that promote recycling or resource conservation, and the municipalities do not have the expertise to launch the recycling activities. In several places, such as Kathmandu, more of the waste could be recycled if there was better infrastructure for collecting recyclables (M. Alamgir). However, collection of recyclable waste is done in several steps such as door to door collection, collection at secondary and primary transfer stations and even in the disposal sites. Due to the faulty collection systems and the low quality of scrap, the recycling rate is low despite of high number of waste pickers working.

Composting

Composting is the second preferred method of solid waste disposal in KUET, mainly due to the high percentage of organic material in the waste composition. The best available technology for composting is regarded as the one that results in the largest energy utilization, since this can replace other more polluting energy sources. Thus, technology description was based on a composting process where the acid hydrolysis takes place in a closed reactor with collection of the forced leachate which is transferred to an anaerobic digestion phase for biogas production. The composting results in two products: compost and electricity. Per Mg of wet biodegradable waste, 340kg of compost is produced, at 51% dry matter. Of the nitrogen in the wastes, 38% is lost in the composting process, according to Kjellberg et al. (2005).The average is based on an efficiency of 38% in the conversion from biogas to electricity; the low end of the range is assuming lower efficiency (29%), while the high end of the range denotes an increased methane yield compared to the process documented in Kjellberg et al. (2005).

Incineration

The technology is a great incinerator with electrostatic precipitator for fly ash, semi-dry flue gas cleaning, and non-catalytic reduction (SNCR) of NO_x. Reported uncertainties relate only to differences in scale and variations within the said technologies. Compared to the ranges collected by Hogg (2001) for incineration plants of the same size, these values lie in the lower end. Due to the high capital, operation and maintenance costs involved for the installation of incineration plants, incineration is not popular as a waste disposal system in the countries being studies. In addition to these, the major portion of the KUET campus waste is organic with relatively high moisture content which leads to a low calorific value. In Bangladesh, some NGOs are operating incineration plant, especially for handling clinical and hospital wastes, yet still the system is inadequate and inefficient. Atmospheric emissions from the incineration of organic waste were calculated by using the chemical formula (C 333 H 528 O 195 N16 PS) of the organic fraction of KUET campus waste.

Landfilling

Besides general findings, it is important to develop In a “traditional” waste management system with appropriate models further, describing the environmental transport and landfilling only, the main environmental impacts, e.g. in a long term perspective. Impact will be afforded by the landfill related emissions, i.e. leachate and landfill gas. For both effects the organic. Energy production from biogas combust ion is regarded as a co -product without emissions. The final efficiency is only11% of the total energy con tent of the gas produced. In most of the university campus landfill is the most preferred method for the final disposal of solid waste. Most of these sites practice open dumping, with no regards to the requirements for a sanitary landfill. However, government and municipalities are already working to develop the sanitary landfill sites in few urban areas. Since land is fast becoming scarce within city limits, new sanitary landfill are often too distantly located compared to the open dumpsites within municipal limits, thereby making the longer collection and delivery time, which is ineffectively costly.

Life cycle impact assessment

According to ISO 14040, “Life Cycle Impact Assessment (LCIA) is a phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a given product system throughout its life cycle”, i.e. From the time natural resources are extracted from the ground and processed through each subsequent stage of manufacturing, transportation, product use, and ultimately, disposal. Life cycle impact assessment provides indicators for the interpretation of the inventory data in terms of contributions to different impact categories, or environmental burdens. The indicator results facilitate the evaluation of products, and each stage in a life cycle, in terms of climate change, contributions to toxicological pressure, land use, etc. In this study, six impact categories included by the CML 2000 method (CML 2 baseline 2000 method is an update from the CML 1992 method) were investigated: abiotic depletion, global warming, human toxicity, acidification, eutrophication and photochemical oxidation. Characteristics of the impact categories are discussed below:

Depletion of abiotic resources
This impact category indicator is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalent sb/kg extraction) based on concentration of reserve sand rate of deaccumulation (Goedkoop et al., 2004).

Climate change
For climate change applied was the IPCC 2001 characterisation model, with a time horizon of 100 years, as also applied by EDIP2003. The category indicator is “kg CO -equivalents”. All carbon emissions from waste treatment are handled in the same way, without regard to their origin (fossil or non-fossil).Hence, in a complete life cycle of a biomass-containing product; there is no net contribution to climate change. Factors are expressed as Global Warming Potential for time horizon of 100 years (GWP100), in kg carbon dioxide /kg emission (Goe dkoop et al., 2004).

Acidification
The majority of acid gases are emitted as sulphur dioxide and nitrous oxides, with small amounts of hydrogen fluoride and hydrogen chloride. The waste disposal systems contribute more to acidification than the recycling systems in the cases of aluminium, glass, paper and steel, again aluminium exhibiting the greatest savings. The savings from the recycling systems are 95% for aluminium, 41% for glass, 80% for paper, and 26% for steel.

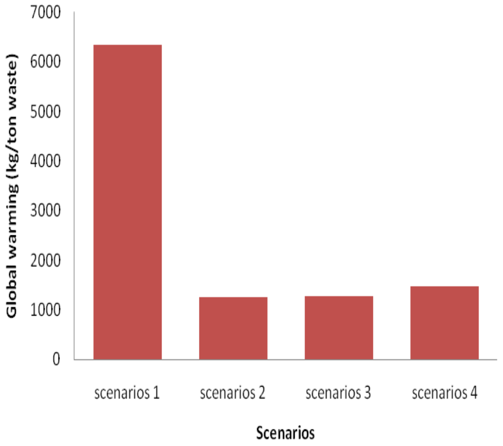
RESULTS
The results of the description investigation per functional unit (1 ton of waste managed) for each impact category for each scenario are reported in Table-2. Global warming: Methane is the most important impact for landfill scenarios S1. The global warming effect for S3 and S4 mostly results from CO_2. S2 is the best scenario for this impact category. Acidification: All of the scenarios except S2 show approximately same trend for acidification from ammonia and nitrogen dioxide in the air. S3 is the best scenario for this impact category because of the displacement with fertilizer.

Table-2: Characterization results

Scenario	Global warming (GWP100) (kg CO2 eq/ton waste managed)	Acidification (kg SO2 eq/ton waste managed
S1	6336	36.96
S2	1250	24.64
S3	1267	18.48
S4	1478	19.71

DISCUSSION AND CONCLUSION
This paper has shown LCA to be a valuable tool which can help the university to plan an integrated waste management strategy that gives preferable environmental outcomes than the strategy suggested by the national waste strategy. In accordance with in figure -1 the results obtained from this study, scenario 2 was found to be the option with the minimum environmental impact (i.e. minimum GWP). However, the LCA process has also proved to be a difficult and demanding process and it is perhaps not reasonable to assume that KUET campus is capable of performing a detailed LCA without some form of guidance. For that motivation, it might be supported with other pronouncement making tools that regard as the economic and social effect of solid waste management.

Life Cycle Impact Assessment provides indicators and methods for analyzing the potential contributors of the inventory data to different impacts categories, such as climate change, contribution to acidification, land use, etc. and, in some cases, in an aggregated way. After compilation, tabulation, and preliminary analysis of the life cycle inventory, it is necessary to calculate, as well as to interpret, indicators of the pressures or impacts that are associated with emissions to the natural environment and the consumption of resources. Earlier characterisation models for eutrophication did not distinguish between aquatic systems and terrestrial systems, actually modelling both as if they were impacts on aquatic systems. Also, they did take into account differences in emission deposition and transport patterns, background deposition levels, and the sensitivity of the receiving ecosystems. Results obtained from this study also support the conclusion that LCA, as an environmental tool, can be successfully applied in an Integrated Solid Waste Management System (ISWMS) as a decision support tool



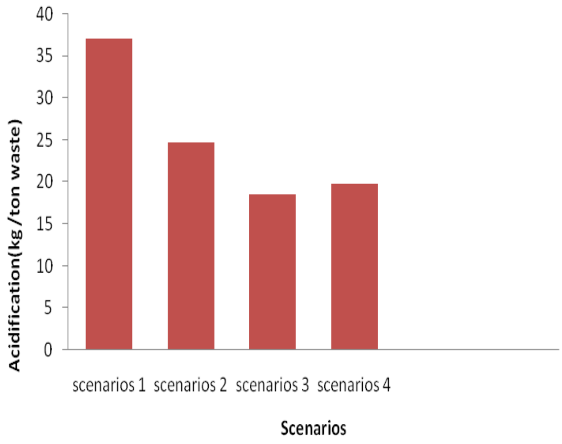


Figure 3: (a) Global warming and (b) Acidification with Scenarios.

ACKNOWLEDGEMENT
Appreciation goes to the Department of Civil Engineering, KUET for the financial support to complete this project.

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ISBN: 978-984-33-7045-7 PI. 54 (1-7)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Scenario of Market Waste Management and Environmental Degradation: A Case Study in Khulna City Area

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ABSTRACT

Khulna City Corporation (KCC) is the statutory body to all types of conservancy services within the city area including management of the market solid wastes. This paper aims at investigating the scenario of ongoing market waste management in Khulna city area and hence formulating a general physical model of the waste materials flow path. The environmental degradation with regards to market wastes was also addressed in this study and safe strategies were proposed to reducing the environmental burdens. An estimated daily total mass of 12 tonnes market wastes were generated in Khulna city area; of which 60 to 70% wastes were collected by KCC through waste reduction, recycling and composting activities and remaining 30 to 40% were directly disposed to municipality drains, nearby ponds and road sides. Irregular collection of market wastes, unscientific disposal practice, lack of enthusiasm of the city dwellers, nonpayment of service charges by the beneficiaries, lack of research, lack of initiatives for recycling of resources, lack of co-operation, etc. were the main difficulties in current market waste management scheme. This study would help to prepare a master plan for the market waste management in Khulna city area as well as implementation techniques for sustainable development.

INTRODUCTION

Comprehensive solid waste management (SWM) programs are one of the greatest challenges to achieving institutional sustainability (Danielle et al., 2010). Effective SWM requires a complete understanding of the composition of a waste stream as well as the activities that determine its generation in the first place (Farmer et al., 1997). Examining waste by generation source is particularly important, as the characteristics and composition of solid waste vary according to its source (Tchobanoglous et al., 1996). Considering this, SWM programs that are based on the reality of the generating source, are far more successful than mimicked programs that have been implemented elsewhere (Armijo de Vega et al., 2008). A variety of approaches have been adopted for assembling detailed quantitative data on the amount, location, and characteristics of a waste stream (Thompson and van Bakel, 1995) some of which include: reviewing waste management records, visual waste assessments, interviewing waste management staff and extrapolating data from other institutions (Ashwood et al., 1995; Yu and Maclaren, 1995; Creighton, 1998). Direct waste analyses or waste characterization studies, however, offer the most effective process for examining the various wastes generated and identifying opportunities for waste reduction, reuse, recycling, and composting (Thompson and Wilson, 1994; Thompson and van Bakel, 1995).

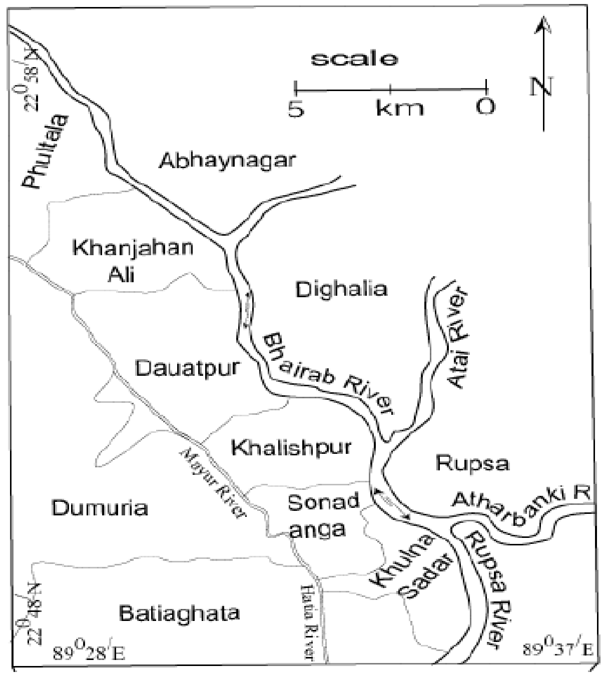

Figure 1: Khulna City Corporation Map

Khulna is the third largest metropolitan as well as the second largest river port city of Bangladesh (Figure 1). It stands by 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 22°47´16´´ to 22°52´ north latitude and 89°31´36´´ to 89°34´35´´ east longitude. The city is 4 meter above the mean sea level (MSL). At present, it has a population of about 1 million (Murtaza, 2002). The city is growing moderately in terms of its population and area. The existing public utility services and facilities cannot adequately cater to the needs of the burgeoning city population. The city generates a huge quantity of waste everyday from different sources. According to the Khulna City Corporation Ordinance, 1984 Khulna City Corporation (KCC) is responsible for collection, transportation, and treatment of solid waste in Khulna City (Murtaza, 2002). Due to its resource and other constraints and limitations, KCC has not been able to manage well entirely the whole task of solid waste as well as market waste disposal. In order to supplement the activities relating to the solid waste as like market waste disposal in KCC area, a number of non-governmental Organizations (NGOs), Community Based Organizations (CBOs) have come forward (Murtaza Md. Ghulam). The objective of this study was to determine the scenario of ongoing market waste management in Khulna city area and hence formulating a general physical model of the waste materials flow path. The environmental degradation with regards to market wastes was also addressed in this study and safe strategies were proposed to reducing the environmental burdens.

METHODOLOGY

This study was conducted in the Khulna Metropolitan city (Figure 1) which is the largest river port city in Bangladesh. This research began in January, 2012 with an evaluation of internal policies and procedure related to the KCC sustainability and waste management, external documents including government regulations and guidelines and various municipal and waste composition studies. Waste haulage and disposal records were obtained through the various facilities department. The location of interior and exterior waste, recycling and compost receptacles were mapped and distinct flows of waste were documented. We identified three approaches to conducting a market waste characterization study: (1) the back end approach, which assesses the institution as a whole, (2) the activities approach, which tracks waste from distinct areas within the various market separately, and lastly, (3) an input/output approach, which tracks materials entering and leaving. There are total 12 markets in KCC. So all the markets divided into 12 separate markets like Phulbarigate, Daulatpur, Chitrali, Boikali, Khulna borobazar, Khulna noyabazar, Khulna New market Bazar, Shandho Bazar, Khalispur, Nirala bazaar, Boyra bazaar, and Gollamari. The sizes of these markets are shown in table 1. This study documented the field survey data from “Tokai” (scavenger), cleaner, community service providers, waste resellers (Vangari shops) and many others shop keepers of Khulna city area. After going to all markets of Khulna city area we contacted the shop keepers, tokai, cleaner, Community service providers and asked them for several data. After collecting these data primarily we collect data from waste collected people of Khulna city area. Then we compare these two data. We saw that there were very small differences among those data. In course of data collection and questionnaire we physically investigated the various environmental conditions in market places of Khulna city area.

Table 1: Major market areas (relative sizes) in Khulna City Corporation

SL.	Name of the market	Relative sizes of market areas
1	Phulbarigate	1.0
2	Daulatpur	3.5
3	Chitrali	1.0
4	Boikali	1.0
5	Khulna borobazar	11.0
6	Khulna noyabazar	2.0
7	Khulna New market Bazar	1.0
8	Shandho Bazar	0.8
9	Khalispur	1.0
10	Nirala bazar	1.8
11	Boyra bazar	0.8
12	Gollamari	1

Fig. 2: Data collection from shop keepers

Fig.3: Photo of cow dung besides the market

Fig.4: Drain and Dustbin of Khulna city area market

RESULTS AND DISCUSSION

Problems in market waste management

By almost any form of evaluation, market waste management is a growing environmental and financial problem in developing countries like Bangladesh. Despite significant efforts in the last decades, the majority of municipalities in the developing countries cannot manage the growing volume of waste produced in their cities. This inability to manage urban solid waste consists of failures in the following areas: Inadequate services, Inadequate financing, inadequate environmental controls, Poor institutional structure, Inadequate understanding of complex systems, inadequate sanitation etc. This part considers the key constraints in terms of the development of integrated, sustainable, partnership-based market waste management systems in developing countries, and the issues that underlie these constraints. The irregular collection of solid wastes, unscientific disposal of wastes, lack of enthusiasm of the city dwellers, nonpayment of service charges by the beneficiaries, lack of research, lack of initiatives for recycling of resources, lack of co-operation, etc. were the main identified problems of the current market waste management in Khulna city area. We have developed a model for waste management and waste marketing that is attached in the next page of this article. This model is an aggregate and integrated model for waste management and marketing. In this model we have shown the sources of wastes, the collection process, the participatory groups, waste recognition and assortment system for marketing them and moreover the total marketing process is shown too. We have also shown the integrated waste marketing process that includes not only assortment but also grading, bagging and selling mechanism of different categories of wastes. A simple marketing mix analysis of the wastes and recommendations for waste marketing can explain the uncovered prospect for sustainable solution by using waste. This covered categorizing the waste as product, pricing them as per their commercial value; make the proper distribution channel, and lastly promotional activities include creating the awareness of the commercial value of the wastes among the community.

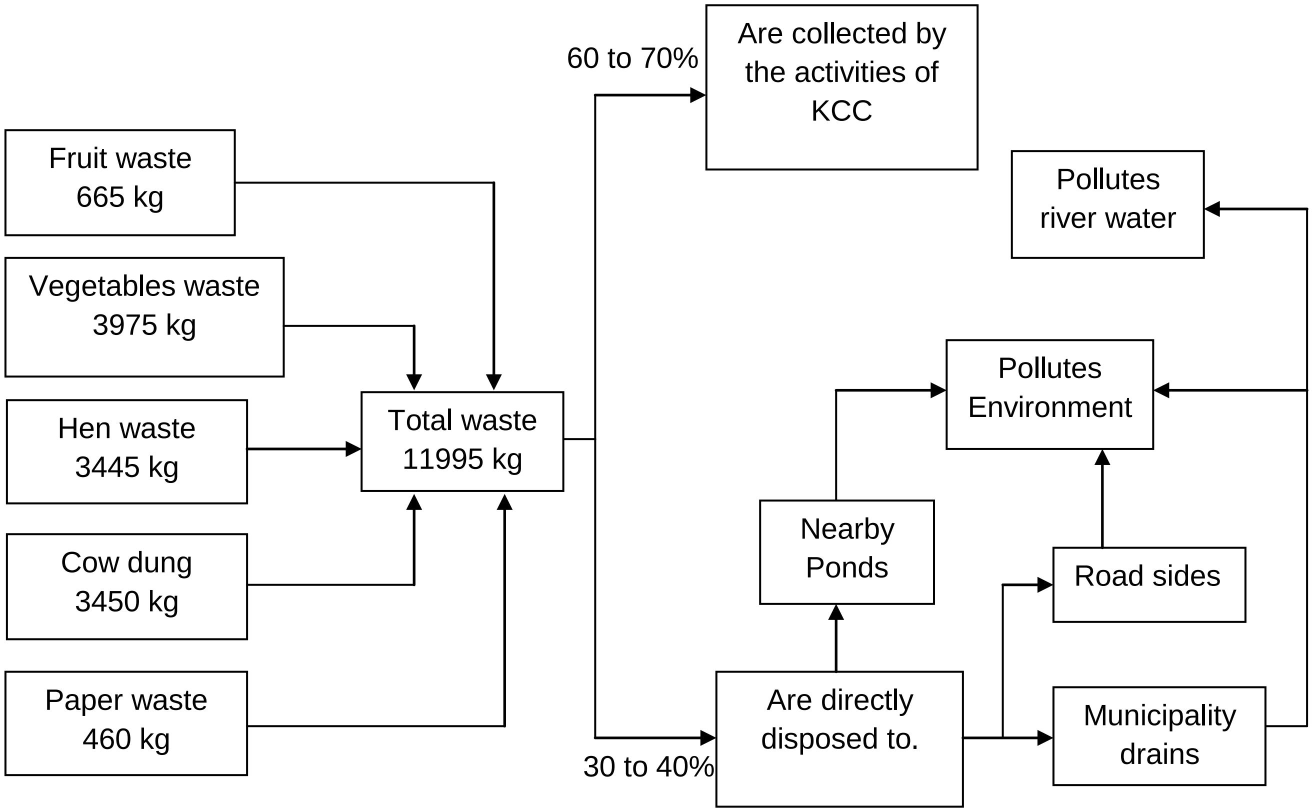

Fig. 5: Flow chart of analysis of market waste for KCC per day.

Strategies for Sustainable Market Waste Management

Strengthening inter-sectoral partnerships support a long-term vision of the goals of waste management in developing countries. This goal is to achieve sustainable solid waste management systems which are stable over time, and which are beneficial to the society, the economy and the environment. The point here is that it is possible, given the state of the art in both developed and developing countries, to bypass intermediate motivations, and to seek to create and implement sustainable waste management systems from the outset. This action plan is set up to pursue this goal. This paragraph defines the different elements of sustainability listed below:

- Sustainability will only be attainable if the current concept of refuse disposal, which imposes great burdens on the environment and resources, is transformed into a closed-cycle system, restoring various natural cycles, thus preventing the loss of raw materials, energy and nutrients.

Organic wastes are typically the heaviest component of a waste stream, thereby costing the most money to dispose of, and have the highest potential to emit green house gases, once buried in a landfill. The high financial and environmental costs of improperly disposed organic wastes make this component especially important when considering opportunities for increased waste reduction and diversion.

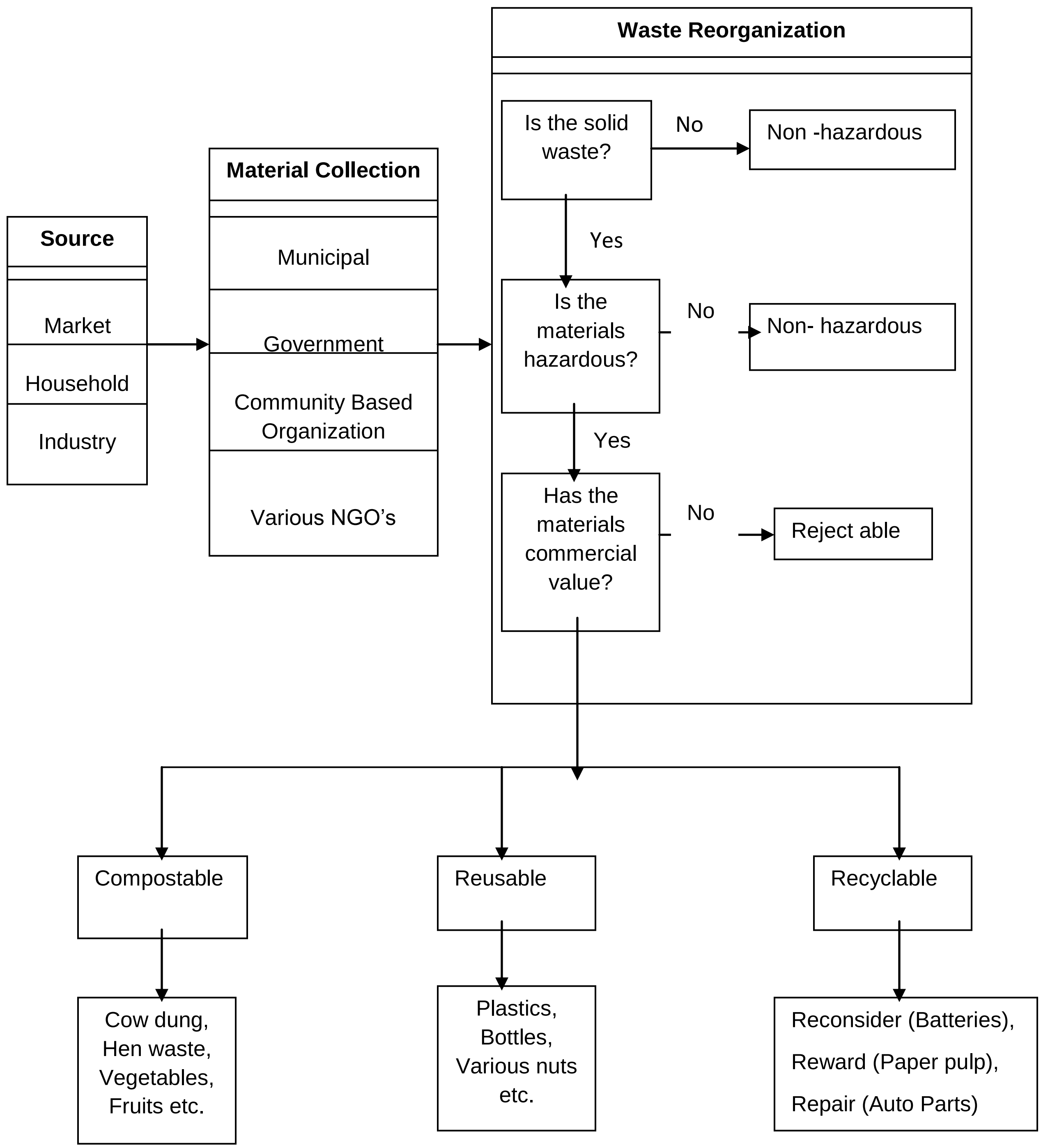

Figure 6: Model for sustainable waste management

CONCLUSIONS

There is a whole culture of waste management that needs to be put in place-from the micro level of household, market to the macro levels of city, state and nation. The general assumption is that Solid waste management should be done at the city level first and as a result; solutions tried out have been essentially end-of pipe. But we should keep this mind that rather than making a long-term holistic approach, we can start it within our community and can create an example for the whole country.

If we can start our waste management process at the micro level, like as community based system then it can be easily manageable as well as it can create examples for others. Most of the developed countries now a day are trying to rethinking about their waste disposal system and developing a wide range of system and approach to minimize the environmental hazard as well as reaching a profitable solution using these wastes.

In our country, we can also dream for a better future, where our environment will be protected as well as we can reach a sustainable solution by using market waste, and develop our entrepreneurial activities. Further this study tried only to develop a theoretical model for better waste management in Khulna city. It needs a complete empirical study to examine the feasibility of this model. This model will also provide the platform for further study and exploration of the waste management and practices in Khulna city.

ACKNOWLEDGEMENTS

The authors like to express thanks to various shop-keepers of different markets of KCC for the opportunity of collecting data form market. Appreciation goes to the Civil Department of KUET for the financial support for completing the author’s project.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.71 (1-11)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

FINANCIAL SUSTAINABILITY OF THE SOLID WASTE MANAGEMENT SYSTEM IN BAHIR DAR, ETHIOPIA

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ABSTRACT

Providing good solid waste management (SWM) services while also ensuring financial sustainability of the system remains a major challenge in cities of developing countries. Bahir Dar in northwestern Ethiopia used the approach of privatizing municipal waste collection, transportation and disposal to the private company Dream Light. This institutional change in 2009 has led to substantial improvement of the cleanliness in the city. The question however is, if Dream Light is able to generate sufficient revenues through their activities to recover their costs. This paper presents a cost-revenue analysis which reveals that further improvements must be envisaged on cost recovery mechanisms to ensure financial sustainability of the system.

INTRODUCTION

Solid waste management (SWM) often represents a significant proportion of the total recurrent municipal budget in cities of developing countries (Scheinberg et al., 2010). Despite the high financial burden, the local authorities often struggle to provide adequate and reliable services for all. Public sector inefficiencies and continuously increasing cost has led local authorities to analyze if this service can better be provided by the private sector (Massoud and El-Fadel, 2002). Increasingly public-private partnerships have emerged as a promising alternative to improve municipal solid waste service performance (Cointreau et al. 2000; Zhu et al., 2007). But even with a new partnership approach the financial aspects of municipal SWM remain critical for ensuring sustainability of the system. This concerns budgeting, cost accounting and recovering sufficient funds for covering recurrent costs of the service as well as accessing additional capital for new investments or large maintenance. Practical methods of budgeting, cost accounting, financial monitoring and financial evaluation are too seldom employed (Schübeler, 1996). Schübeler (1996) suggests that while external capital may often be needed for major investments, preference should be given to user charges and local taxes for financing the recurrent costs whereby some degree of cross-subsidization and/or financing out of general revenues is often needed to achieve equitable service access. Improvement can often be achieved by increasing cost efficiency — “doing more with less”. But as a first step in all these measures it is indispensable to establish a full understanding of the current costs and revenues for provision of the services. The total costs are usually underestimated by up to 50% (Coffey and Coad, 2010). To safeguard financial sustainability it is important that all short-term as well as long-term financial costs are taken into account and that procedures are in place for obtaining regular revenues to meet these costs. The lack of specific financial data is one of the major barriers for improving the financial sustainability of a SWM system (Zurbrügg et al. 2007).

Bahir Dar, a city with 220’000 inhabitants in northwestern Ethiopia, is one of the fastest growing cities in the country (UNEP, 2010a). If the current annual population growth rate of 6.6% continues, the city population will double in 11 years. Thus the need for adequate SWM is unquestionable and well acknowledged by the municipality (Mekete, Atikilt & Hana, 2009). In 2009 the local government took the decision to outsource some of their main SWM activities by contracting the private company Dream Light PLC. As a consequence obvious improvements in city cleanliness have been achieved (UNEP, 2010b). Nevertheless a major challenge remains to ensure that this partnership can endure, whereby one important factor is the degree of financial sustainability, i.e. that ongoing expenditures for providing the service can be sufficiently recovered through an efficient but equitable cost recovery system. The research conducted in Bahir Dar was guided by the question on how financially sustainable the current system is, and if necessary where and how can it be improved. This paper presents a delineation of the institutional and organizational structure and presents and discusses the results of the financial assessment. In conclusion, based on the data available, some recommendations are proposed how the current financial aspects might be improved.

METHODOLOGY

Methods used for this research are diverse, involving qualitative as well as quantitative approaches, and are briefly summarized as follows:

- A comprehensive literature study on financial assessments in solid waste management related to the low and middle country context.
- A systematic search for information, evidence or insight into documents directly or indirectly related to the solid waste situation in Bahir Dar.
- Participatory observations concerning the solid waste management situation in Bahir Dar and its surroundings.
- Material flow analysis (with secondary data sources) involving a system description for solid waste flows in Bahir Dar which was then depicted in a process and material flow diagram.
- Stakeholder identification and assessment delineating the institutional and organizational structure, as well as the influence, interest and attitude situation.
- Semi-structured interviews with a wide range of stakeholders.
- These were crosschecked with information from interview results and gaps were tentatively filled through expert solicitation through a questionnaire based survey.
- To understanding the processes and events that led to a current situation or context historical narratives, timelines and time trend analysis were used which were integrated as questions for the semi-structured interviews. Nevertheless the quantitative financial data collected represents only a snapshot in time and covers the 2-year period from July 2009 to June 2011.

The site visit, interviews, and data collection occurred in Bahir Dar from April to July 2011. Analysis was conducted conjointly with data collection.

The financial assessment and cost-revenue analysis was restricted to the activities of Dream Light, aiming at understanding the financial sustainability of this main service provision stakeholder in the SWM system of Bahir Dar. Other financial flows and important stakeholders such as the informal collection and recycling sector were not included in this analysis. Two cost categories were distinguished in the analysis, up-front investment costs - also called capital expenditures (Capex) - and operational expenditures (Opex). Capex (or Capital Expenditure) are business expenses to create future benefit such as acquisition of assets like infrastructure, machinery, equipment or upgrading of existing facilities so their value as an asset increases. Expenditures required for the day-to-day functioning of the business, like salaries, maintenance , small repairs fall under the category of Opex (operational expenditure). This includes the depreciation of infrastructure and equipment, which was depreciated annually by 20%. Back-end costs (long term costs and externalities) were not considered in this analysis, since these costs are generally difficult to quantify and are most often completely neglected in the budgets by the responsible authorities, e.g. the budgeting for site closure or post-closure care, environmental pollution mitigation costs, etc.

All monetary values are listed in in Ethiopian Birr (ETB), whereby 100 ETB are 5.89 US$ (as of 10.04.2011).

RESULTS & DISCUSSION

The SWM system in Bahir Dar

The classification of stakeholders according to Scheinberg et al. (2010) into providers, users and external agents is used here to present the different stakeholders, functions and their inter-linkages in the SWM system of Bahir Dar (Figure1). Arrows depict either different service functions (waste collection, recycling etc.) support functions (financial, research) or regulatory and legal functions (e.g. national regulation and legislation).

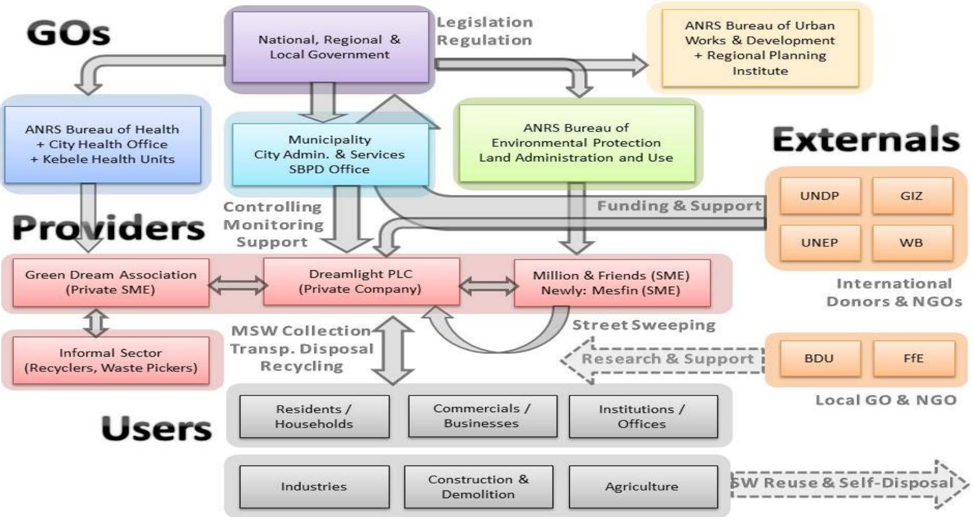

Figure 1: Organizational set-up of the SWM system in Bahir Dar 2011

Abbreviations
ANRS: Amhara National Regional State
BDU: Bahir Dar University
FfE: Forum for Environment
GIZ: German Agency for International Cooperation
GOs: Governmental Organizations
SBPD: Sanitation, Beautification and Park Development
SME: Small & Medium Enterprise
UNDP: United Nations Development Programme
UNEP: United Nations Environmental Programme
WB: World Bank

The SWM system of Bahir Dar has undergone some major organizational and institutional changes in the past years. In 2008 the municipality of Bahir Dar privatized the main municipal solid waste management activities (collection, transportation and disposal at the dumpsite) to a private waste management company called "Dream Light Solid Waste Cleaning and Recycling PLC" (called hereafter Dream Light). Excluded from this contract are activities related to industrial, health care, construction and demolition waste as these are not considered part of municipal solid waste. Street sweeping is partly outsourced to a small and medium enterprise, and in certain areas of the city still provided by the municipal services. Overview, regulation and performance monitoring remain functions and in the jurisdiction of the public sector, mainly the city administration.

A bit more than half (53%) of the total municipal solid waste (MSW) generated in the total 9 kebeles (administrative neighborhood units) of Bahir Dar is household waste from residential areas. Another 27% is waste from the commercial sector, 17% from institutions and 3% from street sweeping (UNEP, 2010a). Average per capita waste generation in Bahir Dar is estimated at 0.25 kg/cap day for household waste only and 0.45 kg/day when also taking into account, commercial, institutional and street sweeping waste streams (UNEP, 2010a). Currently the contract with Dream Light covers for the MSW collection in 8 kebeles One kebele is not serviced by Dream Light but by a small private sector enterprise. Since Dream Light's involvement, the collection coverage increased from 51% in 2005 to 71% in 2010 (UNEP, 2010a). Thus from a total of 102.5 t/day generated, 73 tons/day is collected, leading to substantial improvement of the cleanliness in the city (UNEP, 2010b). However when looking into more detail on individual collection coverage of different solid waste generators there are significant differences. According to Dream Light 70% of the total waste generated in the households and 80% from the commercial sector are collected. Also, street sweeping collects about 70% of litter laying on the 35 km of sealed roads of Bahir Dar. However, only 50% of waste generated by institutions is collected.

Dream Light hires and assigns 270 solid waste collectors, 28 coordinators and one head of field operation to fulfill the contractual obligations. The waste collectors are organized in groups of around 15 people which includes one group coordinator. They operate manual push carts for primary collection of waste from households or else just simply carry the waste bags on their shoulders to designated collection points. These groups are assigned different areas within the city. They provide curb-side collection - solid waste bags are placed by the residents at the households' entrance - and transport the waste to one of the semi-official collection points. There are approximately 100 such collection points distributed throughout the city. At the collection point, the collectors wait for the collection trucks to arrive and then manually load the bags into the trucks. Dream Light has a fleet of 7 low-skip, open, non-standardized, collection trucks, each with a capacity of 4 m^3. An average of 5-6 trucks are operational at any time and regularly in use. They transport the waste from the collection points to an open dumpsite about 7 km outside of the city. The road leading to the dumpsite is predominately a rough gravel road, which strains the older second-hand trucks and leads to frequent breakdowns and need of repairs. Maintenance and repairs of these trucks poses a major problem, as these are of a Chinese brand and the spare parts from this Chinese truck manufacturer are hard to find in Ethiopia. This barrier leads to a difficult procurement, long waiting periods for spare parts and resulting delays until finally the cars can be repaired.

Recycling activities are mainly conducted by the informal sector. On the dumpsite, 10-15 informal waste pickers recover reusable and recyclable materials like metals, glasses, plastic and textiles and sell it to middlemen or Dream Light (mainly plastic recyclables) (Worku, 2012). Furthermore informal itinerant buyers (koralews), about 70 in number, collect recyclables such as metals, plastics, glasses, corrugated iron sheets, tins, car batteries etc. from door to door. They buy from households and resell to one of the 55 middlemen in Bahir Dar (Worku, 2012). Another group of about 50 informal recyclers (lewaches) also collects from door to door but focuses especially on clothes and shoes and exchange these for new plastic containers, sauce pans, spoons, and other household items depending on the quality of material collected. Finally there are two pig farmers located in the north-east of the city that collect 2.5 t/day of kitchen waste from hotels, restaurants and the universities with mule-pulled carts to feed about a total of 650 pigs. However according to UNEP (2010b), recycling of solid waste in Bahir Dar is less than 1% and thus insignificant. The few data collected on the role and relevance of the informal sector shows that this estimation of UNEP (2010b) is most probably too low.

An estimated 73 t/d of MSW is collected and disposed at the disposal site, whereas the remaining uncollected amount (29.5 t/d) is most frequently burned, buried or simply dumped on the lakesides or into rivers. The open disposal dumpsite is not operated considering any sound engineering landfill practice (no entry gate for control and monitoring, no designated cells or tipping face, no compaction, no regular cover layer).

The process flow diagram in Figure 2 illustrates the SWM system at one glance, including the main stakeholders with day-to-day activities, major waste streams and the different process steps.

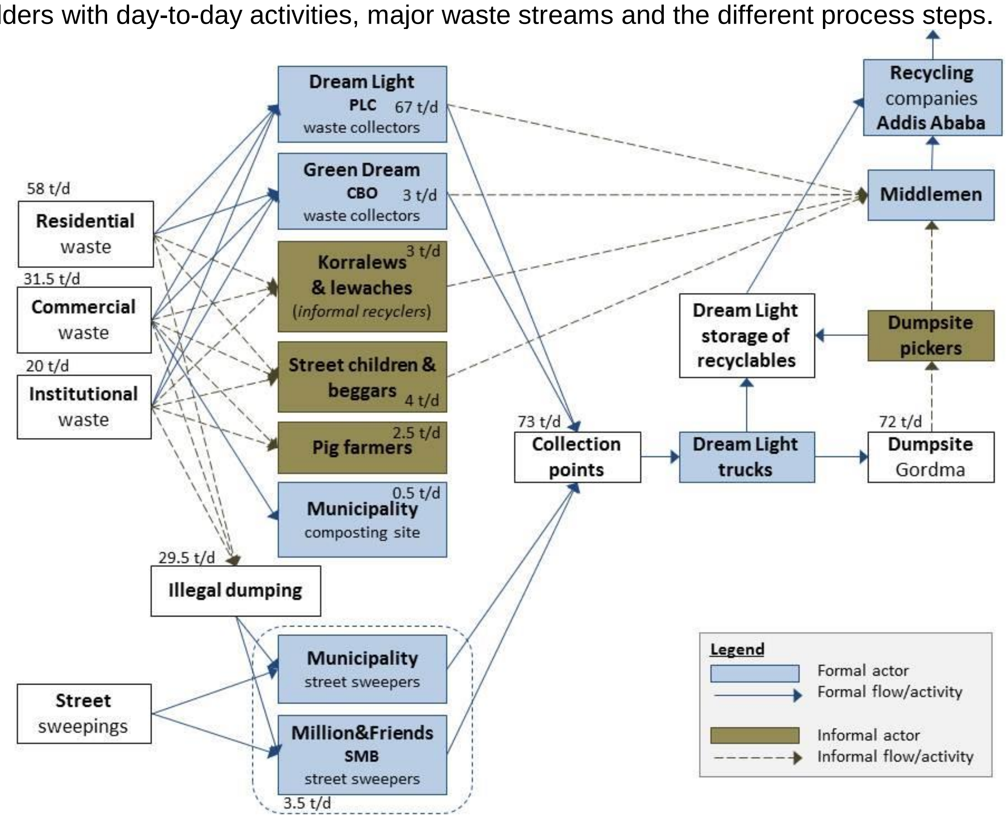

Figure 2: Process flow diagram of the municipal solid waste system in Bahir Dar (Lohri, 2012)

M. Alamgir, I.M. Rafizul, S.M.T. Islam, I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.71 (1-11)

In 2010 an 'Integrated Organic Waste Recycling Centre' was planned and designed by Dream Light and the Addis-based company ThiGro Power. Construction started in 2011 (in 1 km distance to the dumpsite) with the aim to valorize a fraction of the collected organic waste. The term 'Integrated' stands for an approach with three different organic waste recycling technologies: 1. Charcoal briquetting, 2. Anaerobic Digestion, and 3. Composting.

Costs of the current SWM services in Bahir Dar

Dream Light's main costs are split into two different kinds of cost categories: capital expenditures (Capex) and operational expenditures (Opex).

Capital expenditures (Capex): Dream Light obtained three major loans for capital investments (Table 1). They result from capital investments (such as loans), which either have an interest rate or generate opportunity costs due to inflation. In the first two years of operation,

Table 1: Sources of funding and capital investments of Dream Light and for SWM of Bahir Dar in ETB

Type of capital loan	Principal amount	Effective interest	Annual repayment	Comments
Gov't. loan (partly invested for imported waste collection trucks)	2.14 M (1.47 M)	0	Rep. plan undefined	Loan at no interest
Loan of UNDP	1.31 M	0	328'117 ETB	Interest rate of 10% (71'883 ETB) already deducted at the beginning, re-payment plan over 4 y.
Seed capital	0.36 M	0	No rep. plan	Own capital
Total	**3.81 M**	**0**	**328'117 ETB**	

The only major investments in assets were the seven waste collection trucks. Procurement was through the city administration and paid directly through the governmental loan (1.47 Mio ETB). The truck deprecation costs are accounted for under operational costs. The current offices and garages are rented and therefore not part of the capital expenditures.
Other up-front costs, i.e. the costs incurred at the beginning of the business or project, such as expenditures for educating and raising awareness with the public or outreach activities are covered by the City Administration and the NGO Forum for Environment.

Operational Expenditures (Opex): These costs are also called running costs or recurrent costs and include not only operation of the service but also maintenance of the system as well as depreciation. Dream Light has detailed accounting of all their running costs. Figure 3 shows these expenditures in three categories: salaries, motorized vehicles, and all other expenses such as office equipment, handcarts etc. over a period of two years by month.

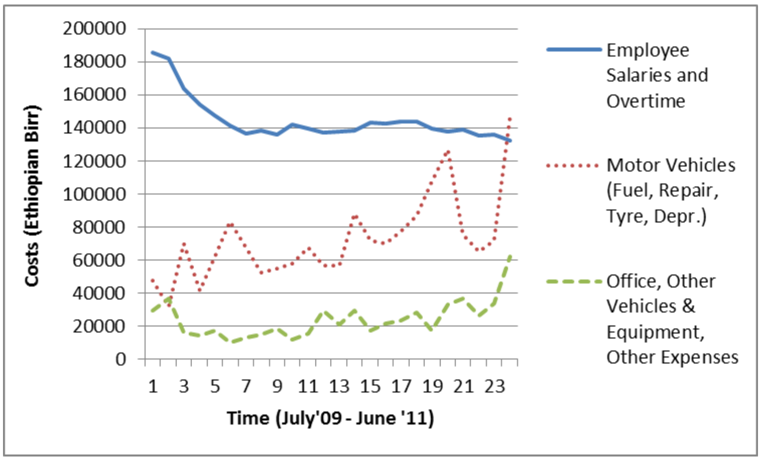

Figure 3: Monthly operational expenditures of Dream Light by cost categories

The graph shows that salaries expenditures decreased by around 26% in the first half year and since then they have been relatively stable. The share of personnel costs with regard to total cost dropped from 66% to 56%. Expenses related to motor vehicles however show a trend of rapidly increasing expenditures, by around 82% over 24 months and an increase in the share of total costs from 25% to 34%. In particular expenditures for fuel/oil/lubricants as well as repair/maintenance have contributed to this overall increase. In the final month of analysis the share of expenditures for transport and vehicle maintenance overpassed the salary expenditures. Figure 4 shows details of these expenditures for motorized vehicles by cost types. Other costs, as shown in Figure 3, have been quite stable and constitute 9 -10% of the total costs. Thus while employee salaries still make up for the bulk of expenditures the costs for keeping the transport fleet operational is increasing steadily and rapidly.

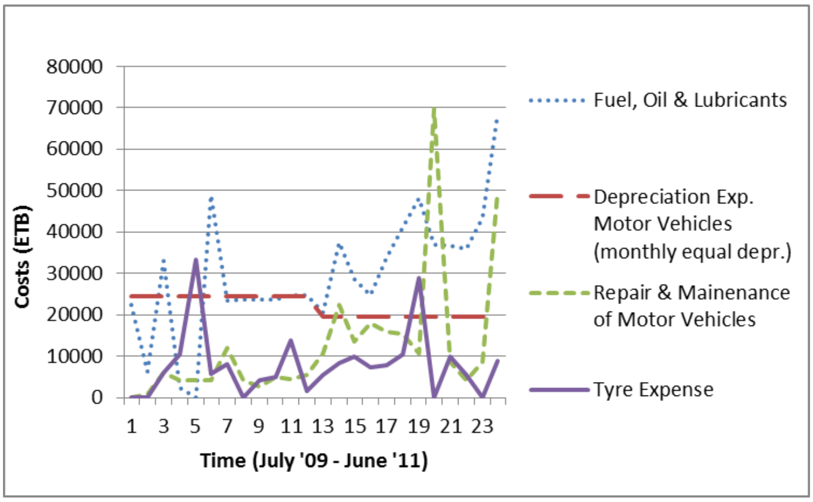

Figure 4: Monthly costs for motorized vehicles

Costs can also be analyzed with the method of process cost accounting, whereby the costs are disaggregated by different functional processes which together define the system, in this case:

- (Primary)-Collection costs (salaries of waste collectors, clothing, phone bills, maintenance of push carts, depreciation of carts)
- Transportation costs (salaries of truck drivers, fuel, oil & lubricants, car wash and greasing, phone, stationary, repair & maintenance of motor vehicles, tires, depreciation of motor vehicles
- Cash collection costs (salaries of fee collectors)
- General administration and support services (salaries of admin. staff, office electricity, water, office supplies, depreciation of offices equipment, computer, accessories, etc.)

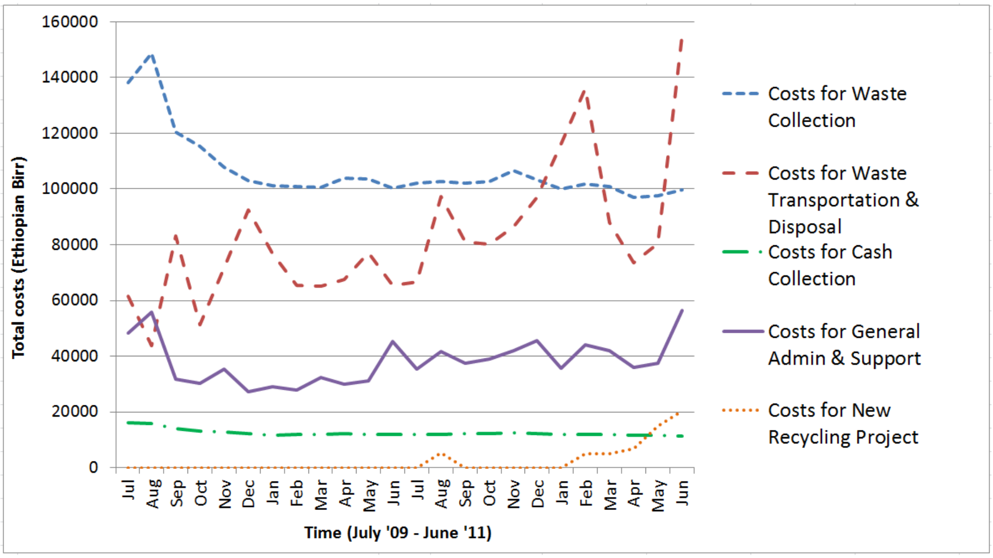

Figure 5: Total monthly costs rearranged by SWM activities between July 2009 and June 2011

Also here the increasing costs for waste transportation (mainly expenses related to motor vehicles) can be identified. Although they do tend to fluctuate quite significantly depending on the specific breakdowns and repairs needed, they have reached an alarming height in June 2011. The yearly total for repair of trucks amounts to 150’339 ETB. Per truck (7 in total) this amounts to 21’477 ETB (1265 US$) per year per truck.

For 2009/10 the total annual costs were around 2.72 Mio ETB, whereas in 2010/11 the same costs increased to around 3.06 Mio ETB.

Revenues

Analyses reveal that Dream Light has only one major stream of regular revenues. This income comes from tariff payments for the solid waste collection service. Only about 1% of the total revenue stream is from the sales recyclables such as plastics. From collection tariffs, revenues can be distinguished by type of waste generator. There are three different customer types: residential, commercial and institutional customers.

Each household is required to pay a monthly fee of 10 ETB to Dream Light’s fee collectors who go from door-to-door to collect it in cash. For commercial enterprises and institutions there are no fixed tariffs. Dream Light negotiates individual fees with each customer based on the waste quantity and frequency of collection. The payment rate is reported as being low: as only about 50% of the households pay the collection fee, whereas roughly 90% of the commercial enterprises and institutions pay the fee regularly.

Of all revenues from waste collection service payments, 86% come from residential and commercial areas and around 13% from institutions. Of the 86% roughly 3% come from the market center which can be considered as one special kind of the commercial customer (Figure 6).

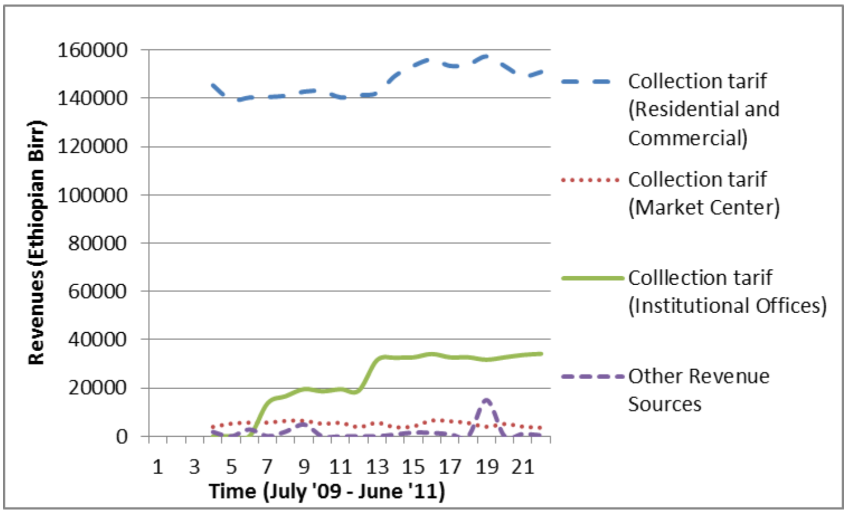

Figure 6: Development of Dream Light’s revenues disagregated by sources

During the first year, the increase in revenues resulted from obtaining new institutional customers. In the second year, the revenue stream increased as more households were serviced. Revenues increased from around 140’000 ETB/month to about 150’000 ETB/month. Revenues from institutional sources remained on the same level at around 33’000 ETB per month.

Comparing costs and revenues

Dream Light’s overall 2-year expenses, revenues and net income are depicted in figure 8. It includes the main operational costs as well as the depreciation of assets and interest on capital.

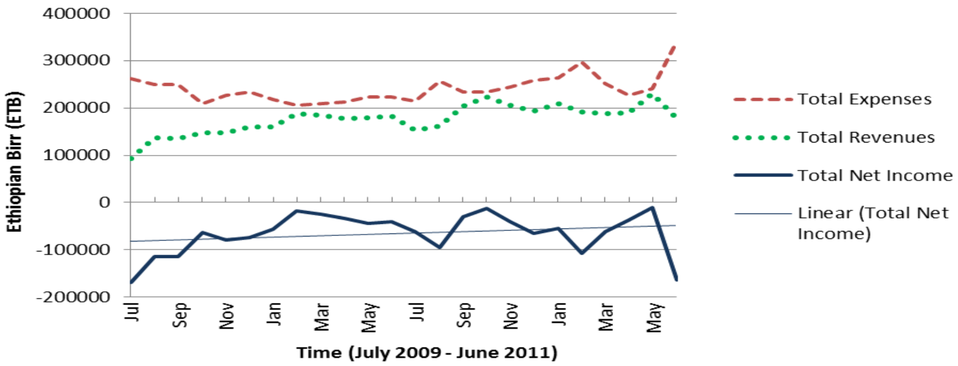

Figure 8: Development of costs, revenues and net income over two years

Figure 9 gives an overview of total costs, revenues and net income of the two examined fiscal years. It shows that for 2009/10 the total annual costs were around 2.72 Mio ETB, whereas in 2010/11 the same costs increased to around 3.06 Mio ETB.

When compared to the waste service of 26'645 tons of waste collected per year (73 t/d) the cost per ton for 2010/11 amounts to 115 ETB (6.7 US$). A family with 11 members per household (refers to the open concept of a household as a group of people living under one roof or within one compound) and an average generation of 0.25 kg/cap day (for household waste) produces 82.5 kg per household and month. The associated cost of collecting this amount of waste is therefore 9.5 ETB per household and month. This is in the range of the currently charged 10 ETB per household and month. However, as the tariff collection efficiency is only 50% the collected revenues are not able to cover the running costs.

The annual revenues also increased during the two years of analysis from 1.89 up to 2.33 Mio ETB per year, which in turn reduced the total net loss from 0.83 down to 0.74 Mio ETB.

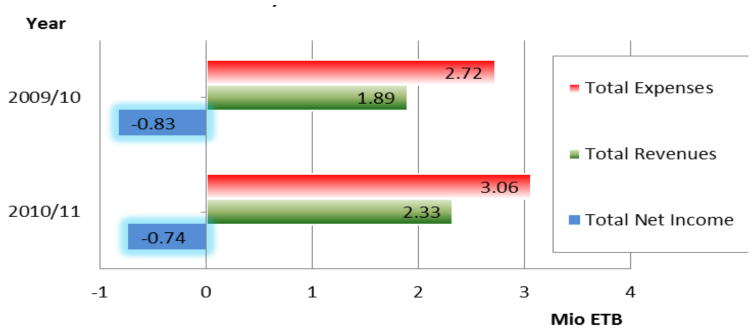

Figure 9: Overview of total expenses, revenues and net income

In addition, it has to be mentioned that Dream Light is in delay with repayment for the loan received from the municipality as well as the loan from UNDP.

The Way Forward

While costs in the SWM system of Bahir Dar have been increasing mainly due to rising expenses related to waste transportation, there is currently only one major cost recovery system in place: The user's fee collection from households, businesses and offices. However, the revenues from the collected fee charges are not sufficient to cover all costs. In other words financial sustainability is currently not met and strategies need to be envisaged to improve and ensure financial cost recovery. Either the revenue streams need to be increased and/or costs have to be reduced.

Revenue streams can be increased by improving revenue collection, by higher tariffs or by accessing new revenue streams through sales of recyclables or recovery of resources and/or energy and thus of increase the value chain of waste. Reducing costs is considered difficult to realize and would necessitate either a time motion study to analyze inefficiencies and potentials for time savings (i.e increasing efficiency), or an investment into newer vehicles to thereby reduce the downtime and repair cost of vehicles. Below two options are presented on how revenues might be increased.

Option 1: Linking solid waste collection- and water supply-fees. Dream Light is pursuing this idea which aims at increasing the currently low rate of tariff recovery. It is based on the system practiced in Addis Ababa and is founded on the assumption that the water consumption of a household correlates with amounts of waste generated i.e. a household that consumes high amounts of fresh water also generates large quantities of solid waste. Thus the waste collection fee will be linked to the water bill. Dream Light has plans to implement this new payment system in Bahir Dar. Theoretically implementation a such an approach is feasible as all households in Bahir Dar have a water meter installed on their compound and each household has to go to the Regional Bureau of Water Supply once per month to pay the monthly water bill else water supply will be cut. The new system can be divided into progressive categories depending on the amount of fresh water consumed per month. The main advantage of the new system is to have leverage in case of non-payment: Water supply can be cut if the residents fail to pay the costs of water supply and waste collection. In addition, as waste charges would be an integral part of the water bill, institutions or commercial enterprise will lose the incentive to try to take care of their own waste themselves (until now frequently burned, buried on-site or disposed indiscriminately) to avoid paying fees. Some increasing cost might result from this aggregation with the water supply utility in terms of administration, however there would probably be a net saving as the household would come to pay their bills thus eliminating the need for the team of fee collectors and payment compliance would also probably increase. The question of how to deal with urban poor that cannot afford either the water of solid waste charges would have to be looked at in details to ensure that the service remains equitable and affordable for all.

Assuming that 100% of household service users would pay the waste collection fee instead of the current 50%, the revenues would also double and an additional 1.8 Mio ETB per year could be collected, which would allow to cover the current deficient net income.

Option 2: Sales of organic waste recycling products – increasing the value chain: As mentioned in the section on capital investment and loans, Dream Light is pursuing the completion of an 'Integrated Organic Waste Recycling Centre' in order to valorize a fraction of the organic solid waste that previously landed on the dumpsite. Figure 7 presents the planned material flow diagram of the first stage in the recycling project. Revenues are expected through:

- Sales of bread in a bakery where the oven is fuelled with biogas from anaerobic digestion of organic waste
- Composting of organic waste as well as digestate from the biogas reactor. The resulting compost shall be used for agricultural fields that belong to Dream Light on which cotton and sesame seeds are cultivated
- Production of charcoal briquettes from organic municipal and agricultural waste by dry pyrolysis. The briquettes shall then be sold as cooking fuel to the public.

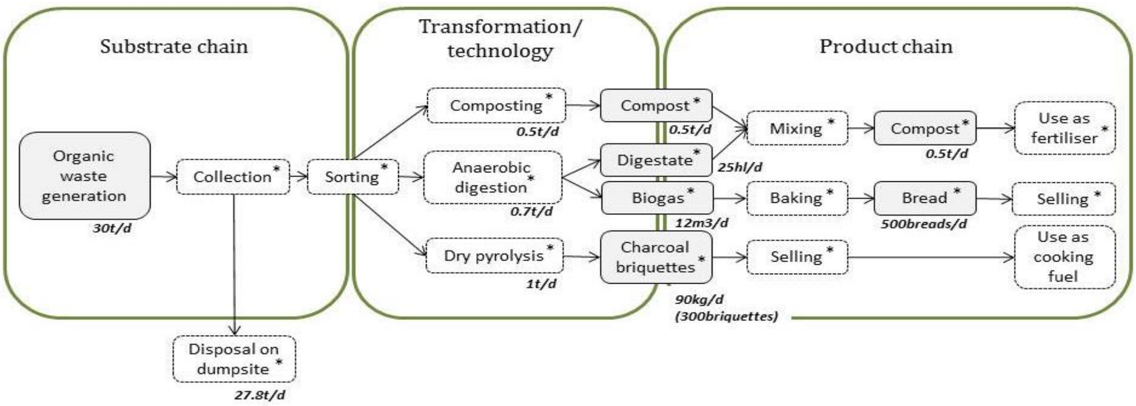

Figure 7: Material flow diagram of Organic Waste Recycling Center in Bahir Dar
(*conducted/controlled by Dream Light)

Dream Light is therefore counting on additional income from the sale of products from the new recycling project, such as biogas-baked bread, charcoal briquettes and compost. The strategy is to cross-subsidize the services of waste collection and transport which are losing money through profits generated by product sales. This idea is to create a value chain with a diversified portfolio of products derived from waste (compost, biogas, charcoal-briquettes) addressing different customer segments. Although this allows Dream Light to distribute risk it also requires a sound business plan for all the value chain segments including a high level of skills and knowledge regarding the technology demands and associated risks. This human capacity inside Dream Light is not yet so well developed. Approached by this concern, Dream Light responded with the strategy to start small with projects at pilot scale, and with this learn from experiences and mistakes, to then modify, expand, and scale-up. This commendable strategy however has a back-side, that the cost efficiency and margin of profit in this period will probably be very low if not also negative and therefore rather than increasing revenues will probably increase losses. As technical performance of these treatment and production facilities are difficult to assess, production cost is also yet unknown. Furthermore also sales of the various products are difficult to estimate. The viability of the business plan for these additional capital investments is thus insecure.

CONCLUSION

By the means of this study, officials responsible for municipal SWM now have more accurate information concerning the costs of waste management. Within the given time period of two years, the study revealed that the SWM system in Bahir Dar is not financially sustainable and major adjustments need to be envisaged to guarantee long-term functioning of the system. Costs are increasing while revenue streams were not able to cover the gap. The revenue stream relies entirely on waste collection tariffs from household, commercial enterprise and institutions. It might be however worth considering that some of the cost be covered by the municipal budget obtained through property and income taxes (Schübeler, 1996). New plans for revenue collection from collection fees are looking towards setting tariffs which are more related to the amounts of waste generated.

Through the well-developed networking and fund-raising skills of Dream Light, they repeatedly obtain access to loans from financial institutions. However these are earmarked for investments and not to cover the financial losses. The proposals on how these loans will be invested to strengthen the revenue stream are considered critical and problematic, without sufficiently obvious business models and plans. There is the risk that the past years of losses are being covered by these additionally obtained loans. This shortcut however does not alleviate the situation but rather postpones it and also diminished the possibility to use the capital for investments and thus to open pathways to reduce the financial burden for Dream Light. Interventions are required very soon to bring this system towards a stronger financial foundation else the private partnership may fail in the medium to long term thus endangering the now well improved and reliable service.

Although the privatization of the SWM in Bahir Dar has led to substantial improvement regarding cleanliness of the city and the financial risk has been transferred to a private company, the municipality remains responsible for guaranteeing a proper SWM system. In case Dream Light's financial situation worsens and in the worst case the company must quit its services, the municipality would most likely not be able to respond and provide adequate services to all city residents. It is thus important and in the interest of all that the City Administration and Dream Light cooperate in implementing functioning cost recovery mechanism to reach financial sustainability.

ACKNOWLEDGEMENT

The authors would like to thank Dream Light, particularly Mr. Getachew Alemnew and its entire staff for collaborating and sharing data openly. Moreover, the authors wish to thank the Swiss Agency for Development and Cooperation (SCD), the NCCR North South and Eawag for their financial support.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M. I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.74 (1-8)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

SOLID WASTE (CO-) COMBUSTION IN POWER GENERATION FOR SUSTAINABLE WASTE MANAGEMENT

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ABSTRACT

Incineration is a widely practiced approach in many countries for managing various wastes. This generally reduces 90% volume and eliminates possible contamination threat from organic materials. Although Bangladesh is a densely populated country, the most common approach adopted for solid waste management is land-filling. On the other hand, scarcity of electric power supply is one of the main obstacles for development of the country. Establishment of new power plant using the heat energy from combustion of waste materials with or without pulverised coal could provide several benefits as stated above. Study identified more than 50 power plant was running with MSW co-combustion in China. Furthermore, the produced ash could be used in various civil engineering applications. This study explored background information related to co-combustion in power generation and suggests that this could be a sustainable solution for waste management and economic development of Bangladesh.

Keywords: Waste management; Solid waste; Power generation, fly ash, co-combustion

INTRODUCTION

Co-combustion of various waste materials with main fuel (generally coal) in power generation could lower the production and emission of greenhouse gases such as NO_x and CO_2. In a statistics KEMA indicates that replacing 5% coal energy by biomass could lead to 300 Mton CO_2 emission saving per year (KEMA, 2009). As an alternative route of waste disposal and management, co-firing could also be potentially beneficial. To the date, co-combustion in power generation has been sought in many countries including the USA, Europe, Japan and China. Whilst among the European countries the Netherlands being pioneer in this sector (McCarthy *et al*., 2003). There have been over 100 co-firing plants in Europe. Some of the co-firing plants operated in trials or demonstrations basis, for example in the UK and USA. The co-firing plants in countries, for example the Netherlands, Denmark, Finland and Sweden are mostly running in commercial basis.

Bangladesh is a country with 160 million populations of which only 50% has access to electricity. As per the Ministry of Power, Energy and Mineral Resources, current generation per capita is only 252 kW. As of October 2012 power generation from natural gas estimates 75% of total production while coal counts only 3.75% (BPDB, 2012). On the other hand, as per Dhaka City Corporation daily solid waste production was approximately 3000 tonnes, which was dampening in 3 disposal sites around the city (DCC, 2005). New power plants with co-combustion facilities could potentially reduce power scarcity and provide better ways of waste management. Generally, fly ash from coal based power plant is one of the potential supplementary Cementitious Materials (SCMs) for using in concrete construction. Co-combustion of coal with secondary fuels could potentially change the fly ash characteristics. Therefore, the current practice and factors associated with co-combustion technology needs to understand for decision making. This paper discussed processes for co-combustion, materials used, environmental factors and the produced fly ash properties to adopt the option for this country.

CO-COMBUSTION POWER PLANTS STATISTICS

Table 1 and 2 shows examples of some biomass co-combustion experience in the USA and Europe respectively. In the USA up to 20% co-combustion has been noticed for trial and pilot basis whereas its level was limited to 5% for commercial application. Similar experience has been noted in the European zone. Wide range of materials including switchgrass, wood, straw, paper sludge, liquid organics, petcoke, natural gas etc was considered. In the USA up to 700 MW plant (Ottumwa) was run with 5% co-fuel while in Europe that was 900 MW plant (Studstrup – 4) at Denmark with up to 20% wheat straw co-combustion.

Table 1. Biomass co-combustion experience in US utilities.

Plant	Capacity	Co-fuel(s)	Co-fuel, %	Firing	Scale
Gadsden, AL	60 MWe	Switchgrass	5	Direct	Commercial
Ottumwa, IA	700 MWe	Switchgrass	5	Direct	Commercial
Seward15, PA	147 MWe	Wood	5	Direct	Trials
Dunkirk, NY	100 MWe	Wood	10-20	Direct	Trials
Dresden 4, NY	11 MWe	Wood	-	Direct[1]	Trials
Sandia National Laboratory	30 KW	Straw	-	Direct	Pilot

[1]Separately injected
AL: Alabama; IA: Iowa; PA: Pennsylvania; NY: New York

Table 2. Biomass co-combustion in European utilities

Plant	Capacity	Co-fuel(s)	Co-fuel (%)	Firing	Scale
Amager – 3 (Den)	250 MW_e	Wheat straw pellet	10, 20	-	-
Vestkraft – 1 (Den)	125 MW_e 330 MW_{th}	Danish straw	10 – 25	-	-
Studstrup – 1 (Den)	150 MW_e 380 MW_{th}	Wheat straw	0 – 20	-	-
Studstrup – 4 (Den)	350 MW_e 900 MW_{th}	Wheat Straw	0 – 20	-	-
DTU (Den)	5 KW	Danish straw	-	-	Pilot
Amer-8 (NL)	645 MW_e	Paper sludge	3	Direct	Commercial
Amer-9 (NL)	600 MW_e	Petcoke	5,10	Direct	4-week test
Amer-9 (NL)	-	Demolition wood	5	Indirect[1]	Commercial
Gelderland-13 (NL)	600 MW_e	Demolition wood	5	Direct	Commercial
Maasvlakte 1,2 (NL)	518 MW_e	Liquid organics Biomass pellets Pet cokes	1 8 5,10	Direct	Commercial Commercial 4-week test
IVD (Germany)	0.5 MW	Straw	-	-	Pilot
Kymijarvi (Fin)	-	Wood, REF, Natural gas	15e	Indirect[1]	Commercial
Zeltweg (Aus)	-	Biomass	10	Indirect[2]	Commercial

[1]Upstream gasification, [2]Upstream pyrolysis
Co-fuel inputs as thermal % except (e): electrical%
(NL: Netherlands; Den: Denmark; Fin: Finland; Aus: Austria)

KEMA has done a wider range of study on co-combustion, both in trail and commercial application. Range of materials covered for co-combustion study included demolition/waste wood, fresh wood, sewage sludge, petcokes, paper sludge, hydrocarbon gas, biomass pellets, municipal waste (plastic fraction), coffee ground, cacao shells, poultry dung, meat and bone meal, biomass blend. In their experimental run the secondary fuel(s) levels were 3-42%. Power generation was carried for 1 MW trial unit and up to 600 MW commercial power plants (Thompson, 2008).

CO-COMBUSTION MATERIALS

Wide range of co-fuels has been used in co-combustion for power generation, such as vegetable biomass (Wood chips, straw, olive shells including any other vegetable fibres), green wood and cultivated vegetable biomass, demolition wood, municipal sewage sludge, municipal solid waste (Raw or separated), food waste, bone meal, paper sludge, petroleum coke (Pet coke), tyre-derived fuels (TDF), virtually ash free liquid fuels and gaseous fuels.

The latest version of European Standard for fly ash EN 450-1 (2005) restricts the amount of co-fuels could be used in co-combustion process up to 20% of that of pulverized coal in terms of calorific value. Another constrain is that the used 20% co-fuel should not contribute more than 10% ash in total ash production in order to use this ash in concrete construction.

Classification of Co-fuels

Co-fuels are characterized as ‘clean fuel’ and ‘contaminated fuels’ based on their performance on utility waste stream (including ash quality) and emission level as shown in Table 3. The use of fuels classified as ‘contaminated fuels’ is being in the lower level in co-firing.

Table 3. Classification of co-fuels (van Ree *et al., 2001*)

CLEAN FUELS	CONTAMINATED FUELS
Unprocessed wood waste	Demolition wood
Miscanthus	Verge grass
Cereal straw	Chicken litter
Cocoa bean hulls	Pig manure
Olive wastes	Sewage sludge

Biomass co-combustion of coals with lower volatile matters show increased NO_x emission. However, the trend is opposite bio-fuels with low nitrogen content. Some bio-fuels, for instance alfalfa stalks, rice hulls, and clean urban wood waste are reported to contain higher level of fuel nitrogen compared to coal. In general, bio-mass contain less amount of sulphur compared to any type of coal which may result reduced sulphur emission with flue gases.

Co-fuel Properties

Laux *et al*. (2000) reported analysis of sawdust and switchgrass and compared them with another two coals notably western sub-bituminous Black Thunder coal from Powder River Basin (PRB) and high volatile eastern coal from Illinois. Table 4 shows the proximate and ultimate analysis of the fuels.

Table 4. Biomass and coal analysis (Laux *et al*., 2000)

Proximate analysis		Sawdust	Switchgrass	Black Thunder (PRB)	Illinois #6
Fixed carbon (FC)	%	9.34	12.19	34.94	44.98
Volatile matter (VM)	%	55.03	65.19	30.72	35.32
Ash	%	0.69	7.63	5.19	7.43
Moisture	%	34.93	15.00	29.15	12.27
Ultimate analysis					
Carbon	%	32.06	39.68	51.3	66.04
Hydrogen	%	3.86	4.95	2.87	4.38
Oxygen	%	28.17	31.77	10.46	5.66
Nitrogen	%	0.26	0.65	0.68	1.40
Sulphur	%	0.01	0.16	0.35	2.79
Higher heating value	Btu/lb	5431	6601	8888	11731
Higher heating value	MJ/kg	12.62	15.34	20.66	27.26
FC/VM ratio		0.17	0.19	1.14	1.27
lb fuel N/10^6 Btu		0.48	0.98	0.77	1.19
lb fuel S/10^6 Btu (as SO_2)		0.04	0.48	0.79	4.76

It was found that fossil coal contains 3-4 times fixed carbon than biomass whereas the volatile mattes were found to be higher in biomass than the coals. In the same study Laux *et al.* (2000) also demonstrated that co-firing up to 15% sawdust, a maximum 10% NO_x reduction was achieved. Robinson et al. (1998) performed ultimate analysis and compared between red oak wood chips, imperial wheat straw, and two coals sourcing from Pittsburgh and Eastern Kentucky of USA. They also compared their oxide composition as shown in Figure 1. As with Laux *et al*. (2000), major difference with coal was noted with respect to fixed carbon and volatile matters content in co-fuels.

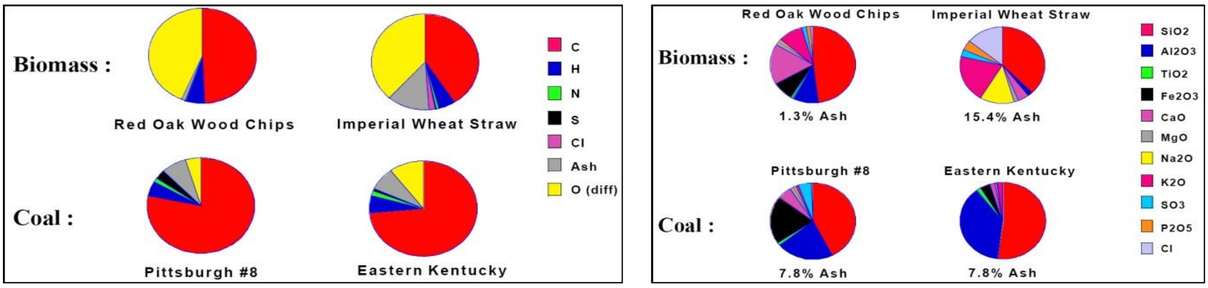


Figure 1. Ultimate analysis and oxide composition of biomass and coal (Robinson *et al*., 1998)

Chinese record shows more than 50 power plants were co-combusting municipal solid waste (MSW) with coal for power generation (Fan *et al*., 2008). They use combined (burnable and unbearable) MSW as in China usually collected without separation. The estimated heat value of this MSW is as low as 4200 $kJkg^{-1}$.

Jia *et al*. (2002) illustrated highest level of use of alternative fuel in California, USA. They experienced successful application of 100% pet coke in power generation and other utilities like Tennessee Valley Authority. Pet coke is a by product occurs as heavy residue from the petrochemical refining of fuel oils and commonly found in five varieties. Delayed cocking is the most commonly process which accounts for more than 90% of all pet cokes. Different types of cokes are used in their specific application; however, the majority of pet cokes are used as energy source. Cement kilns or fuels for the boilers in power generation are wider application as energy source. Among the varieties sponge coke is considered as the most preferable for power generation units. Replacement of coal with pet coke is gaining interest in power industry due to better compliance with environmental emission and improved ignition with higher flame stability.

Being cleaner and more economical, scrap tyres are used as alternative to coal as fuel in various utilities such as boilers, cement kilns, pulp and paper mills. Statistic shows in the USA, 2.4 Million tonnes scrap tyre was used as Tyre-Derived Fuel (TDF) in 2007, which accounts approximately 54% of total generated waste tyres. A total of 200.6 thousand tons of scrap tyres were consumed by 17 industrial boilers, for example Hillman Power in Michigan, Allegeny Power in West Virginia etc. as TDF in 2007 (RMA, 2007). Typical properties of TDF are summarized in Table 5.

Table 5. Properties of TDF (96% wire removed) (STMC, 2000)

Proximate analysis		*Minor elements (as oxides)*	
Volatile Matters (VM)	66.64	Zn	1.52
Fixed Carbon (FC)	27.96	Ca	0.378
Ash	4.78	Fe	0.321
Moisture	0.62	Cl	0.149
Ultimate analysis		Cr	0.0097
C	83.87	F	0.001
H	7.09	Cd	0.0006
O	2.17	Pb	0.0065
S	1.23		
N	0.24		
Heating value HHV (MJ/kg)	37.8		

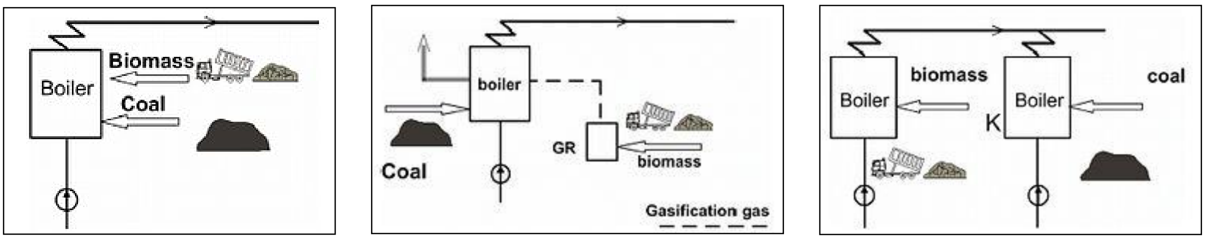
Emission Issue

NO_x is formed by oxidation of nitrogen molecules present in the fuel or from the atmospheric nitrogen in high temperature burning. Co-firing of fuels which are less rich in nitrogen content (e.g. straw) can lead to lower NO_x emission. However burning of other nitrogen rich co-fuels (manure) needs to set additional NO_x reduction measures (e.g. SCR or SNCR) to comply with the emission criteria. Rüdiger *et al*. (1996) proposed gaseous fuels from pyrolysis or other sources like methane from anaerobic fermentation as better kind of secondary fuels. Co-firing of biomass can also reduce NO_x formation by lowering the flame temperature, modifying the combustion dynamics or from dilution of fuel nitrogen from the coal itself (EPRI, 2000).

CONSIDERATIONS FOR CO-COMBUSTION POWER PLANTS

Co-combustion Plants Classification

Typical co-combustion power plants produce electrical output ranging from 50-700 MW. The majority of which runs with pulverized coal system, however, alternative system, for example fluidized bed combustion is also noticed. Depending on the burning system, co-combustion is classified in three categories such as i) direct co-combustion, ii) indirect co-combustion, and iii) parallel co-combustion. The brief concepts are shown in Figure 2. In the direct combustion system the co-fuels are pelletized (in case of biomass) before adding to the pulverized coal and thereafter feed them into the main combustion chamber or the co-fuels are feed in a separate burner simultaneously.



(a) Direct combustion (b) Indirect Combustion (c) Parallel combustion

Figure 2. Type of co – firing (EUBIA, 2010)

In the indirect combustion system, different techniques are applied to optimize the thermal and mechanical efficiency of the burning system. Typically fuels in liquid or gaseous forms are driven from pyrolysis process of co-fuels in a separate reactor and then added with pulverized coal system in combustion process. This process also helps to lower the NO_x emission level with a few modifications in the combustion condition. The parallel combustion is practically a variety of indirect combustion system in which coal and biomass burns separately and also the flue gas stream extinguishes through separate paths and later meet together before emission from the system. This process helps to drive separate ashes from coal and co-fuels preventing contamination between them, however, it is an expensive process due to higher initial cost of the utility which needs to fix before the operation.

Plant Design Considerations

In designing co-firing plant it is essential to consider co-fuel properties for example a) HHV, b) bulk density, and c) composition of co-fuel. Bulk density and moisture content of co-fuels have significant impact on its handling and storage. High moisture fuel could reduce the boiler efficiency because it requires additional energy to dry the fuel. In addition, furnace heat transfer, boiler fouling should be considered for proper functioning of co-firing plants.

Further to the above, co-fuels rich with volatile matters, volatize independently and earlier then fossil fuels while the fuel particle to particle interaction changes. This phenomenon lowers the ignition temperature and rapidly consumes the available oxygen. Care should be take in co-firing bio-fuel in a low-NOx system as lack of oxygen could impact negatively on flame length and burnout and combustion could be delayed.

The followings are major technical challenges associated with co-combustion which need to deal:

- fuel preparation, storage, and delivery
- ash deposition,
- fuel conversion,
- pollutant formation,
- increased corrosion rates of high temperature components,
- fly ash utilization, and
- impacts on SCR systems.

FLY ASH PEROPERTIES

Fly ash is an established supplymentery cementitious materials for concrete construction which offer structural, environmental and economic benefits (McCarthy *et al.*, 2012). However, the change in fly ash quality resulting from co-combustion, needs to evaluate before using it in concrete to ensure sufficient pozzolanicity. van den Berg *et al*. (2001) reviewed the change in chemical properties of co-fired fly ash. Table 6 gives an account of the summary of findings. Minor change in chemical composition of co-firing ash was observed from their original coal fly ash. Therefore, where the produced fly ash properties conforms to established standards, could be used in concrete construction.

Table 6. Changes in chemistry in co-combustion compared to reference coal-only fly ash (van den Berg *et al*., 2001)

CO-FUEL	LEVEL	INFLUENCE ON CHEMICAL PROPERTIES
Sewage Sludge	-	With increasing sewage sludge, SiO_2 decreased, Fe_2O_3, CaO and P_2O_5 increased. Other than phosphate no deviations to reference fly ash.
Biomass	-	The same conclusions are valid for co-combustion of biomass as for co-combustion of sewage sludge.
Petroleum coke	10-20%	Co-combustion gives higher Vanadium and Nickel concentrations in fly ash. No other deviation to reference ash.
Paper sludge	10%	Co-combustion gave lower SiO_2 and higher CaO concentrations in fly ash. Chemistry otherwise within the range of common fly ashes.
Straw	20%	Co-combustion gave a small decline in SiO_2 and a slight increase in K_2O and Na_2O also found. Unclear if this causes enrichment of alkalis.
Wood	14%	Co-combustion had a minor influence on chemistry.
Other materials	-	Other materials including bone meal (1.6%), cocoa shells and poultry litter (up to 3%) have been used as co-fuels. Minor change to chemistry noted

CONCLUDING REMARKS

Incineration of waste materials is one of the available management techniques as it greatly reduces the waste volume. The valuable heat energy produced by co-firing waste with pulverised coal could potentially be used for power generation. Experiences of co-firing for power generation are discussed in this paper. Associated factors such as fuel type and their properties, considerations for co-firing power plant design are also included. Studies showed minor difference between the co-fired fly ash and that produced from coal only combustion. The produced fly ash could be used in various applications. Therefore, co-combustion of waste materials with pulverised coal for power generation could be sustainable solution for waste management and power scarcity of Bangladesh.

ACKOWLEDGEMENTS

Support from Chittagong University of Engineering & Technology (CUET) is gratefully acknowledged.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.77 (1-10)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Comparative Analysis of Traditional Open Truck and Hauled Container Systems of Waste Collection in Dhaka City

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ABSTRACT

The two most common collection systems of dhaka north and south city corporations are open truck based collection and hauled container system. A study has been carried out for assessing the collection systems and comparing them. Time and motion survey, weighbridge data analysis, focus group discussion and interview of municipal staff, conservancy officers, conservancy inspectors and drivers and truck crews were carried out as study methodologies. Results show within the round trip haul distance of 12 to 15 km, open truck can make at least 2 trips and container carrier can make 4 trips per shift. The actual trips made and the trips for which fuel is allocated are not always same. Time ratio of traditional open truck collection for pickup, unloading and travelling are about 58%, 9% and 31% of total trip time respectively. The capacity usages of vehicles are 95% to 132% and 70% to 91% for open truck and arm-roll container carrier respectively. Collection systems' efficiency and effectiveness improvement is possible considering proper matching of time, place and method between primary waste discharge and secondary collection.

INTRODUCTION

The existing Capacity for Solid Waste Management (SWM) of local government organizations (city corporations, municipalities) cannot meet the service demand of citizens in Bangladesh. 'Capacity for Solid Waste Management' ranges from individual skills to organizational and institutional/societal capacities (Fukuda-Parr et. al., 2002) and encompasses software and hardware assets and capabilities. The Capacity is related to sustainability of SWM. Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) of former Dhaka City Corporation (DCC) are mainly operating 5 different types of collection systems. Systems are (1) Hauled Container System (HCS), (2) Open Truck (OT) based collection system, (3) compactor truck based collection system, (4) collection system using trailer and (5) pay loader and dump truck based collection system. Each of the collection system can also be categorized based on different variables, e.g., capacity of vehicles or carriers, fuel used (diesel or CNG), loading or pickup methods of waste etc. Around 181 open trucks and 194 container carriers and 40 compactor trucks have been deployed in DCC with an estimated carrying capacity of 3631 ton per day. Maximum coverage of waste collection is done by HCS and OT based system. A study has been carried out on how effectively and efficiently these collection vehicles and systems are working and comparisons between them are made. Time and motion survey, weighbridge data analysis, focus group discussion of DCC field staff conservancy officer (CO) and conservancy inspector (CI), and interview of drivers and truck crews were taken as study methodologies**.** This paper focuses on the analysis of first two collection systems, (1) and (2). Comparison is made based on determination of various efficiency indicators. Merits and demerits of two systems and system improvement options are indentified and suggestions are made. Findings can be used for waste collection system planning and system improvement in almost similar conditions e.g., other city corporations of Bangladesh.

Conceptualization of Primary and Secondary Collection:

Waste collection consists of two parts, namely primary and secondary collection (Figure 1) in DNCC and DSCC. City Corporations (CCs) are responsible for secondary waste collection to remove waste from its dustbins/containers, and transport the waste to final disposal sites (Clean Dhaka Master Plan, 2005). Residents are responsible for bringing their waste to CCs' waste collection points where dustbins and containers are located. NGOs/CBOs/private sectors work as primary collection service provider (PCSP) to collect waste from door-to-door and transport to the dustbins/containers, compactor stations or sometimes to vacant lands, by rickshaw vans. At present, PCSPs are prevalent in most of the areas of DNCC and DSCC. 'Local Government (City Corporation) Act 2009' is the basic regulatory document regarding street/drain cleaning, waste collection and transportation. According to the act, City Corporation is responsible for secondary collection and allowed to provide dustbins or other receptacles at suitable places, and to require residents to bring their waste to the dustbins or receptacles. However, it is not clearly mentioned who takes responsibility of primary waste collection where such dustbins or receptacles are not provided (Clean Dhaka Master Plan, 2005). Secondary collection is the collection of waste from communal bins, storage points, or transfer station, and transportation to the final disposal site (Rahman, et al., 2010). This study analyzes the two types of secondary collection systems which are open truck and container collection.

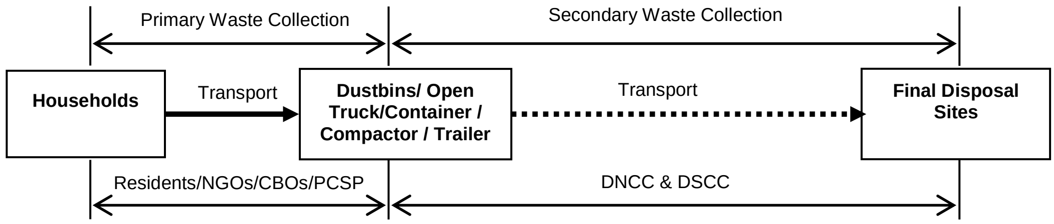

Figure 1: Waste collection system in Dhaka City
Source: Adapted from Clean Dhaka Master Plan 2015 (2005)

Conceptualization of Hauled Container System (HCS)

Collection system in which the containers used for the storage of wastes are hauled to the processing, transfer, or disposal site, emptied, and returned to either their original location or some other location are defined as hauled-container system (Peavy, et al, 1985). Rahman, et al., (2010) described in the book of Solid and Hazardous Waste Management that in this system, an empty storage container (known as a drop-off box) is hauled to the storage site to replace the container that is full of waste, which is then hauled to the processing point, transfer station or disposal site. In this system, tilt-frame container or trash-trailer vehicles are commonly used. The driver is responsible for hauling operation and plays the main role for driving the vehicle, pickup and unloading the containers. In Dhaka, a helper assists the driver for safety reasons and fastening chains with containers at the time of picking up loaded container and positioning empty container. HCS is usually night time collection.

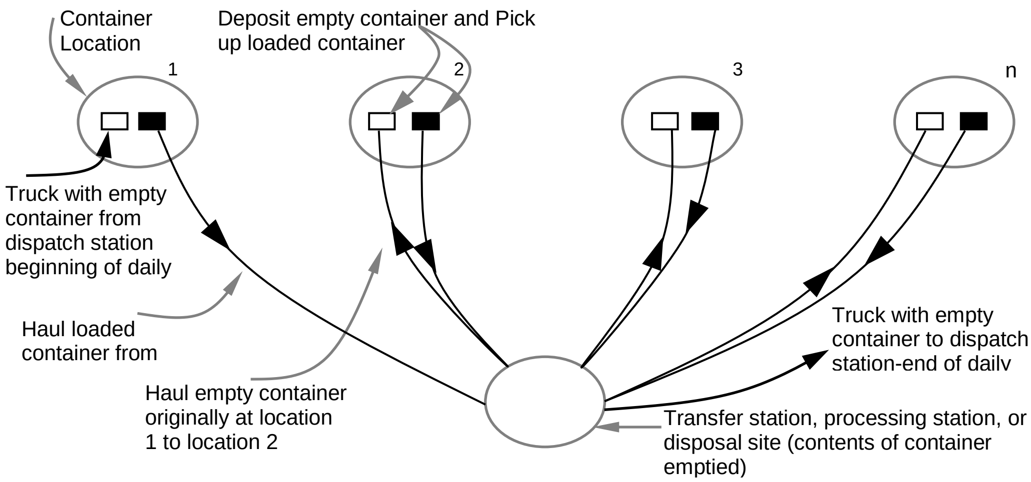

Figure 2: Schematic of operational sequence for Hauled Container System (Exchange mode)

Source: Tchobanoglous, et al., (1993)

DNCC and DSCC have several types of containers and carriers. In terms of capacity, there are 3, 5 and 7 ton containers. According to fuel used, there are CNG fueled and diesel fueled carriers. This study mainly focuses on 7 ton capacity diesel fueled arm-roll container carrier.

Conceptualization of Traditional Open Truck (OT) Collection System

Traditional OT collection is typically used in morning time for removing waste from street sweeping, dustbins, extra waste beside containers, drain cleaning, construction debris and garden trimmings. This collection system also removes wastes being generated by shops and restaurants. Collection stations in this system vary frequently as creations of open dumping spots are uncertain. Loading method is manual. Based on requirement open trucks are used other time of the day as in VIP wards and wards with special cleaning requirements or if morning truck cannot remove all the waste. A typical flow diagram of OT collection system is shown below. The capacities of open trucks are usually 3 ton and 5 ton, there few 1.5 ton vehicle. This study mainly concentrated on 3 ton capacity vehicle. Number of officially assigned cleaners per vehicle for picking up and unloading of waste is 4~6 per vehicle.

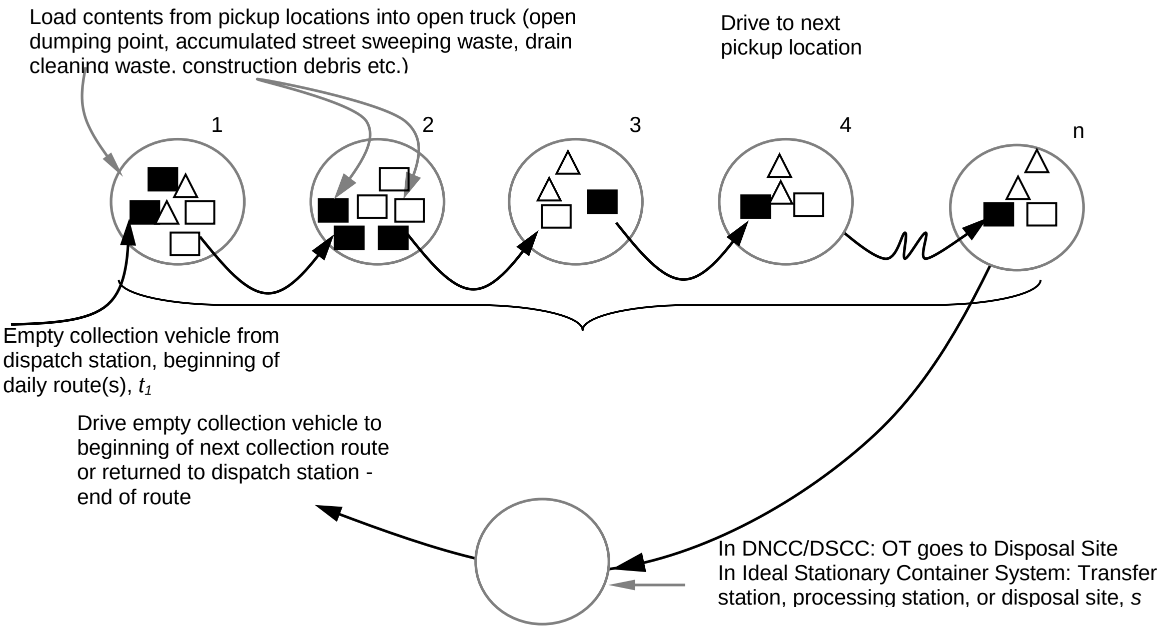

Figure 3: Schematic of operational sequence for OT Collection System

Source: Adapted from Tchobanoglous, et al., (1993)

METHODOLOGY

Selection of Study Area

The study areas were selected on the basis of accessibility of information and convenience to carry out interview, field visit and which can represent result for a typical community of Dhaka. There are always threats if any study is taken place with vehicles from drivers' union and scavengers'' union. Careful consideration has been taken in this regard. For traditional OT collection, Ward 36 (new 13, DSCC) and for arm-roll container collection, ward 33 and 53 (new 10 and 19, DSCC) are selected for study as shown in the following Figure 4.

Time and Motion (T&M) Survey, field observation, interview of stakeholders and schedule of survey

The movement of vehicle and time spent in different stages of collection cycle were surveyed to find out the time consumption in different stages of full collection cycle. The variations of time consumptions of two collection systems were measured and used to determine efficiency indicators with waste amount and manpower used. Travel lengths of the vehicles were measured to understand the speed of the vehicle and comparisons of the two systems are made. It is important to get an idea of time requirement to make a trip for certain round trip haul distance. The data collected from weighbridge installed in the landfill site was used to understand overall performances of the vehicles in term of numbers of trips and waste amount in short time series. Physical observation and interview were also taken with related workers, staff and officials - before, after and at the time of time and motion (T&M) survey. At the time of T&M survey crew behaviours were monitored to understand whether improvement could be made. Several discussion meetings and interviews were organized among field level staff of study areas to rationalize the results found from T&M survey and weighbridge records. Some data, found as exceptional or not typical were avoided in calculating average. In interview, some of the questions were predetermined, while others were open. Questions were asked according to a flexible checklist but not in the form of a formal questionnaire. There may be four types of interviews: individual, key informant, group and focus group. Interviews can provide in-depth, inside information if trustful relationship is established with informants (Ahmed, 2004). On the basis of this notion, target interviewees, study areas and vehicles to be surveyed were selected.

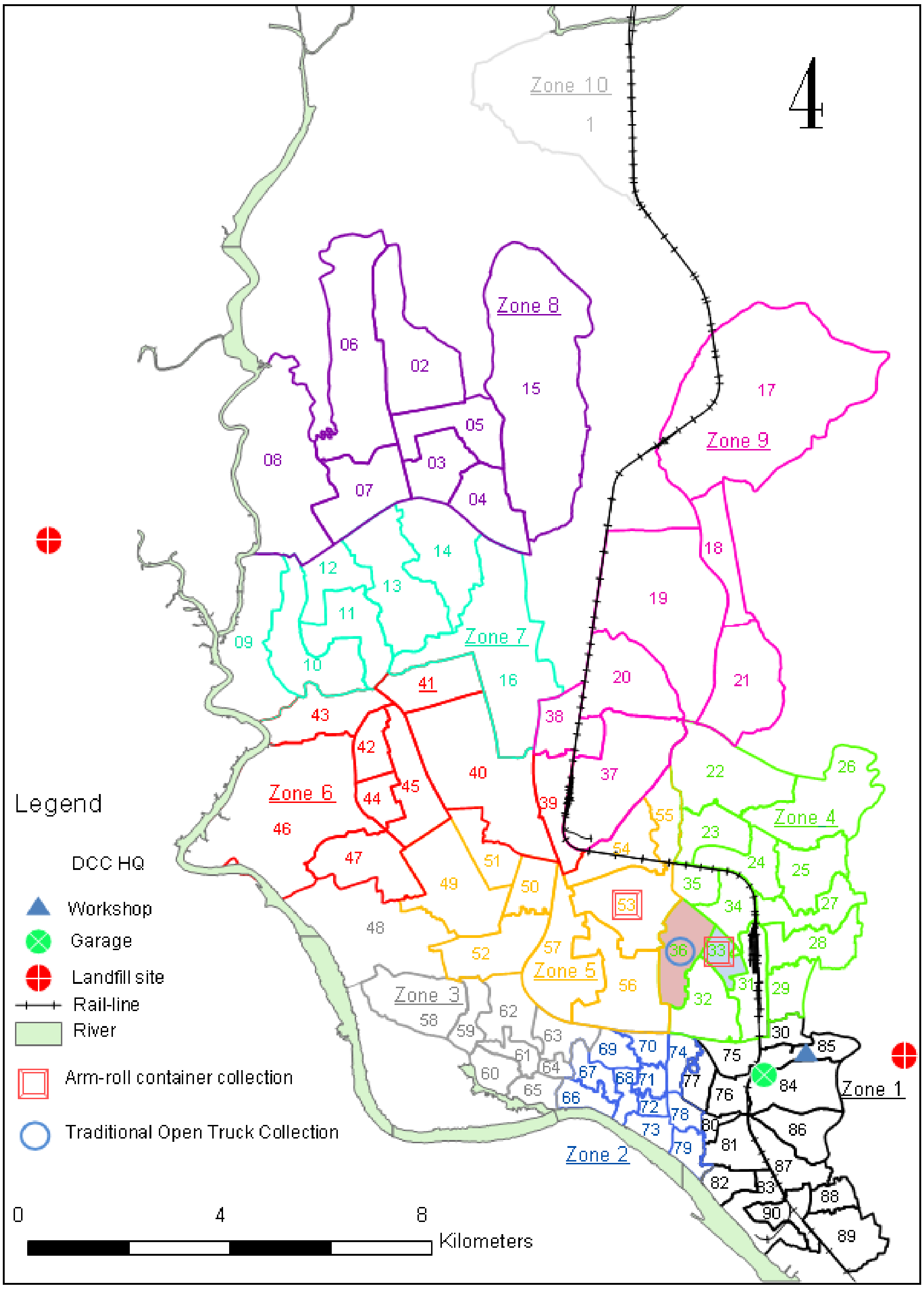

Figure 4: Map of study areas with collection systems in former Dhaka City Corporation

T&M survey for open truck was carried out in April 2009 for two days in traditional morning collection. Another two days data of T&M survey of January 2008 of similar vehicle also incorporated in analysis to rationalize surveyed data. And HCS was surveyed in June 2011 for two nights for 7 ton arm-roll container collection.

Determination of efficiency indicators

The working efficiency of collection workers were calculated as how many workers spend how much time to load and carry per ton of waste and how much time was required for collecting and disposing per ton of waste. The loading efficiency of vehicles was calculated on the basis of percentage of vehicle's capacity. Wide varieties of efficiency parameters can be generated from T&M survey and weighbridge data which reflect not only the efficiency of the time, vehicle or crew but also give an idea of improvement measures. Percentage of time taken in different components of a collection cycle is calculated with respect to Total Trip Time (TTT). TTT is the total actually engaged working time in the full collection cycle. It is time from beginning from garage at the start of work and to the moment of arriving at garage after finishing the work. In this time several trips may be made. The following break up or time ratio can be made on the basis of total trip time (figure 5):

- Total travel time, when vehicle is in travel (t_1 + TT_1 +TT_m + TT_n + t_2)
- Net pickup time, it is the time required just to load the vehicle, (LT_1+LT_2 + LT_n)
- Total time spent in the collection area is the total time taken for waste collection only.

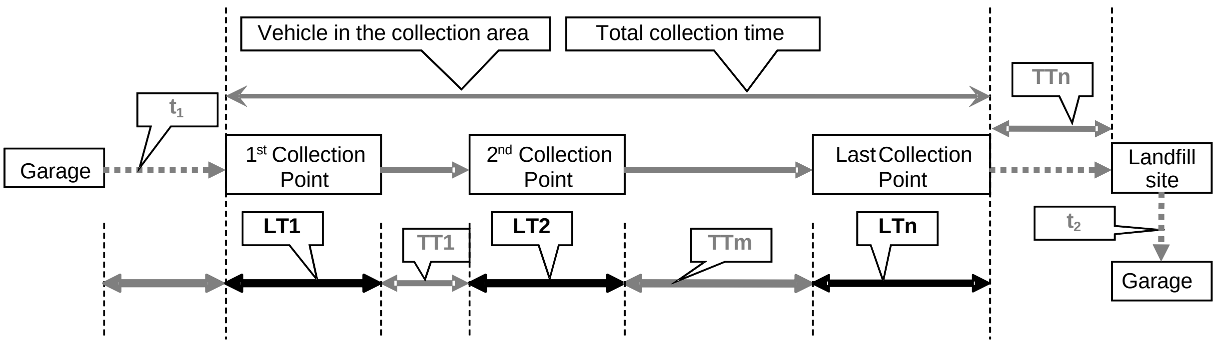

Figure 5 Time fraction sketch for OT collection

- Time efficiency rating (E) of collection workers is calculated as how much percentage of time labors were actually engaged in work with respect to the total assigned working time. It is an index showing the efficiency of collection workers during the working hours.

  E = 100% x {1(TTT-BT-RT- other time not actually engaged in work) + NP x (TTC + TTU)} / {(1+NP)} x PNWH = 100 % (∑actually engaged labor-hour)/(∑assigned labor-hour)

  Where, TTT = Total Trip Time, RT= Recycling Time, BT = Break time, NP= Number of collectors except driver, TTC = Total time of collection or pickup, TTU= Total time of unloading.

  TTT = total travel time + total pickup/collection time + Weighbridge time + Break time + fuelling time + others, PNWH = Prescribed number of working hours per shift.

Other efficiency indicators such as gross labor efficiency, net labor efficiency, net pickup time per station, need speed in collection area, speed of the vehicle and unloading time is measured as follows:

- Gross labor efficiency as Gross person x minute /load = {(number of driver + number of collectors) x (total trip time)}/ load.
- Net labor efficiency = (Net person x minute) / load = {number of driver x (total trip time – break time or any other time not related to collection and transportation) + number of collectors x (pickup time+ unloading time)} / load
- Net loading or pickup rate is measured as net collection time in minute/load in ton.
- Net pickup time per station per person is calculated net pickup time/(total number collection stations or points x number of person).
- Gross speed in the total trip time is travel distance in full collection cycle per unit time as km/hr.

RESULT AND DISCUSSION

Performance / Efficiency Indicators of Traditional OT and Arm-roll Collection

A summary of study of traditional OT system and 7 ton arm-roll container collection system is depicted in the Table 1. Findings are based on T&M survey and weighbridge data analysis.

Table 1 Summary of findings of OT & Arm-roll container collection systems

Evaluating Parameters	OT collection	Arm-roll container collection (HCS)
Collection area	Ward 36 (New 13, DSCC)	Ward 33&53 (New 10&19, DSCC)
Vehicle / registration Number	11-0828	R-2
Vehicle Capacity in ton	3	7
Crew Size	4 (assigned 5)	2 (assigned 2)
Round trip haul distance	12 to14 km	12 to15 km
Total travel distance as km/trip	17.6±0.38	13.89±0.05
Trips/day	1 (assigned 2)	4 (assigned 4)
Total Trip Time in minute, TTT	252±16 (1 trip)	319±48 (4 trips)
Collection stations/trip	9.3 ±1.5 (10 stations/trip)	1 (4 station/shift or night)
Fuel allocation	3.5 km/liter	3 km/liter
Cost effectiveness in terms of fuel allocation for surveyed vehicle capacity (taka/ton)	12 (L/trip)*56(Tk/L)/3.22(T/trip) 209	17(ltr)*56(tk/ltr)/5.57 (T/trip) 171
Number of trips/shift (trips/day or trips/night)	Assigned trips/day: 2 Trip/day from T&M: 1 weighbridge : 1.11 trip/day	Assigned trips/night: 4 Trip/night from T&M: 4 weighbridge : 3.5 Trips/night
Total waste transportation and disposal (ton/shift)	3.27±0.6	23±4
Net pickup time or Pickup time (minutes/trip)	126 to 162 (146±18) Around 58% of TTT	4 to 13 (10±2) About 12% of TTT
Unloading time, minutes/trip	18 to 26 (22±4) Around 9% of TTT	3 to 5 (4±0.2) 5% to 6 % of TTT
Travel time	1.3 hour/trip 28% to31% of TTT	3.5 to 4.5 hours/night 0.875 to 1.285 h/trip 74% to77% of TTT
Load per TTT, kg/hr	778 ±118	4359±1427
Load per transporting time, kg/hr	2489±341	5742±1715
Net loading rate or pickup time, Minute/ton	46 ±10	1.8 ± 0.6
Managed waste in per unit distance per unit time calculated from Load/total distance/ total time as kg/km/hr	44±7	79±26
Vehicle capacity utilization calculated as ton/trip and as percentage	Ton/trip:3.27±0.6 T&M: 95% to132% (109%± 20%) Weighbridge: 108%	Ton/trip: 5.6±1 T&M: 70% to 91% Weighbridge: 80 %
Net overall speed as km/hr	14 ±1	14 ±1
Time efficiency rating	36% to 42% (39%±4%)	36% to 42% (39%±4%)
Gross labor efficiency as person-minute/ton	260 to 360 (314±48)	22 to 36 (29±9)
Net labor efficiency, person-minute /ton	209±84	18±4

ISBN: 978-984-33-7045-7, PI.77 (1-10)

Comparative Statement

The open trucks working in DNCC and DSCC are usually assigned to make two trips unless special trip is assigned. In practical, it has found that open trucks usually make one trip unless additional trip with fuel (in addition to two trips) is allocated. However, for surveyed OT, the fuel was allocated for two trips. The surveyed container carrier was assigned to make 4 trips per shift and it was found to make 4 trips per night.

The weighbridge records of trips information are shown in Table 2 and Table 3. Weighbridge data showed that 56% and 88% capacity (trips/day or trips/month) was prevailed for OT and arm-roll container respectively. And vehicular capacities as ton/trip were 108% and 80% for OT and arm-roll container systems respectively. The loading more than 100% of capacity of OT may reduce the life to truck and may require frequent repair and maintenance. Open truck is found to be most useful and effective collection system but due to significant numbers of trips being lost (false trip) it can be regarded as inefficient collection system. The reason of over loading is intentional reduction of trips and save the fuel from allocated amount. Many vehicles do not use weighbridge regularly which is a barrier for system improvement-planning and difficult to understand accurate existing system capacity. If someone makes two trips, other drivers accuse him or complain to drivers union. Several discussion meetings were organized to understand the reasons behind the trip loses. Some of the interviewees was found to be shy or afraid to respond this question. Several CIs (in charge of a ward) mentioned that they were weak to drivers and it was not possible for CI to control drivers. CIs sign the log books where written trips numbers are not always same as practical. In this perspective, container collection is more efficient as shown in following tables.

Table 2 Weigh bridge record of surveyed vehicle in 2011

3 Ton OT	Jan	Feb	Mar	Apr	May	Jun	Average	Capacity used
Ton/trip	2.82	3.63	3.27	3.9	3.47	2.24	3.22	108%
Trips/month	31	33	50	36	26	25	33.50	56%

Table 3 Weigh bridge record of surveyed 7 Ton Arm-roll container in 2011

7 Ton Arm-roll	Feb	Mar	Apr	May	Jun	July	Average	Capacity used
Ton/trip	5.1	5.3	5.6	5.9	5.7	5.8	5.57	80%
Trips/day	3.8	3.9	2.7	2.6	4	4.1	3.52	88%

Time efficiency ratings for both collection systems were found similar i.e., 39%±4%. It is calculated based on the ratio of actually engaged labor-hour to the officially assigned labor-hour. Ratio shows that labor productivity can be increased more. However, practically drivers get overtime allowance even though they work much less than 8 hours e.g., 252±16 and 319±48 minutes for OT and container collection respectively. It is an important reason of reducing labor productivity. Majority of the time of full collection cycle of OT is consumed in loading, around 58%. According to focus group discussion of staff (CIs & COs), interview of crews and field inspection, it was found that it would be possible to minimize the pickup time with an optimum combination of number of labor. Officially there should be five crews but one crew (cleaner) was found to be absent always which could contribute to reduce the pickup time. The percentage of time fraction is illustrated in the figure 5.

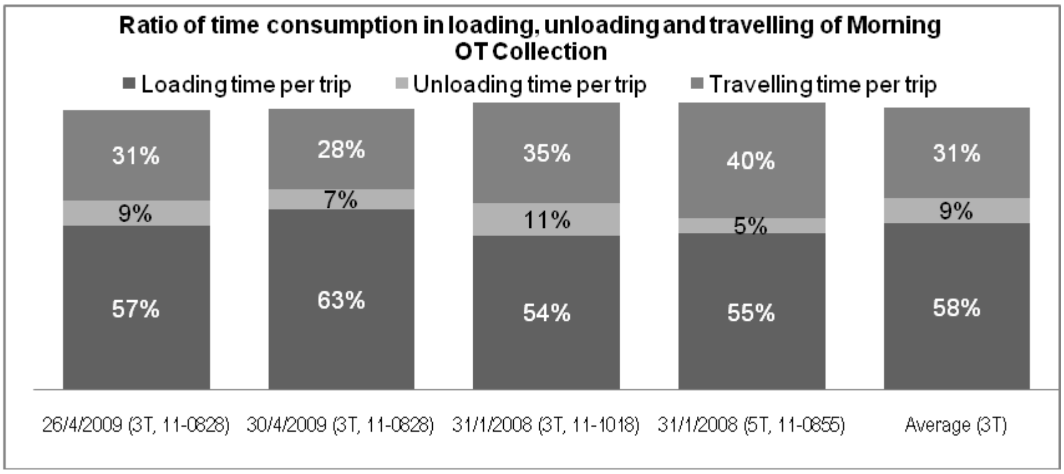

Figure 5 Time ratio of traditional OT collection

Merits and demerits of OT and Arm-roll container collection system

The both collection systems have advantages and disadvantages which are summarized below in various aspects. OT collection is traditional collection. It is day-time collection (usually early morning) whereas arm-roll container collection is night time collection. OT collection systems collect waste from open dumping points from the community including street sweeping waste. Just after the collection of OT, the community is clean. However, container stays whole day in the community and create public nuisance and traffic congestion.

Health Safety

The crews do not use safety gears in both collection systems. There is high risk of injury to load the OT due to pickup or loading and carrying of waste and there is risk also of sharp materials. There is no practice of manual lifting and placing of container to the carrier and almost no risk of injury. But the height of the container is not convenient enough, it caused back pain of cleaners who work day-long to load the container. Unsafe or careless movement of the crews was observed in both collections. The frequency of accident is higher in the container collection and cases of alcoholic drivers were found in night time container collection. The OT and daytime drivers were found as no alcoholic.

Environmental Soundness

Odors and scatting of wastes are common in both collection system but this situation is more common at OT collection and there is no leachate control facility. Long time pickup operation creates public hazard in OT system. Day-long staying of arm-roll container in community may cause leachate contamination and scattering of waste surrounding the container because of improper use. Most of the OT vehicles are old, consumes more fuel and emit more particulate matter, GHG and unburned hydrocarbon than container carriers.

Loading/pickup method

Street sweeping and commercial waste are being loaded by tukry (basket) & shovel to the OT and arm- roll containers are loaded by tukry, hand trolley and any other means. There are cases where the loading or pickup height was found not within the reach of crews' comfortable limit i.e., 1.6 meter (UNEP 2005).

Effectiveness

OT collection is effective in everywhere, where vehicle can get in and are suitable for commercial, domestic, garden and backyard trimmings, construction and demolishing waste and drain cleaning waste. On the other hand, arm-roll container collection is not suitable if container positioning and carrier maneuvering spaces are not available. Floor should be paved otherwise container collection operation is very difficult. Not easy to load in open top containers because of its height. Arm-rolls are to pickup and unload by its carrier. Construction waste and drain cleaning waste are not typically carried by container collection system.

ISBN: 978-984-33-7045-7, PI.77 (1-10)

Susceptibility to scavenging

The sorting of recycle items by the informal pickers and truck crews are found in OT system. However, the susceptibility of scavenging is more in container collection system than OT system. PCSP workers, informal waste pickers and CC cleaners are engaged in picking the recyclable items from container but at the time of hauling the container there is no sorting.

Personal preference of drivers

OT drivers prefer day time collection and tend to enjoy time with family member in afternoon and night. Drivers who prefer night time collection are engaged in container collection system. Container carriers are more preferable to the drivers usually because of fuel saving or surplus.

Public acceptance

OT and container collection might be suitable where less public interaction prevail. Cleaners mainly clean and load OT in the morning. Community people do not like container because of bad smell all the time in their travel route, space consumption and traffic congestion. Communities residing in the close proximity of containers are always in complaining attitude to remove containers. Container system is suitable for vegetable markets or large waste generating point or special cleaning purposes to remove huge amount of waste.

Stakeholders' cooperation

Stakeholders' (community, appointed cleaners and PCSP) cooperation is required for primary collection and at interface between primary and secondary collection. Stakeholders' cooperation in bringing waste to the OT collection points and container locations are urgent. Timely and careful discharge is most important for OT system whereas container collection system requires only careful discharge as container remains in the community continuously.

Workers relationship

Cooperation among the crews was found good in both collection systems. Attitude of the OT drivers to the ward inspectors (CIs) was found not well enough since inspector insist to make officially assigned trips and remove all accumulated waste which is not satisfactory to the driver.

CONCLUSION

Both collection systems have different merits and demerits, based on the situation and careful judgment, choice of the system should be sorted out for continual improvement of SWM services. Though container collection is very efficient and cheaper than OT collection in terms of fuel cost per ton of waste and trips/shift but due to the lack available spaces it cannot be used everywhere. OT consumes majority of its time in collection phase alone, 58%, which needs to be reduced by increasing crews' number. Time efficiency rating of both collection systems can be increased from 39% to further by increasing crews working hours. It has found that within the round trip haul distance 12 to 15 km, OT can make 2 trips/day and HCS can make 4 trips/night in less than assigned working shift (8 hours) which can be point of reference to be crossed to get overtime of the drivers. The managed waste calculated as kg/km/hr (total load/total distance travelled/ total time) is found 44±7 and 79±26 for OT and HCS system respectively. In terms of system operation efficiency as kg/km/hr, arm-roll container collection can be regarded as almost two times more efficient than open truck based system.

Efficiency and effectiveness standardization of regular collection is required to be set based on more sample survey, trial and error and laboratory tests. And management decisions to be taken to promote the standards.

Different efficiency indicators vary with collection time, method of collection, crew-size and cooperation of community. Collection systems' efficiency and effectiveness improvement is possible considering the issues of proper matching (harmonization) of primary and secondary collection in terms of time matching (timely discharge and collection), station matching (discharge in right place) and proper discharge (manner of discharge).

ACKNOWLEDGEMENT

The authors wish to express their sincere gratitude to the Team Leader and Chief Advisor of JICA Expert Team, Mr. Akio Ishii, Deputy Team Leader of JICA Expert Team, Mr. Takatoshi Arai, Chief Waste Management Officers of DNCC & DSCC for their support to execute the study; and the participants of the survey.

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Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

All Waste One Solution: A Model for Rural Bangladesh

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ABSTRACT

In Bangladesh, waste management is commonly thought as a municipal activity and is often absent in rural areas resulting polluted and unhygienic environment. Animal excreta, human waste, poultry manure, domestic waste, agricultural waste, paper waste and water hyacinth are the main refuges in rural Bangladesh. Proposed waste-to-energy approach consists of a well planned digester feed for all rural wastes where the in-plant reaction procedure should be the same as like the traditional one, but no need to add extra water. Individual digestion of different feedstock is well established; however, mixing of all waste in together in one single plant is the novelty of this model. Moreover, It's may significantly improve rural environment by prevent the ground water pollution and can contribute to economy by produce more bio-fuel, fertilizer and fish-feed. Following this concept, a model has been developed that comply with triple bottom line parameters of society, economy and environment.

1. INTRODUCTION

Bangladesh is mainly divided into three segments on the basis of socio-cultural development and economic prospects. They are (i) Rural Area, (ii) Semi-Urban Areas and (iii) Urban Areas. In the Urban Areas, the wastes are managed by the Municipal Authority or City Corporation. But in the Rural Areas, Municipality services are yet not present, whereas in some Semi-Urban Areas – it is rarely exist. The rural inhabitants do not follow any waste management (WM) roadmap which creates an unhealthy and polluted rural environment day by day. Around 23.39% population lives in urban areas [19]. That means 76.61% population lives in rural areas [11]. Now, the population of Bangladesh is 150 million where a significant portion (around 75 Percent) living in rural areas without any waste disposal facilities [12].

Consumption of traditional biomass energy has already exceeded the regenerative limit and there prevails energy crisis in rural areas in Bangladesh. Over 90% of energy consumption in rural areas of Bangladesh consists of biomass with per capita consumption of 2.93 tons per year in 2004 [12]. The proven gas reserves may support electricity generation, fertilizer production, Industrial, Domestic, Commercial, Transport (i.e., CNG) and other need for about only further 50 years [2]. The efficiency of traditional use of biomass is only 5% to 15%. Bangladesh has small coverage of forest i.e., 15% and actual tree coverage is not more than 7 to 8% and of the total traditional fuel supply 90% is wood [2]. Now, in rural Bangladesh, only 32% households have access to electricity where more than 75% peoples resides [2]. . At the local market level, biogas has two types of economic uses – (i) the gas itself as fuel and (ii) the bio-slurry as fertilizer or fish-feed. Both are marketable [21]. All of these factors strongly stimulate to develop a strategic model for the total waste management (both solid waste and waste water) in the rural areas which is easy adaptive, low cost solution and fulfill the energy demand at the same time. Effective implementation of this model may earn significant financial incentives for the rural inhabitants also. Economic benefits, saved time and energy, environmental benefits, health benefits and non availability of other fuel sources are the impact parameters to flourish the proposed rural WM method. Biogas offers a sustainable solution, at least in part, to all these problems facing by rural Bangladesh.

2. BACKGROUND AND LATENT POSSIBILITY OF THE PROPOSED RURAL WM METHOD

From the very beginning, rural women's were uses animal excreta (mainly cow-dung) and poultry waste on the periphery of jute-stick and drying them in the house yard by sunlight for cooking purposes for its high burning rate. Later the biogas plant technology was developed with only the cow-dung as the raw materials. Consequently, the biogas plant from the domestic waste and human excreta are individually developed. In the recent time, the biogas plant also proof successful with the agricultural waste such as rice husk and various crop straws. Another research has been occurs with the feasibility of water hyacinth and paper waste as the biogas raw materials –the result is significantly positive. In Bangladesh, 22 million cattle excreta, available dung nearly 220 million kg/day, 0.037 cubic meter of biogas has got from one kg of dung i.e., obtainable cattle dung can create 2.97×19^9 cubic meter gas which is the same to 1.52×10^6 tons of kerosene or 3.04×10^6 tons of coal [20]. About 80% of the total cow dung can effectively be use for biogas production and it is possible to construct 4 million biogas plants in Bangladesh. From these plants a huge quantity of organic fertilizer will be available to supplement chemical fertilizers for agriculture (nearly 50%) [7]. Dr. Khurshidul Islam, Sr. Advisor of SED said 1 kwh electrical energy can be generated from 0.71 m^3 of biogas which can be produced from 20 kg of cow dung obtained from 2 cows per day. High temperature is good for biogas fermentation [1]. Rai (2000) says the ideal temperature for methane producing bacteria is about 35^0 C which is very common in Bangladesh.

In 1972, first biogas plant was established at Bangladesh Agricultural University (BAU). A 6 m^3 digester volume family (for 6 persons) size biogas plant was established for cooking and lighting. In Bangladesh, cow dung based biogas plants used 4 to 13 (Avg. 6) cows dung and poultry litter based plants used 250 to 1212 (Avg. 1180) poultry birds. In the proposed method, one can go for biogas plant though he has no cow or poultry farms [21]. In Bangladesh, contribution of non-renewable and renewable energy is about 35% and 65% respectively [20]. About 40% of the total primary energy comes from renewable energy mainly biomass. The percent distribution of different types of traditional fuels are as follows – Cow Dung 16.49%, Jute Stick 5.72%, Rice Straw 9.18%, Rice Husk 18.59%, Bagasse 2.55%, Firewood 26.29%, Twigs Leaves 11.39% and Other Wastes 9.15%. It has been shown that, the daily gas production rate from different biomass in Bangladesh is about 17.05×10^6 m^3/day in the year 2001 where, gas production from the municipal solid waste is only 0.85×10^6 m^3/day. That means 16.2×10^6 m^3/day of gas production is possible in the rural areas [19].

3. MOTIVATION OF THE STUDY

In the PURA Community of South India, they use biogas not only for cooking operations but also for electrical generator and submersible pump for drinking water and in agricultural land, diesel engine for cultivation, and for home electrification etc [16]. Several countries in Asia have embarked on large scale programs on domestic biogas like China (about 20 million household digester by 2007), India (about 4 million units by 2007), and Nepal (more than 180000 plants by 2008). Africa is little bit slow but takes initiative also (2 million digester by 2020) [22]. 50 m^3/day biogas projects based on night soil (i.e., human excreta) and Food Waste was established for primary tribal Ashramshala at Jabepur in India [10].

In Ghana, the village Apollonia, biogas plant which used animal dung and human excreta produced 12.5 kW generators to provide electric power for street, home lighting as well as cooking and bio-slurry used for agriculture. Biogas based generator developed by Bogra Poultry Complex in Bangladesh [12]. In Bangladesh, we have only 25,000 biogas plant [13]. NDBMP wants to increase biogas plant 37,269 by 2012 and the budgeted cost was estimated 374988248 BDT [11]. Now it should be wise to proceed for the WM method like **"1 house 1 biogas Plant"** or **"1 family 1 compost plant"** for our rural inhabitants. If the rural inhabitants of Bangladesh could use animal excreta, human excreta, domestic waste and agricultural waste in a same biogas plant – it may function well due to the following reasons -------

(A) The proposed combined biogas plant may generate a significant volume of bio-fuel or methane gas and power such as electricity and heat. Traditional biogas plant required extra water to feed in digestion chamber. The proposed model does not require any additional water.
(B) The proposed biogas plant is progressively improving the rural environment by proper treatment of all types of fermentable solid waste and waste water they produced.

(C) The proposed model may omit different sanitary constructions (such as septic tank, soak pit, waste bin and landfill) because all the wastes are collected by a same plant. This reduces a significant construction cost and save valuable land also.
(D) The bi-product of biogas may be use as organic fertilizer or compost in the rural agricultural land. This compost minimizes the cost of fertilizer and increase the land fertility sustainably.
(E) The bio-slurry may also used for the rural fish feed.
(F) The proposed method nullifying the de-sludge operation of septic tank after regular time interval.
(G) Bio-slurry in the form of compost or fish feed has a significant salable price. If the rural inhabitants proceed for selling – it will be a financial incentive also.
(H) The proposed rural WM method fully prevents the underground water pollution by the natural absorption of soak pit periphery wall and its leakages.
(I) The construction of proposed biogas plant is as like to the traditional biogas plant with a predesigned increased volume of each chamber. Our local mason can easily construct the biogas plant with our local technology. The proposed waste to energy approaches required very low maintenance cost with less skilled workmanship.
(J) The proposed waste to wealth approach reduces the pressure on the natural gas stock of Bangladesh and decreases the uses of wooden fuel (Lakri) as well as carbon emission.
(K) Cooking by biogas is comfortable, less time consuming specially for women (1100 hours per year and 3 hours per day) with no black smoke. Proposed method drastically reduces (25% to 3%) the frequency of accidents from fire in the kitchen by using the traditional biomass. Each Biogas users saves in average 250 kg of firewood annually which directly reduces the deforestation [21].
(L) Biogas reduces Green House Gases, CO_2 emission, and heat loss at the time of cooking [22].
(M) Most of the biogas experts report that, generally they would prefer fertilizer from cow dung which is less effective due to having gas in it, but in the case of bio-slurry there is no gas and it is very effective for soil [21].
(N) Proposed rural SW management method reduced mosquito induced diseases. Almost 6 out of 10 household (used biogas plant) do not have any mosquito induced diseases, which was previously at the level of one third only [21].
(O) In the rural area, Latrine coverage is significantly increase last ten years, from 28% in 1995 to 65% in 2005 [6]. The percentage of households using sanitary latrines has goes up from 69% in 2006 to 75% in 2011 after biogas plant have been installed and attached with latrines [21]. Each year, Bangladesh produces seven million metric tons of urine. In the latrine attached biogas plant, human excreta are 10% of total feed stocks [6].

4. MATERIALS AND METHOD

In the rural areas of Bangladesh, mostly the waste produced from animal excreta, human excreta, and from domestic waste. All of these have bio gas producing potentials. The tentative list of wastes produced by the rural inhabitants are given hereunder-------

- Cattle and Buffaloes dung and urine
- Sheep and Goats dropping
- Human excreta and urine
- Poultry waste or manure
- Kitchen waste water and solid waste such as cutting pieces of perishable vegetables and fruits
- Bathroom waste water from bathing, hand washing and cloth washing
- Agricultural waste such as rice husk and crop straw
- Paper Waste
- Plant weed and leaves and
- Water hyacinth etc

Biogas consists of 60 to 70% methane and 30 to 40% CO_2 and other gases depend on feed stocks [11]. 6 different sizes of biogas plants are available in Bangladesh, i.e., 1.2, 1.6, 2.0, 2.4, 3.2 and 4.8 m^3/day. A plumbing network is required for the whole system with anyone size mentioned earlier. The Biogas plant should have a pre-design by considering all the possible loads and space requirements. In the inlet – all the collection pipes will be meeting at a point. The in-plant reaction of proposed biogas plant will be as same as the traditional biogas plant. Hopefully, the proposed method provides a good result because the different time and temperature of fermentation are supportive for the different biogas materials used under this method. Also there will be no shortage of these raw materials due to its availability in the rural region with almost free of cost. All of these parameters create a multiplier positive effect in the long run.

4.1. Human Excreta as Biogas Raw Materials: Biogas generation in the rural Ethiopia varies from 20 m^3 to 30 m^3 in seven digesters established in 2000-2002 where the main raw material was only human excreta driven from the school toilets [3]. For the treatment of human excreta in the rural areas, the traditional process is to create the septic tank and soak pit near the latrines. From the latrines, all the wastes (i.e., both excreta and urine) are going to the septic tank and then the liquid part goes to the soak pit. At the soak pit – a significant portion of waste water are absorbed by the periphery wall. If there is any leakage produces in the ring of periphery wall – it may catastrophically polluted underground water zone. Moreover, all these sanitary constructions are a matter of cost and occupying the valuable land. Also these sanitary constructions needed a regular de-sludge operations. In the proposed WM method, all the human excreta and urine are collected by a pipeline and directly goes to the biogas inlet.

4.2. Animal Excreta as Biogas Raw Materials: For the treatment of animal excreta, the rural inhabitants are directly used it in the agricultural land or sometimes it's used to prepare the composting. In the proposed WM method, the utility of the animal excreta becomes higher. First, it is used for the biogas generation and then it becomes compost fertilizer or fish feed. The villagers could undoubtedly use sheep and goat dropping with cattle and buffaloes dung in the biogas plant simultaneously. Together this manure may increase the biogas output significantly.

4.3. Poultry Waste or Manure as Biogas Raw Materials: Large Scale Poultry farming is a profitable concern in the rural zone of Bangladesh. Total gas production capacity of poultry waste is almost twice to that of cow-dung [1]. Poultry sector has grown annually 4.2% in Bangladesh [17]. The poultry manure has a significant fermentation property. So, poultry manure may use in the biogas digestion chamber as a raw material in addition with other feedstock. There are approximately 22570 commercial poultry farms housing 8410000 layers and 57845000 broilers in Bangladesh. These poultry farms are producing approximately 4474 tons (i.e., 1.63 million tons every year) of excreta every day [19]. Small scale biogas plants are popular in rural areas because a majority of the rural households keep some birds and many are small-scale commercial poultry producers.

4.4. Domestic (Kitchen and Bathroom) Waste As Biogas Raw Materials: Appropriate Rural Technology of India (ARTI), Pune (2003), has developed a compact biogas plant which uses food waste rather than any cow dung as feed stock, to supply biogas for cooking. The plant was sufficiently compact to be used by urban and rural 2000 families in Maharashtra. 2 kg of such feed stock produces about 500 gm of methane within 24 hours reaction. Conventional cow dung based plant have to use 40 kg feed stock to produce same quantity of methane but after 40 days later [9]. The ARTI has been made by fiberglass reinforced plastic tank. This system becomes very widespread in India where 12000 household digesters have been already implemented [8]. In rural area, the waste water from kitchen and bathroom are disposed of normally in the soak pit or in the adjacent flowing canal nearest to the houses. Basically in the kitchen two major types of waste produced. One is liquid waste and another is solid waste (i.e., pieces of unused vegetable and fruit cutting). Both these categories of kitchen waste and bathroom waste water contains sufficient nutrients which may use in biogas digester directly with other feedstock. Such kind of operation is environment friendly due to the minimization of underground water pollution and energy production simultaneously. Kitchen and bathroom waste water may fulfill the moisture demand of the biogas plant so that extra water does not require in the proposed plant to make slurry.

4.5. Agricultural Waste or Residues as Biogas Raw Materials: In rural areas, a huge amount of agricultural waste is produced every year. They are mainly rice husk and various crop straws, plant weed and leaves. Generally, agricultural residues are generated during crop processing e.g., milling and grinding etc. In Bangladesh, yearly needed biomass is 39 million tones and 50% comes from agricultural residue [2]. Previous research proves that, this sort of agricultural waste has a satisfactory fermentation property [1]. Due to the availability of a large volume of agricultural waste, rural inhabitants could easily use it in the biogas digestion chamber. In Nigeria, rice husk use at chemically treated powder form with un-powdered form at a ratio of 1:1 and the water to waste ratio is 2:1 [5]. But in the proposed digester, no need to add extra water with the solid rice husks. In case of plant weeds and leaves – villagers may directly feed it in the biogas digester. The plant weeds and leaves have no economic values except the firing at the kiln (i.e., Chula) for cooking. But if villagers use them in biogas plant, they could also contribute in the methane gas production. Due to its synergistic mixing properties with all other biogas raw materials, it doesn't need any primary treatment before feeding in digester.

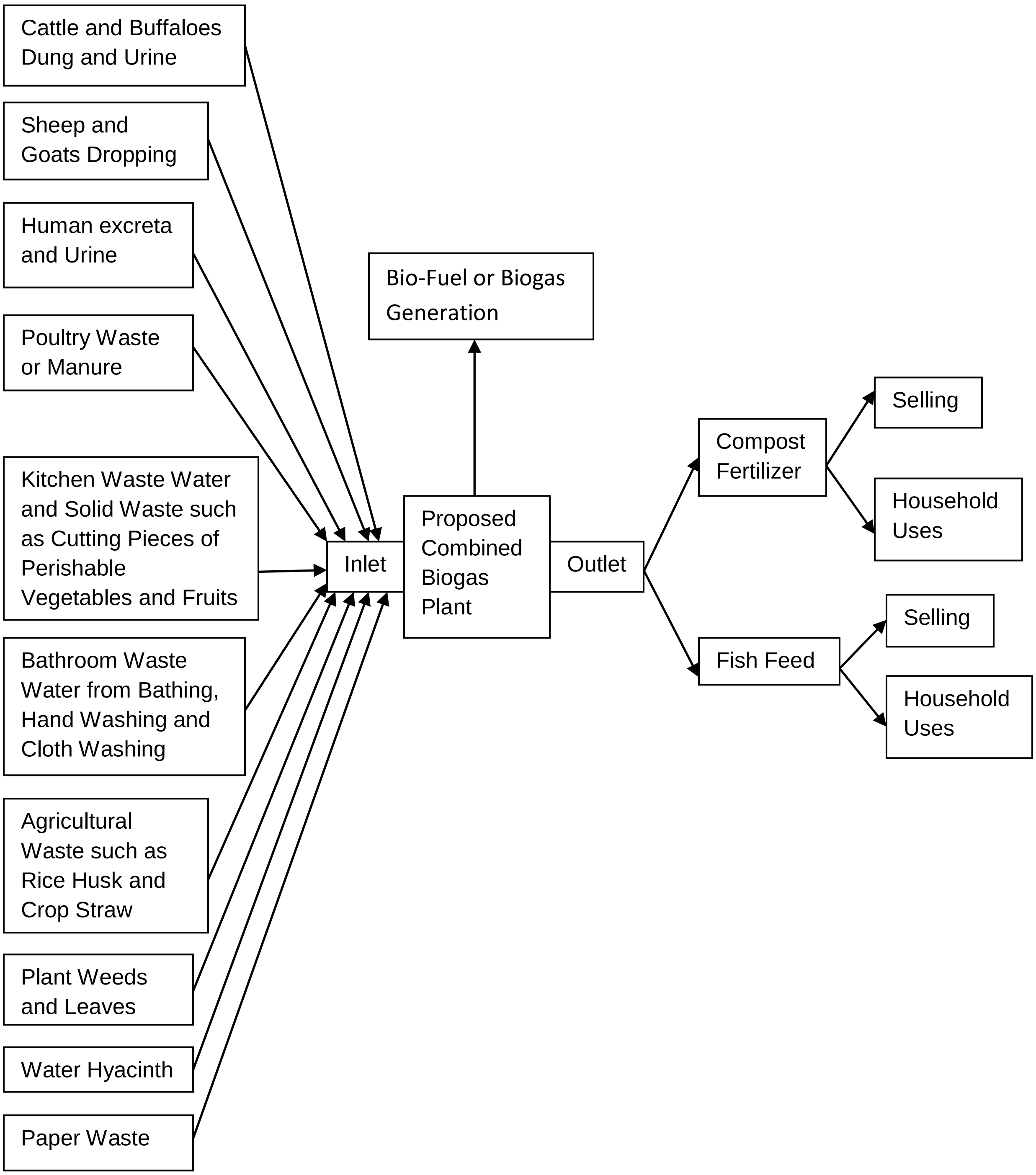

Figure 01: Proposed Rural WM Method through a Combined Biogas Plant where all the Wastes are Feed Together for Energy Generation, Compost Fertilizer and Fish Feed Production Simultaneously.

4.6. Water Hyacinth as Biogas Raw Materials: Now a days, water hyacinth is also proves to be a good biogas generating components. Recent researches argue that, constituents of biogas from water hyacinth were found very similar to that from cow-dung [1]. In Bangladesh, existing water bodies of rural areas produced a huge amount of water hyacinth and sometimes they are excessive in quantity so that the villagers are curtail and separated them from the water bodies because of its sunlight restricting properties which is bad for the aquatic ecology. Water hyacinth has no further use in the rural society except animal feeding. But it has a latent biogas optimization characteristic. Villagers could use it in addition with other biogas raw materials. It may significantly increase the biogas production in the plant.

4.7. Paper Waste as Biogas Raw Materials: In the rural Bangladesh, villagers are use the paper waste in the firing of cooking or sale them to the rural hawkers. In University of Nigeria, a study of biogas production potential of paper waste and its blend with cow dung was invested in 1:1 ratio with waste to water ratio was 1:3 [4]. The study revealed that paper waste is a very good biogas producer with effective retention period of 77 days and yield 8.8 m^3/kg/day of biogas [4]. The blending of paper waste with cow dung favorably enhanced the physiochemical properties of the feed stocks and will give sustained gas flammability throughout the digestion period of the waste since animal wastes are good starters for producing of biogas [4]. Rural inhabitants in Bangladesh could also use their paper waste in the proposed biogas plant effectively with other feed stocks.

4.8. Precaution to Feed In Biogas Digester: It should be ensured that foreign materials like earth, sand and gravel should not be in the digester [15]. Basically, this proposed biogas plant permits all sort of above mentioned rural waste. But before feeding, rural inhabitants should be confirmed that – a primary sorting is needed for separated out all non-biodegradable elements only. Agricultural waste such as rice husk, crop straw, plant weed and leaves and water hyacinth should be washed out before feeding because of dust, soil and foreign particles should not along with it. Again, from the solid kitchen waste, the non perishable components must be sorted and separated out before feeding in the plant digester. For the Hard particle of kitchen waste i.e., coconut shell, egg shell, peels and chicken mutton bones, these will be crushed by mixer grinding before feed in the digester [9]. The paper waste must be fully wetted in water before feed in digester [4].

5. COMPARISON BETWEEN EXISTING AND PROPOSED RURAL WM METHODS

Following diagrams were shows how proposed rural WM method is superior to the existing WM method---

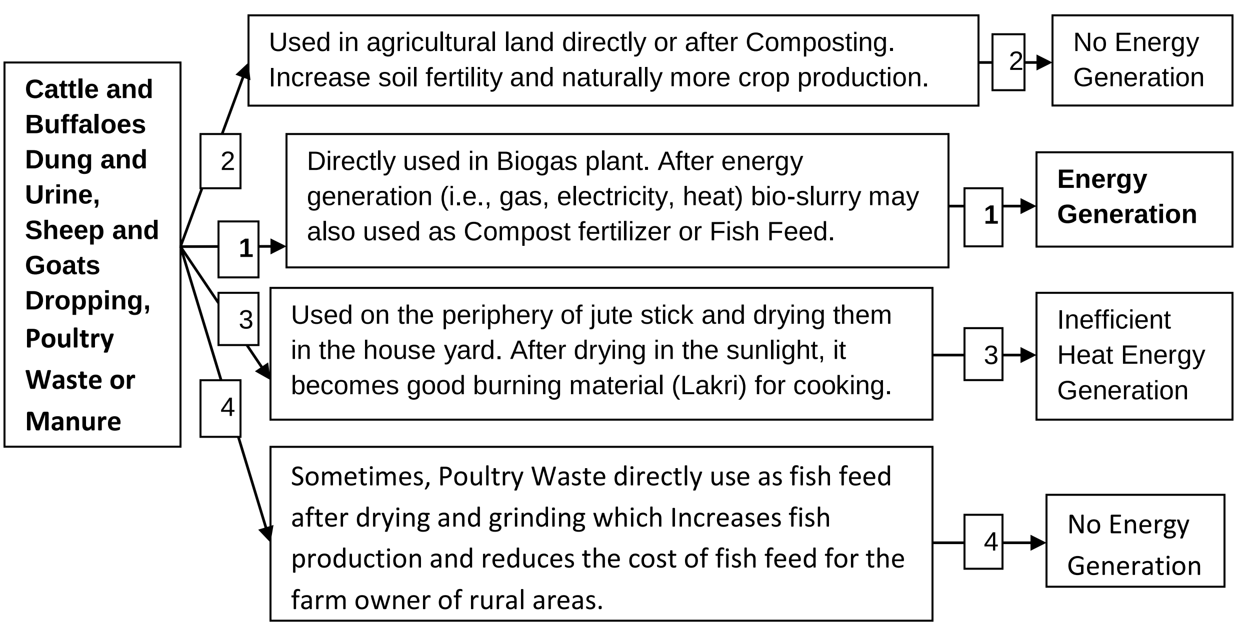

Figure 02: For Cattle and Buffaloes Dung and Urine, Sheep and Goats Dropping, Poultry Waste or Manure – Flow Line **1** is the only Energy Generation Option

ISBN: 978-984-33-7045-7, PI.85 (1-11)

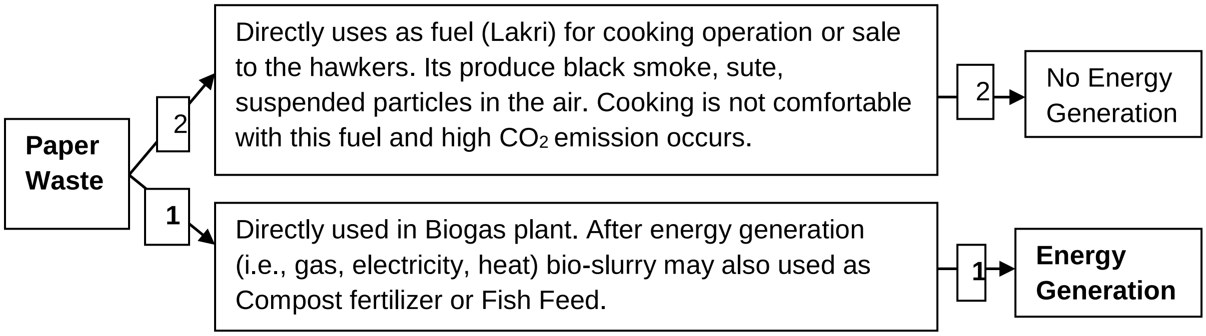

Figure 03: For Paper Waste **–** Flow Line **1** is the only Energy Generation Option

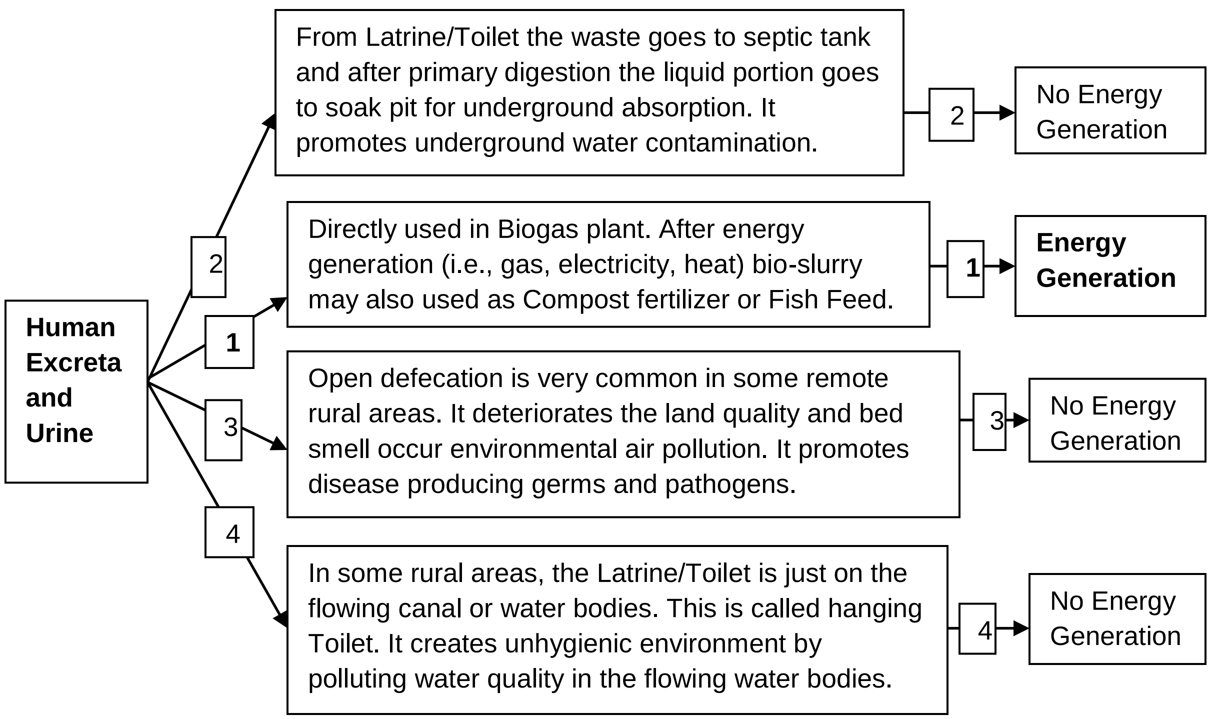

Figure 04: For Human Excreta and Urine – Flow Line **1** is the only Energy Generation Option

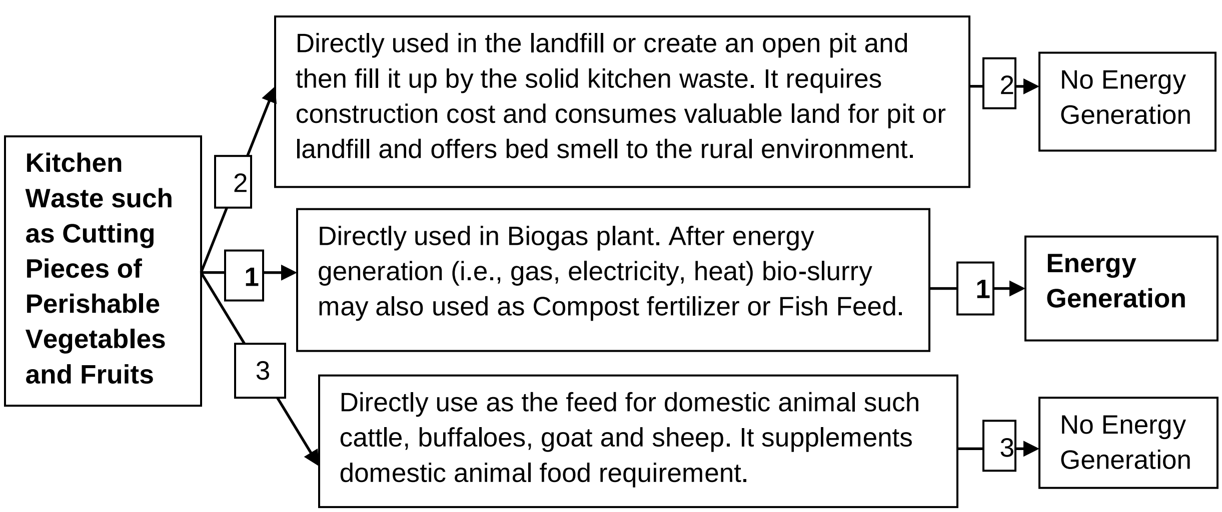

Figure 05: For Kitchen Waste Such as Cutting Pieces of Perishable Vegetables and Fruits – Flow Line **1** is the only Energy Generation Option

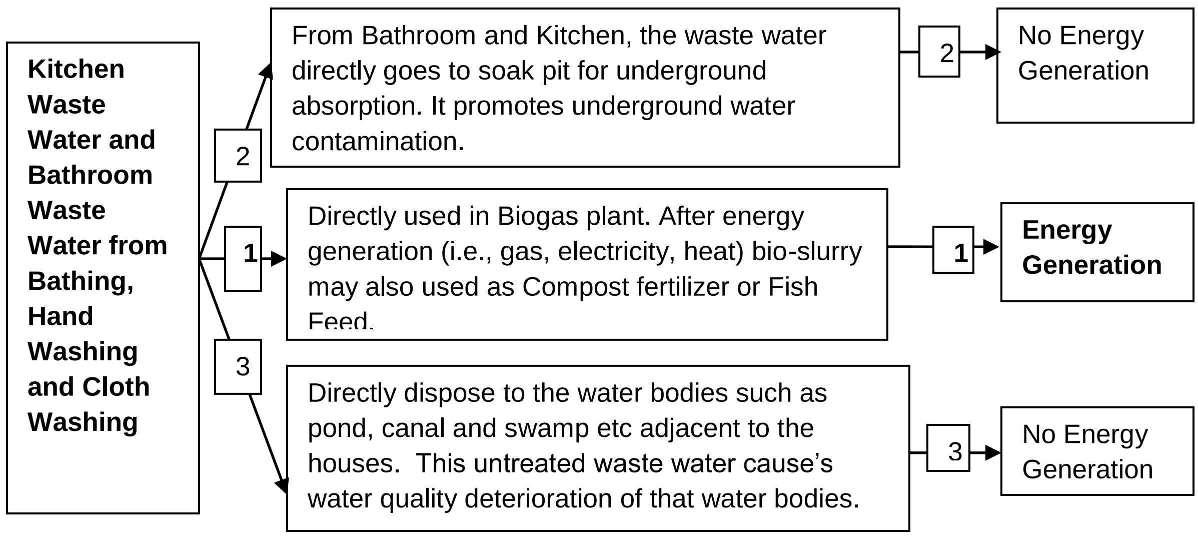

Figure 06: For Kitchen Waste Water and Bathroom Waste Water from Bathing, Hand Washing and Cloth Washing – Flow Line **1** is the only Energy Generation Option

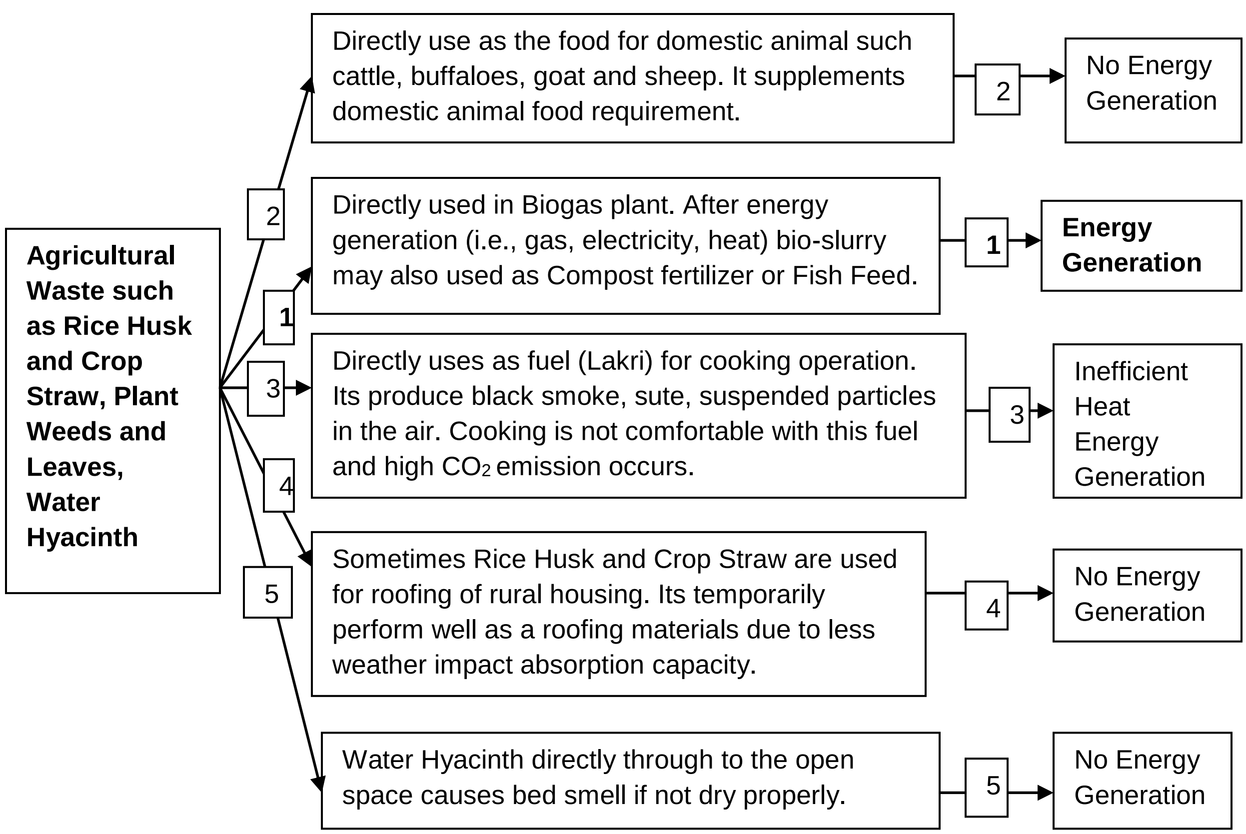

Figure 07: For Agricultural Waste Such as Rice Husk and Crop Straw, Plant Weeds and Leaves and Water Hyacinth – Flow Line **1** is the only Energy Generation Option

6. PROPOSED RURAL WM METHOD MEETS THE THREE (3) BOTTOM LINES OF SD

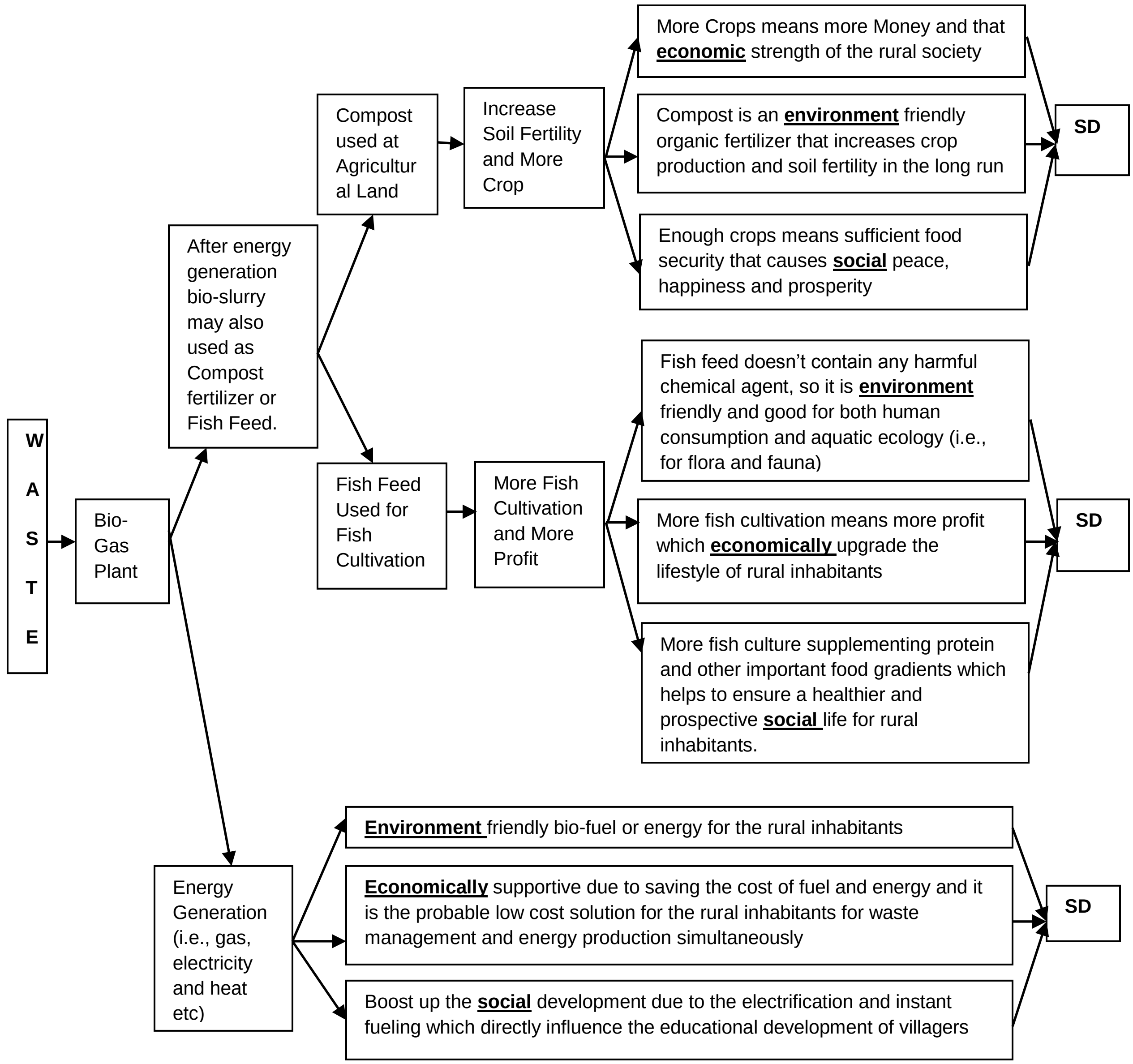

Figure 08: Proposed Rural WM Method Meets the Three Bottom Lines of Sustainable Development **(SD)**

7. DISCUSSIONS AND CONCLUSIONS

Energy crisis is a vital problem all over the world. The fossil fuel and natural gas is limited and has a significant carbon emission effects. Moreover price of these energy sources become higher day by day. The biogas could use in the petrol engine after some relevant modification [18]. Bangladesh have an optimal temperature ranges in between 20^0 C to 35^0 C. Sometimes it reaches 40^0 C. A biogas digester can operate in such kind of temperature through the year. In the rural area of Bangladesh, where the municipality facilities is not yet available – the inhabitants could proceed for the proposed model of biogas plant where they can dispose all the waste with saving the cost sanitary constructions and valuable land. 60 percent of the biogas plant owners have no training [21]. IFRD scientists are conducted over 215 training courses with 10000 men and women trainees in Bangladesh [14]. Bangladesh Govt. should patronize the proposed WM method by loan facilities, technical support and providing adequate training. Since biogas provides direct benefit to the rural women by reduction of workload, they should directly involve in the decision making process of proposed rural WM process. It is directly increases the presence in school of rural girls. Villagers could use biogas bi-product as compost fertilizer and as fish feed. Both of these are environment friendly and also a financial incentive to the medium earned rural inhabitants. Proposed waste to wealth approach nullifying the underground water contamination by soak pit leakages and preventing the open air bed smell producing digestion of water hyacinth. Rural Inhabitants could easily adopt the sustainable technology to form large scale of biogas uses not only for cooking purpose but also mitigates the existing rural electricity problem as well [20]. For the above environmental, social and economical positive effects of this proposed WM method or biogas plant – we could recommend this model for sustainable waste management in the context of rural Bangladesh.

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ISBN: 978-984-33-7045-7, PI.86 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Waste Transfer Station Operations in Karaitivu, Sri Lanka under the Cluster Waste Management Arrangements: Learning Experience in Developing Countries

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ABSTRACT

The European Union funded Environmental Remediation programme implemented by United Nation of for project Services tackled the waste management and disposal problems in the coastal strip of Ampara district, this is the highly populated and largely waste generated area in the district. Lack of land available for proper disposal facility and the distance to the identified land in Addalachenai area forced to form a cluster based waste management system. Accordingly, cluster waste transfer station and common landfill were constructed and managed. The waste management committee with service agreement allowed the Local Authorities to manage the facilities and tackle the issues and problems faced by them. The transfer station operations are done and the tipping fees calculated based on the weighted loads. The tipping fee is paid to the Addalachenai form the fees received in the transfer station for the landfill operations. The first waste transfer station in Sri Lanka and the second largest landfill at the moment managed by cluster model successfully. The waste analysis shows that the climatically influences directly affect the amount of waste generated and disposed.

INTRODUCTION

Solid waste management is one of the most serious local environmental problems in Sri Lanka in the recent days. It has become a big threat to public health, the beautiful natural environment and to the national economy. Local Authorities often face severe difficulties in the management of solid waste in an environmentally, socially and economically feasible manner. Municipal Solid Waste Management services in most developing countries are unsatisfactory and the most common problems associated with it in these countries are lack of 1) institutional capability with technical expertise; 2) financial resources; and 3) legal provisions and role designation (Visvanathan et el, 2004). Ampara district in the Eastern Sri Lanka, ravaged by prolonged ethnic war lasted for 30 years and rampaged by the Tsunami in December 26th, 2004, has been experiencing serious issues related to solid waste and environmental management.

The area of Addalachenai, Kalmunai, Karaitivu, Sammanthurai and Ninthavur is home to 31,020 families and approximately generating 56.4 tons of waste per day as of now. The five local authorities are located along the coastline of Ampara district and Table 1 indicated that the population and the population density are high in the first 4 local authorities. The wastes generated in the area were dumped in lagoons, canals and along the beaches, openly dumped and burnt in environmental sensitive areas, were common practices in almost all of the above-mentioned local authorities.

Table 1 Demographic Details

Local Authority	Population		Area (km^2)	Density	Waste generation (estimated in tons)	
	Urban	Rural			Urban	Rural
Kalmunai MC	89346	7678	59.90	1620	35.7	3.1
Sammanthurai PS	24,279	29,927	123.01	441	9.7	12.0
Ninthavur PS	13,415	12,237	36.30	707	5.4	4.9
Karaitivu PS	10,954	8,092	8.94	2130	4.4	3.2
Addalachenai PS	19,770	22,991	56.96	750	7.9	9.2

Thus, it had become a major strain on these local authorities to collect wastes from urban areas and dump it elsewhere within the local authority area. The practice can be summed-up as just mere removing of waste, or cleaning one part and making another area dirty. In 2007, the abovementioned local authorities were included in the implementation of the Environmental Remediation Programme (ERP), funded by the European Union and implemented by the United Nations Office for Project Services.

RATIONAL FOR CLUSTER FORMATION

During the feasibility phase of ERP, it was found that there was no suitable land for the construction of engineered landfill facility in the densely populated local authorities. Therefore ERP along with the participating local authorities decided to establish a cluster landfill which would be shared by the five local authorities. The Divisional Secretariat of Addalachenai and Addalachenai Local Authority were able to identify a suitable land in the purview of Addalachenai Pradeshiya Sabha, the area of which is substantial enough to accommodate the wastes coming from the five local authorities. However, the distance between densely populated area and the cluster landfill is around 26 kilometers. Transferring waste in the small collection tractors to 26 km is time consuming and expensive, so that a mechanism to transfer the waste cost effectively to the cluster landfill was inevitable, thus the cluster transfer station as a complementary facility came into being.

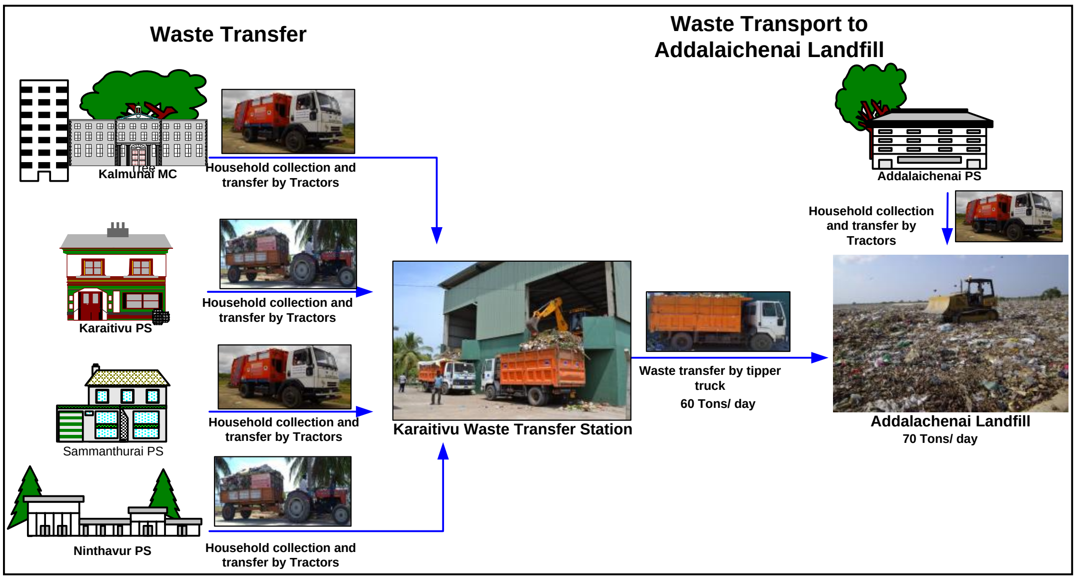

Figure 1 Process flow of wastes from local authorities to waste transfer station landfill

According to US EPA 2002 “Waste transfer stations play an important role in a community’s total waste management system, serving as the link between a community’s solid waste collection program and a final waste disposal facility. While facility ownership, sizes, and services offered vary significantly among transfer stations, they all serve the same basic purpose consolidating waste from multiple collection vehicles into larger, high-volume transfer vehicles for more economical shipment to distant disposal sites”. As Karaitivu Pradeshiya Sabha is in the mid-point the sharing local authorities,

it was decided to set up the waste transfer station in the KaraitivuPradeshiya Sabha area and a suitable land was identified for the construction of waste transfer station.
Based on figure 1, the participating local authorities are allowed to bring the waste and pay a fee per ton basis. The local authorities use their own vehicles for on-site collection and deliver waste to waste transfer station, where bigger transport vehicle will bring the wastes to cluster landfill. Addalachenai Pradeshiya Sabha manages the waste disposed as per guideline prescribed by the government and central Environmental Authority.

WASTE MANAGEMENT COMMITTEE

The cluster board of management was formed to ensure the sustainability of the cluster system. Negotiations among the local authorities were facilitated by Assistant Commissioner for Local Government (ACLG) through:

1. Service agreement between Karaitivu Pradeshiya Sabha and the 3 other local authorities, Kalmunai, Ninthavur and Sammanthurai for the operations and management of waste transfer station.
2. Service agreement between Karaitivu Pradeshiya Sabha and Addalachenai Pradeshiya Sabha for the operations and management of the Addalachenai landfill.

For the supervision and management of the two service contracts, it was agreed and decides upon by the participating local authorities and ACLG to organize a landfill and transfer station management committee to oversee the progress of implementation of operational activities of the local authorities for both facilities. The powers, duties and functions of the management committee were defined by the service agreements.

The management committee members are: Assistant Commissioner of Local Government as chairman; Commissioner of Kalmunai; Secretaries of Karaitivu, Addalachenai, Ninthavur and Sammanthurai Pradeshiya Sabhas; Regional Director of the Central Environment Authority and UNOPS-ERP representative. The management committee agreed to meet once a month to discuss issues pertaining to the cluster system and to exchange progress reports of the facilities, financial reports, and tipping fees and so on.

RESULTS AND DISCUSSIONS: WASTE TRANSFER STATION OPERATIONS

The trial waste transfer operations were done in October 2010 with the manual labour force to push the waste into the trucks. However, it was realized that the use of backhoe loader would be an advantage not only for pushing waste in to the trucks but also for better compaction using the bucket. Since December 2010 the normal waste transfer station operations started in Karaitivu and the waste is transferred to the cluster landfill. As and when the collection vehicle enters into the waste transfer station facility, the weight of the collection vehicle with load is recorded and the weight of the empty vehicle is measured. Then the waste manifesto is prepared and issued to the relevant collection vehicle and the copy is sent to Karaitivu LA and another copy is kept for reference. Monthly the total waste quantity is calculated and the tipping fee invoice is prepared for issuance. The tipping fee rate is LKR 675 per tonnage as decided by the cluster waste management committee. Initially the tipping was proposed based on the assumption of the operational expenses and maintenance costs. Latter, it was compared with the actual expenditures and reassured. The financial obligations and tipping fees matters were always discussed with the monthly cluster meeting held with the all-party presents.

The operation manual for the waste transfer station is prepared and required training for the head of solid waste management unit, supervisor and laymen were provided by Environmental Remediation Programme. In addition, continuous monitoring and facilitation is being continued to completely develop the capacities and operations skill. However, it is expected that end of June 2013 the waste transfer station operations will be self-managed by the committee and sustained as per the cluster agreements.

Initially the participation from Ninthavur and Sammanthurai was low as indicated in the Table 1. However, with time and involvement of the environmental monitoring teams, the waste collection and transfer to the Karaitivu went up and normal. It could be noted that during the rainy season the amount of solid waste received had gone up due to additional moisture. Richardson et al, 1974 had also stated the seasonal variation in waste quantities appears to be associated with variations in quantities of grass clippings, tree cuttings, and yard wastes during the springs and with leaves from trees in autumn. Also large reduction is collection can be observed during the peak dry periods.

It is noted that the Kalmunai Municipal council could not pay a big amount of tipping fee refer the Table 2. This is mainly due to the lack of financial revenue in the council. However, it is important to mention that the user fee collection for the solid waste management services from the communities though a bylaw is recently got though the legal procedure and will be in the Sri Lankan Government Gazette by end July 2012. Thereafter, most of the local authorities could collect the user fee and recover most of the solid waste management expenses.

Table 1 Waste Received by Transfer Station during the operations

Month	Kalmunai Municipal Council	Ninthavur Pradeshiya Sabha	Sammanthurai Pradeshiya Sabha	Karaitivu Pradeshiya Sabha	Total
Dec-10	507	17		251	775
Jan-11	556	7	-	217	780
Feb-11	688	54	22	203	967
Mar-11	917	112	236	233	1,498
Apr-11	743	137	172	212	1,263
May-11	978	214	273	234	1,698
Jun-11	986	181	274	228	1,670
Jul-11	901	160	308	223	1,592
Aug-11	880	188	207	212	1,489
Sep-11	887	128	233	216	1,465
Oct-11	817	183	156	203	1,360
Nov-11	946	266	153	241	1,606
Dec-11	1,034	205	366	274	1,879
Jan-12	953	290	320	267	1,829
Feb-12	960	245	284	231	1,720
Mar-12	871	246	310	206	1,633
Apr-12	836	200	293	207	1,536
May-12	917	201	247	235	1,599
Jun-12	745	152	204	197	1,299
Jul-12	811	186	326	216	1,540
Aug-12	843	164	317	232	1,557
AVG after Mar 2011	890	192	260	226	
MAX after Mar 2011	1,034	290	366	274	
Percentage (AVG)	57%	12%	17%	14%	

Table 2: Tipping Fee Flow at Karaitivu Waste Transfer Station

Tipping fee/Local Authority	Amount of Money in LKR			
	Kalmunai	Sammanthurai	Ninthavur	Karaitivu
Total Tipping Fee	10,871,668	2,739,228	2,151,570	2,895,590
Paid Tipping fee	6,613,153	2,235,539	1,579,504	2,895,590
Balance to be paid	4,258,515	503,688	572,066	-

Körner et al 2006 states that the ultimate purpose of landfill disposal is to stabilize the solid waste and to make it hygienic through proper disposal and use of natural metabolic processes. The cluster engineered landfill in Addalachenai for serving 5 local authorities were constructed though the Environmental Remediation Programme funded by European Union. The landfill consists of the operation area, leachate collection system and treatment system.

Full operations were also started since 2010 December by the Addalachenai local authority. The main source of the waste is coming from the waste transfer station and the Addalachenai Pradeshiya Sabha itself brings their waste to the landfill. Similar to the waste transfer station, the climatic influence can be observed form the Figure 2. During the dry period, the weight is low and raining period weight is much more.

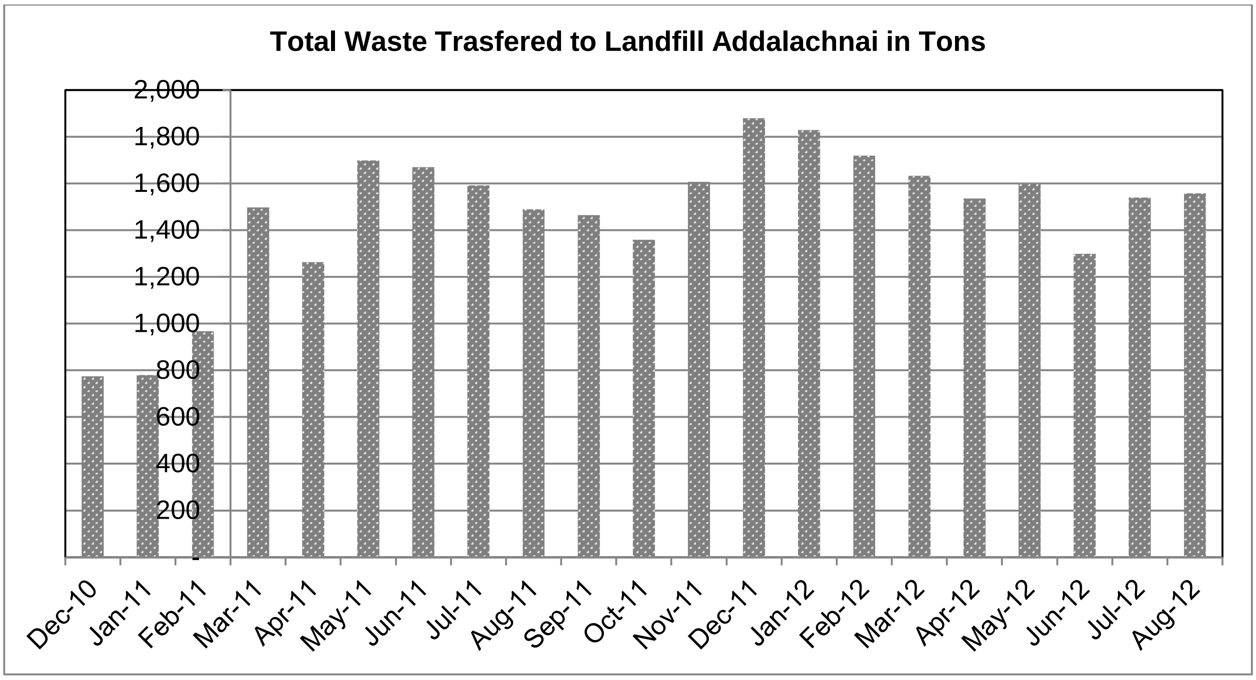

Figure 2 Waste Amount dipositetd in the Engineered Cluster landfill from 5 Local Authorities

It is important to point out that the landfill operations become normal and full scale operation after Mar 2011. Since then, the waste is maily received from waste trasfer staion and directly from the five local authoriies. The addalachnai Local Authority receive LKR 151 per ton of waste from each local authoritied based on the cluter landfill agrememnt signed. It is obvious that the major contributor to the landfill is the waste transfer station, Karativu as shown in the Table 3. Still some special wastes like slaghterhourse waste are directly disposed by other loacal authories. The landfill day to operation and maintances are covered by the tipping fee contribution from other locla authoriies and Addalachnai itself.

Table 3 Tipping Fee paid to Addalachenai Local Authority

Tipping fee/Local Authority	Amount of Money in LKR by WTS Karaitivu
Paid Tipping fee	4,207,338.07

CONCLUSIONS

The cluster approch for solid waste management facility is practiced for the first time in Sri Lanka. In addtion, it is believed that the first waste trasfer station and the second largest and operational landfill is reflected in this paper. The relavant techncial capacity and the infrastructures were provicded by the European Union funded Envioremtnal remediation programme. This cluters model is one of the best model operated in Sri Lanka and can be applied in most of the Sri Lanka local contect in the other districts.

The transfer station and shared landfill meant that all the participating Local Authorities had to work together to a common goal. In a post conflict region with significant tensions between communities, this seemed an ambitious task. The facilities require cooperation, as well as some level of trust in the partner Local Authorities, particularly as there are tipping fees involved. This meant that getting the management and decision making arrangements right was critical, as well as the systems to record data transparently. Once the systems were in place, any misgivings were able to be moved beyond, with the end goal that everyone would benefit from a cleaner environment and a solution to their waste management problems. The success of the programme has not only been a functional waste management system. In addition it has been an avenue for dialogue and cooperation between the LAs. Everyone produces rubbish - and this common problem has brought the LAs together through the facilitation of ERP and the ACLG/CLG offices. Focussing on this very practical problem has been a great pathway to forge new ways of working together in the post conflict period.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the European Union for generous financing this Enviornemtnal Remediation programme which was a part of the European Ampara Partnership in Ampara District.

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ISBN: 978-984-33-7045-7, PI.91 (1-8)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Life Cycle Assessment (LCA) of Municipal Solid Waste Management System in Kathmandu Metropolitan City

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ABSTRACT

As of little research on the waste management sector in Nepal, the decision support system is not well established. This has resulted in poor planning and execution of engineered facilities related to waste collection, treatment and disposal. In this study Life Cycle Assessment (LCA) is used to investigate the Waste Management System of Kathmandu Metropolitan City (KMC). The assessment was based on three scenarios: business as usual (BAU) which includes collection, transport and landfilling, the energy recovery with recycling and conjunctive disposal system comprising of composting and landfilling. LCA methodology was applied in order to determine the most environmentally friendly option. Municipal Solid Waste (MSW) management methods considered in the three scenarios included collection and transportation of MSW, Material Recovery Facility (MRF)/Transfer Station (TS), recycling, composting and landfilling. The life cycle inventory was prepared using Integrated Waste Management Model (IWM_1). Thereupon, the output of inventory was allocated to four impact components included: greenhouse gases, acidic gases, eutrophication and energy consumption. An ecological index was achieved from inventory values for each scenario. Results obtained are being further analyzed and recommendations are made to establish a sustainable MSW Management System.

Key words: *Life Cycle Assessment (LCA), Municipal Solid Waste Management (MSWM), Kathmandu Metropolitan City (KMC), Sustainable*

INTRODUCTION

Municipal Solid Waste (MSW) generation rates are increasing rapidly in Asian countries as a result of accelerated urban population growth, unplanned urbanization and increasing economic activities and resources consumption. And the solid waste management systems in many developing countries in Asia are not so satisfactory (Visvanathan et al., 2004). As a capital city of a developing country the rapidly urbanizing Kathmandu Metropolitan City (KMC) is facing the difficulties regarding the Municipal Solid Waste Management (MSWM).

KMC has a population growth rate almost 3.4 times the national rate, from 2001 to 2011, Nepal's national population grew by 1.4% per year while KMC's population increased at 4.76% year (CBS 2011) which creates an unprecedented stress on city's limited resources and infrastructure creating MSW management problems (Dangi et al., 2009). Researchers argue that a complex issue due to the changing life styles of people, under-estimated contributors and stakeholders (Jha et al., 2011). The solid waste management in KMC is facing the improper management. Since it's the responsibility of the city authority, the tendency of them is to seek the solution by attributing the SWM largely as an engineering function. The scenario in KMC is comparable with other least developed Asian Country Cities.

According to Census 2011, the population of KMC is over 1 million and the average unit generation of solid waste in KMC is 0.3 kg/person/day. The daily waste generation from the different sources was found as 480 ton/day at the end of 2011. The table 1 shows the data of the waste sources and corresponding quantities:

Table 1: Generation of Waste from different sources (KMC, 2011)

S.N.	Sources	Quantity (ton/day)
1.	Household Waste	330
2.	Commercial Waste	50
3.	Street Waste	50
4.	Waste from Nearest VDCs	50
	TOTAL	480

Among this organic waste comprises the 63.22% of the total waste; plastic comprises 10.8% of total waste while least is metal which comprises 0.42% of total municipal waste. The collection rate is 96% while 4% remain uncollected.

Table 2: Amount of waste collected from different site (KMC, 2011)

S.N.	Collection	Quantity (ton/day)
1.	Roadside Collection	358
2.	Door-to-Door Collection	43
3.	Container Collection	60
	TOTAL	461

The municipal solid waste generated also has several impacts on environment and has contribution to global climate change (Tabata et al., 2010). Regarding the rate of waste production and its composition, different alternatives might be used for waste management systems. The LCA can be used as an environmental assessing tools for comparing and analyzing of the environmental impacts of the solid waste management systems (Khorasani et al., 2012). Hence a number of studies in the literature used LCA as a comparative tool for different MSWM schemes (Al-Salem and Lettieri, 2009), (Khorasani et al., 2012), (Stypka, 2002), (Menikpura et al., 2012). The purpose of this study was to use LCA as a tool to compare the three different SWMS options and determine the most feasible and environmental friendly system for KMC. For this three different scenarios were developed and then compared with respect to their environmental impacts and fuel cost using the Integrated Waste Management (IWM-1) model (Stypka, 2002).

The figure 1 shows the composition of the municipal solid waste of KMC.

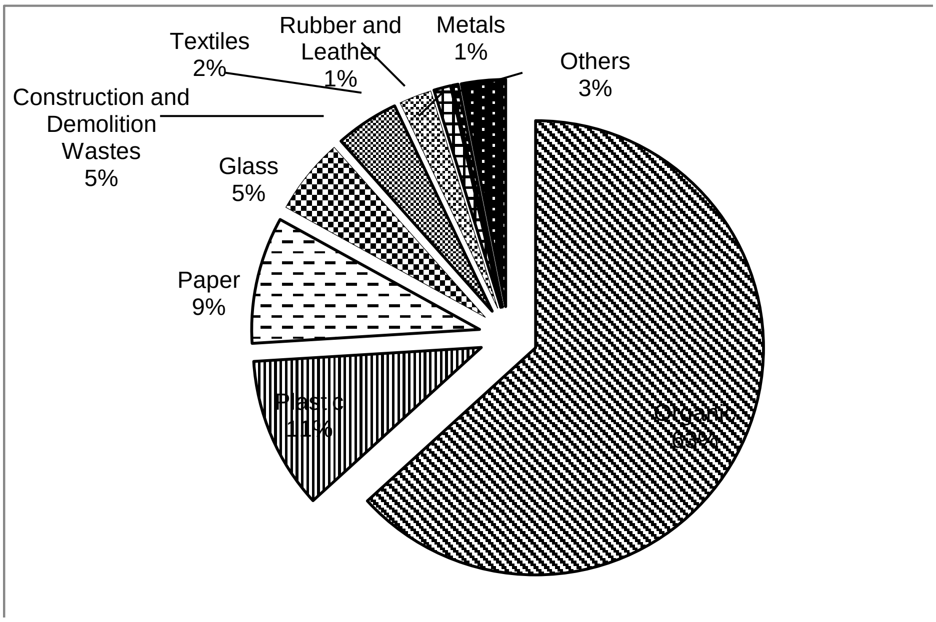


Figure 1: Composition of Municipal Solid Waste of KMC

RATIONALE

Life cycle assessment (LCA) is a useful tool to evaluate the performance of Municipal Solid Waste (MSW) management system. It expands the traditional focus on "cradle to grave" impacts of a product or service. The European Union regulation proposes a hierarchical system based on 4 subsequent levels: reduction of solid waste production, recovery of material, recovery of energy and landfill disposal. The application of LCA is not much, in practice in Nepal. Therefore, efforts were put together to provide a brief preview of the LCA concept which helps in identifying the best scenarios among the three provided. This study focuses on the Life cycle of Municipal Solid waste management system of KMC. It is believed that LCA helps the planners in government bodies to develop a holistic view and reflecting the incorporation of LCA in decision making processes and encompass various tools to avoid burden shifting between impact categories, products and dimensions.

OBJECTIVES

The major objective for this study is to make an LCA of MSW of KMC and to find sustainable alternatives for solid waste management (SWM). This study focused on comparison of the alternatives and scenarios of the Waste Management and assessment of consequences of different structures settled in the process of MSW management. The specific objectives of the study were:

- To assess the environmental impacts scenarios (water and air pollution, energy consumption and residual waste) related to a municipal solid waste management system by evaluating the overall waste production rate.

- To identify more sustainable waste management systems for Kathmandu Metropolis.

METHODOLOGY

Life Cycle Assessment (LCA)

According to ISO 14040 (1997), LCA consists of four phases performed in an iterative manner. These phases are: Goal and Scope definition, which serves to define the purpose and extent of the study to indicate the intended audience and to describe the system to be studied as well as options will be compared. Inventory analysis or the Life Cycle Inventory (LCI) focuses on the quantification of mass and energy fluxes. Life Cycle Impact Assessment or LCIA, which aims at the understanding and evaluating the magnitude and the significance of potential environment impacts of a system (Clift et al., 2000). Interpretation, evaluates the result from the previous phases in relation to the goal and scope in order to reach the conclusions and recommendation (Assamoi and Lawryshyn, 2011).

Scope and Goal Definition

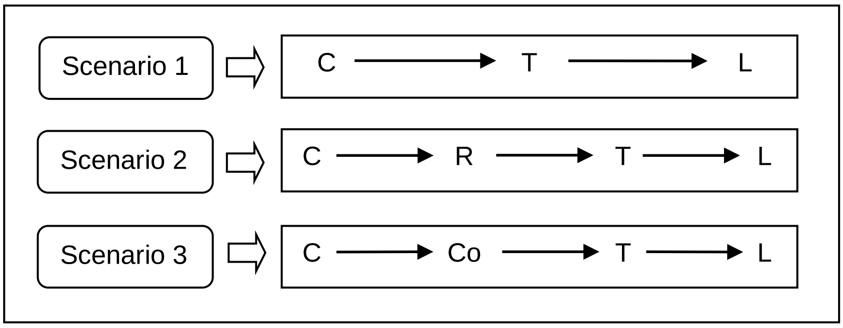
Three different scenarios of Municipal Solid Waste Management System (MSWMS) that include different MSW processing and/or disposal methods were developed, and then compared with respect to their environment burdens like Global warming potential (GWP), Acidification potential (AP), Eutrophication potential (EP) and total Fuel Energy Consumption. The scenarios were based on the current system of Municipal Solid Waste Management of Kathmandu Metropolitan City.

The Functional Unit and System Boundaries

The functional unit in this study has been defined as the total amount of waste generated in KMC in a year, i.e. Household, Commercial, Street and Nearest VDCs. The System boundaries selected for the LCA of waste was defined as the moment when material ceases to have value, evidently considered as waste.

The Scenarios

The three scenarios were considered for this study as illustrated in figure 2. The scenario 1 is Business as Usual (BAU) which includes collection, transport and landfilling, which is the current status of MSW of KMC. The scenario 2 is energy recovery with recycling where the recyclable waste are recovered and recycled. And remaining the wastes is landfilled. And the scenario 3 is conjunctive disposal system comprising of composting and landfilling.



Note: C: Collection, T: Transportation, L: Landfilling, R: Recycling, Co: Composting

Figure 2: Three scenarios of MSWM used in this study.

Life Cycle Inventory (LCI)

The data used in this study was collected from the sole institution that is responsible for the waste management in Kathmandu Metropolitan City i.e. The Environment Management Department and Solid Waste Management Section. The data were of last year i.e. 2011. The data used were population of KMC, waste characteristics, waste collection rate, composition by weight and operational data of landfill site of KMC. The data were fed to the model, including % landfill input, processing capacity, composting rate, recycling rate, diesel fuel consumption cost (NRs/ton consumed) and distance to landfill site (km).

Life Cycle Impact Assessment (LCIA)

In any LCIA result of life cycle inventory, the objective of the study is converted to the managerial forms which are to be achieved. Here to perform the LCIA, the methodology and the standardization used does not have the global acceptance because the necessary data does not exist. And the scientific methods for the long time assessment, has not presented (Khorasani et al., 2012). The approach of the “Lower is Better” has been used since 1990s and assumed that all values from one type of stress are gathered together without considering the place and time of stress and due to their characteristics that may cause harmful changes in environment (White et al., 1997).

Interpretation

This final stage of LCA includes the reviewing of all the stages of LCA. Comparative analysis was also carried out. The results were backed up with the proper justification and reasoning.

RESULT AND DISCUSSION

The scenario based on the data was gathered at the life cycle inventory stage. The table 3 shows the amount landfilled, the amount of waste generated per year, waste that can be used for composting and the amount of waste that can be recycled in each of the scenarios. The scenario 1 represents the Business as Usual where landfilling is the only option for disposal that exceeds the 168265 tons of waste annually. The waste that can be recycled in scenario 2 is 39930 tons per year. The organic waste that can be used for composting is 106360 tons. The organic waste is more than 60 % of the total municipal waste of KMC (see figure 1).

Table 3: Amount (Gg/year) landfilled, that can be recycled and that can be used for composting in each of the developed scenarios.

Scenario No.	Amount of MSW landfilled (Gg/yr)	Amount of Waste that can be recycled (Gg/yr)	Amount of Waste that can be used for composting (Gg/yr)
1	168.26	-	-
2	128.33	39.93	-
3	61.90	-	106.36

Quantification of the environmental impacts:

Global Warming Potential: The IPCC waste model showed that the CH_4 emissions from the open dumping are significant for the first 40 years after waste disposal. Based on the characteristics and conditions, IPCC default values for Sisdole Landfill site different factors the estimated total potential methane generation from 1 tonne of waste is 29 kg of CH_4 (UNFCC, 2008). And the conversion factor for kg CO_2 equivalent for 1 kg CH_4 is 21 (DEFRA, 2012).

Acidification Potential: According to Nielsen and Hauschild landfill model (Neilsen and Hauschild, 1998), it was estimated that 0.65 kg of H_2S is emitted from 1 tonne of waste. From this data overall acidification potential is 1.22 kg SO_2 equivalents per tonne waste.

Eutrophication Potential: Nitrogen is a major substance in waste and the key contributor for the eutrophication potential. The estimated eutrophication potential for one tonne of waste is 16.42 kg of NO_3^- equivalent (Menikpura et al., 2012).

Fuel Consumption for operation: According to the data provided by KMC, the total fuel cost including diesel and petrol for the collection, transportation and management of the waste for fiscal year 068/069 is approximately 745 thousand Nepali rupees annually. This means KMC spends NRs. 0.226/tonne of waste managed.

Table 4: Comparison of the Scenario results

Scenario No.	**GWP (Kg CO_2 eq. per waste managed in landfill per year)**	**AP (Kg SO_2 eq per waste managed in landfill per year)**	**EP (kg NO_3^- eq per waste managed in landfill per year)**	**EC (Total consumed operating fuel (NRs/ waste managed in landfill per year)**
1.	102.47E+06	20.52E+04	27.62E+05	74,5251
2.	78.15E+06	15.65E+04	21.01E+05	29,003
3.	37.69E+06	7.55E+04	10.16E+05	13,989

GWP: Global Warming Potential; AP: Acidification Potential; EP: Eutrophication Potential; EC: Energy Consumption for transportation and management of waste from transfer station to landfill.

Impact assessment, limitations and need for further research

The study was more focused on the amount of waste managed by landfilling rather than the waste recycled and waste composted. In this aspect the impact assessment of the waste recycled and waste composted with relevant to the environment impacts viz. GWP, AP, EP are to be carried out. In the scenario 1 i.e. BAU, the total amount of waste collected is total amount of waste landfilled. In scenario 2 and scenario 3, the waste that can be recycled and waste that can be used for composting respectively are excluded. The impacts on working environment of staff of KMC, casualties, noise, odour are excluded. Researchers have an opportunity for further research in these limitations.

Policy Implications

In Nepal, no LCA studies have been conducted to analyze systems as discussed in this research. The studies of this type must be conducted to establish a better understanding for the current MSW management system. LCA will aid on the establishment of the databases for the policy makers, influencing their decision and stakeholders concerning in environmental friendly way.

The policy implications of obtained results usually depend on the aim of the policy itself (Finnvedan et al., 2005). The results obtained here promote a need for the sustainable method of MSW management of KMC considering the conjunctive disposal system with composting and landfilling that reduces the all four environmental impacts excluding the inefficient collection system, low public participation, landfill location and operational improvements. Still scenario 3 can provide a better and more environment friendly waste management.

CONCLUSION

This study was carried out to determine the best suitable and sustainable municipal solid waste management system out of the three given scenarios developed for the KMC. This was executed by using the LCA as a tool to compare different options. To the best of the author's knowledge, no LCA study has been conducted on KMC in system aspect. The main findings are of the study done are described in following points:

- The current practice which is scenario 1 it has highest GWP which contributes to climate change and considered bad in terms of other environmental impacts too.
- The scenario 3 is best with regards to GWP, EP as well as EC.
- Scenario 2 was with medium environmental impacts unlike the higher scenario 1 and lower scenario 3.

In accordance with the results we had, scenario 3 was found to be the option with minimum environmental impacts (less GWP, AP, EP) and cheap in case of fuel consumption cost. As well the result is influenced more due to the higher composition of the organic waste that can be composted and the GWP can be controlled by it. The final results obtain from this study can be applied for the integrated solid waste management system (ISWMS) as an environmental tool.

ACKNOWLEDGEMENT

The contribution of Golden Gate International College (GGIC), supervisor Dr. Nawaraj Khaatiwada, Kathmandu Metropolitan City, Environment Management Department and Solid Waste Management Section is deeply appreciated.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.93 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Diagonostic Report on Swm in Nepal: Key Issues, Challenges and Way Forward

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ABSTRACT

Similar to other least developed countries, little effort has been put in carrying out research on the issues of solid waste management (SWM) in Nepal. The immediate reason behind this is the low priority given to the engineered facilities for solid waste collection, transportation and disposal activities. As of this, little is known about the actual state of the SWM in the urban areas in general and municipal areas in particular. The overall outcome that emerges from the sporadic studies/researches carried out is endowed with several uncertainities and grey areas which is of little help to ascertain the actual situation and develop a long term strategy. In these contexts, this study was envisioned to establish some of the urban SWM perspective for the municipalities through qualitative and quantitative surveys, interviews, and data collection from 58 existing municipalities in Nepal with 70 highly qualified and trained researchers. As analysis of these survey results indicated realistic explanations that in the past used to complicate and sometimes even challenge the widely held assumptions about the SWM at the national level. The findings of the study include information on the per capita waste generation, existing collection, transportation and disposal facilities, institutional arrangement and resources allocation for engineered facilities. Ultimately the key outcome of the study is a diagnostic report on SWM in Nepal with highlights on key issues, challenges and the way forward. It is anticipated that report will serve as key reference document on the sector in Nepal as well as the South Asian region. This paper provides an overview of the report highlighting key issues, challenges and prospects of SWM.

KEYWORDS: Solid waste, generation rates, Nepal, policy decisions, Municipalities

INTRODUCTION

Solid waste collection, transportation and disposal is one of the major challenges for municipalities in Nepal. The functional elements of an engineered Solid Waste Management (SWM) system include: reduction at origin, on site handling, storage and processing, collection, transfer and transport, processing and recovery, and final disposal. Migration to economically vibrant areas, haphazard urbanization, changing consumption patterns, and incremental ad-hoc approach in addressing the urban issues are the key reasons leading to the rise of SWM problems. Unmanaged disposal of hazardous waste, for example from hospitals and clinics, is adding additional challenges in managing the solid wastes. The immediate reason behind the bleak situation in the sector is the mismatch between the demand of services and supply of recourses in all aspects of SWM. Decisions are not based on empirical evidences and long term strategy and, therefore, peace meal approach predominates. As of this, little is known about the actual state of the SWM in the urban areas in general and municipal areas in particular. The overall outcome that emerges from the sporadic studies/researches carried out is endowed with several uncertainties and grey areas which is of a little help to ascertain the actual situation and develop a long term strategy. In these contexts, this study was envisioned to establish some of the urban SWM perspective for the municipalities through qualitative and quantitative surveys, interviews, and data collection from 58 existing municipalities in Nepal with 70 highly qualified and trained researchers.

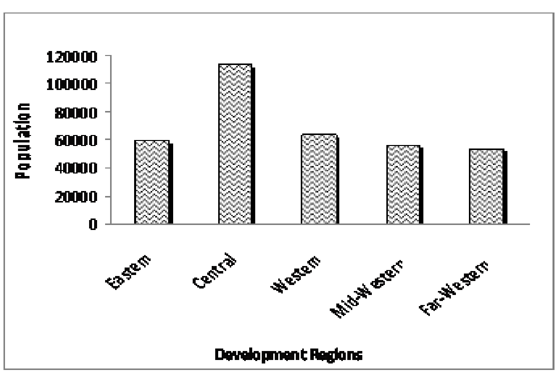
MATERIALS AND METHODS

The task started with the review of literature. The researchers were selected and the field plan was finalized. Survey questionnaires were developed considering the difference in the ecological regions and statistical compliance. Two days training was conducted for the researchers. Dummy spreadsheets were also prepared and field testing of the questionnaire and the software were also conducted. Field survey was carried out and the both primary and secondary data and information were collected. Sampling for the selection of respondents was done in four stages. In the first stage, 58 municipalities of Nepal were considered as strata using stratified sampling technique. The sample size for each stratum was determined by probability proportional to size (PPS) sampling technique (i.e. greater the stratum size; greater the sample size). Wards were then selected from the municipality by random sampling technique. From the selected wards, households were identified by Right-Hand-Rule technique. The criteria for the selection included mainly the socio-economic status such as income level, population density, and urban-rural settings. Thus, at the fourth stage a respondent was selected from the selected households for interview. Monitoring of the survey was also carried out. The field information was gathered and an analysis was carried out. The results obtained were compared and collated with the existing information. Finally, the Diagnostic Report was prepared and the outcomes were disseminated.

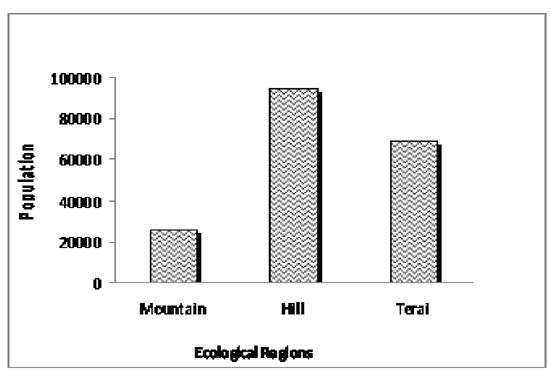
RESULTS AND DISCUSSION

Background information of the Municipalities

The municipalities cover about 2.25 % of the total area of the country. The geographical coverage of the smallest to the largest differ by a factor of 30 (Banepa – 6.07 km^2 ; Triyuga – 322 km^2). Significant number of municipalities cover a large fraction of the rural area dominated by the agricultural fields or forests. The highest built-up area was found to be 322 km^2 in Kathmandu. Municipalities like Kathmandu and Biratnagar have no rural wards whereas like Kamalamai, Khandbari, Dasarathchand and Damak have some rural wards. Some municipalities like Butwal, Lekhnath, Janakpur, Bhadrapur, Tansen and Pokhara have more than 75% of their wards located in urban areas. Fig. 1 shows the average population of the municipalities as per the development and ecological regions. It is obvious that the central region and the hilly areas have the highest figures due to location of capital city and the concentration of the municipalities in and the proximity of Kathmandu Valley. It is of interest to note here that the average municipal population in the country as of 2011 is 78000.



(a) Variation as per the development regions



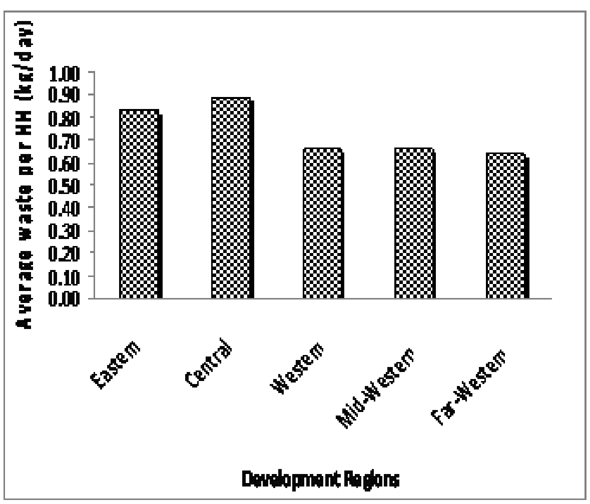
(b) Variation as per the ecological regions

Fig. 1 : Average population of the municipalities

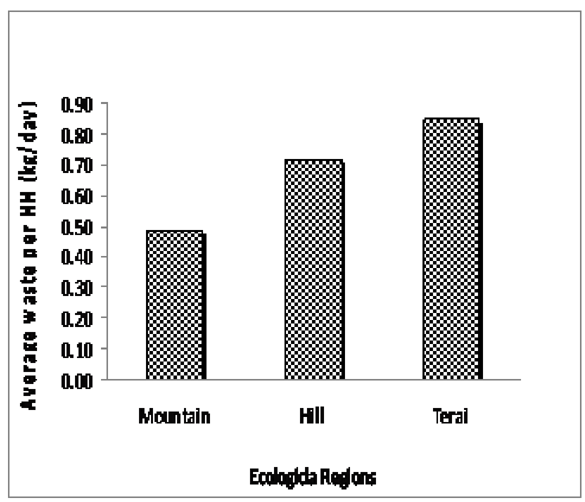
Waste generation and collection

The total sample size of 3233 households from 58 municipalities, varying from a minimum of 50 HHs to 220 HHs gave an average per capita waste generation figure of 0.16 kg per capita per day. Similarly, the average HH waste generation was found as 0.8 kg/day. Fig. 2 shows the variation of generation rates in different regions. Tchobanoglous et.al (1993) and Vesilind et al. (2002) showed that waste generation rates could vary depending on the season, months and day of the week. An observation made during the survey showed that Sunday mornings and the following morning of the festival and ritual days such as marriage ceremonies resulted with the largest generation of the wastes. However, Nippon and Yachiyo (2005) found little or no conventional season-specific impacts on household waste generation in Kathmandu Valley. Instead, they found 0.23 kg/capita/day with 250 kg/m^3 of bulk density among 40 households examined in April 2004 (the dry season) and 0.25 kg/capita/day with a bulk density of 174 kg/m^3 for 400 households studied in September 2004 (the wet season). Nippon Koei Co. Ltd. and Similarly, Khatiwada et al. (2009) conducted a survey in 15 municipalities and found an average per capita waste generation of 0.166 kg/day. They also reported average collection coverage as 42% which varied from as low as 16% (Gularia) to as high as 80% (Bharatpur). But, it is noted that geographical location with climatic variation varied the average household generation rate as shown as Fig. 2.

A study carried out in 2004 indicated that the total waste generation of 58 municipalities of Nepal was 1369 tons/day with the per capita waste generation of 0.25 kg/person/day. Further, the municipal authorities collected only 42% (average of 58 municipalities) of total solid waste generated in urban areas (IDI, 2004). This study showed that the total waste collected in 58 municipality was 1283 tons/day. With an assumption of linear growth, it can be concluded that the average annual growth of municipal waste collection is 15 %. The variation of the waste collection data as per the two types of regions under consideration is shown in Fig. 2. The least collection was recorded at Dhulikhel (1.89 tons/day) and the highest one was recorded at Kathmandu (467.8 tons). As it is obvious to note that the institutional share of the waste is highest in the Kathmandu Valley which is clearly reflected with the figures of central development region in Fig. 3 (a) and the hill Fig. 3 (b). The lowest share of commercial and institutional components was found in Gorkha (5.63 %) and the highest value was found in Kapilbastu (55.37 %). Such drastic variations on the two non-household components is due to the higher share of the rural areas where there is relatively less commercial and institutional facilities.

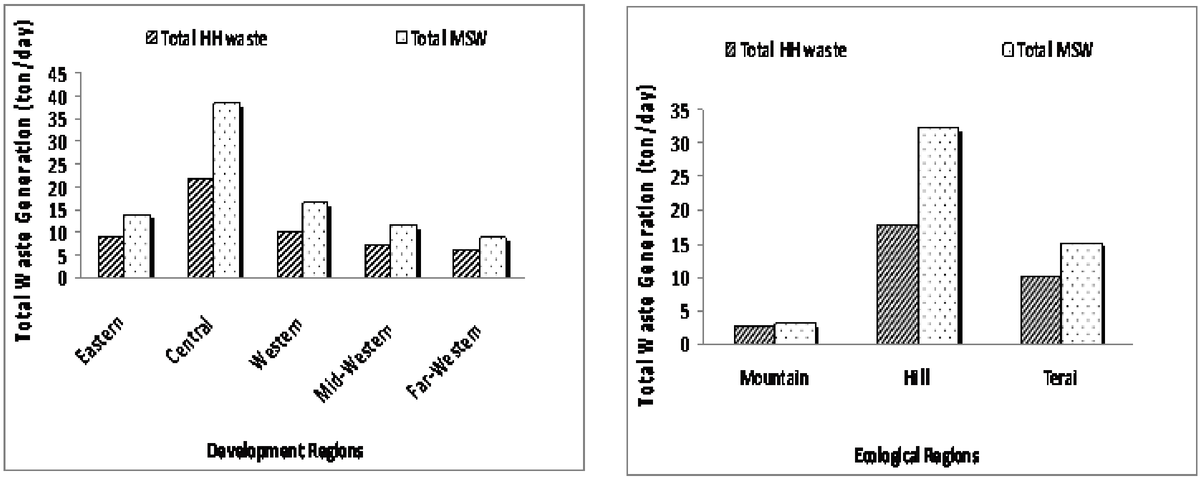


(a) Development Region wise



(b) Ecological Region wise

Fig. 2 : Average household waste generation



(a) Development Region wise data (b) Ecological region wise data
Fig. 3: Lumped data of waste collection in the municipalities

Waste characteristics

Physical analysis of the waste samples collected from the households during the survey was carried out to determine the composition of waste. The average values for different waste fraction in terms of percentage composition by wet weight were obtained. Average physical composition in the municipalities revealed seven categories which were: organic waste, plastics, paper and paper products, glass, metals and textiles (Fig. 4). The analysis of waste composition 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%. It is remarkable that some of the municipalities were found to reuse most of the kitchen waste generated for different purposes, e.g. feeding the pigs, pigeons and cattle thus resulting in lower waste generation rates.

Solid waste disposal

Effective and efficient solid waste management approach was almost absent in majority of the municipalities. Current waste disposal practices included dumping at either open places or poorly engineered disposal sites. Due to lack of human and financial resources, and political instability, it has been a challenging task to operate and maintain disposal sites at minimum sanitary standards.

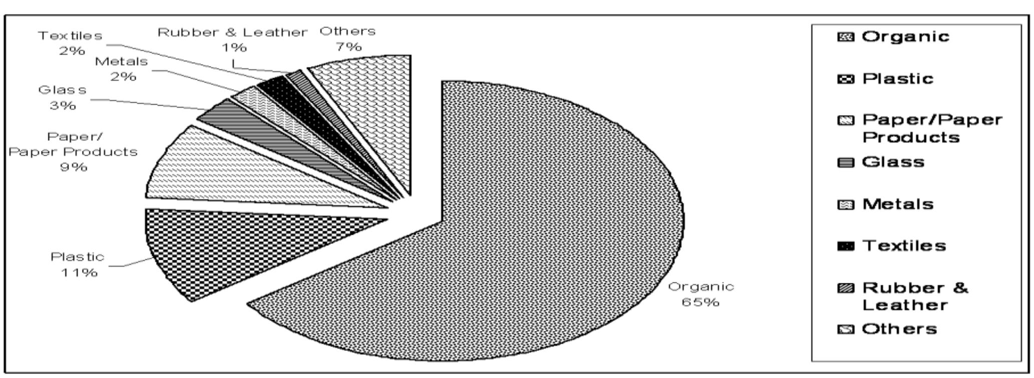


Fig. 4 : Waste Characteristics

ISBN: 978-984-33-7045-7, PI.93 (1-6)

Many municipalities are yet to find the sites for construction of treatment facilities and sanitary landfill sites and untreated waste at crude dumping sites causes health and environmental problems. Several municipalities do not even own land for the landfill sites to be constructed in future. There is an urgent need to identify and allocate suitable parcels of land for setting up treatment and disposal facilities. The disposal sites in most of the municipalities are mainly riverbanks, depressed land/dumps, open pit or temporary open piles as given in Fig. 5.

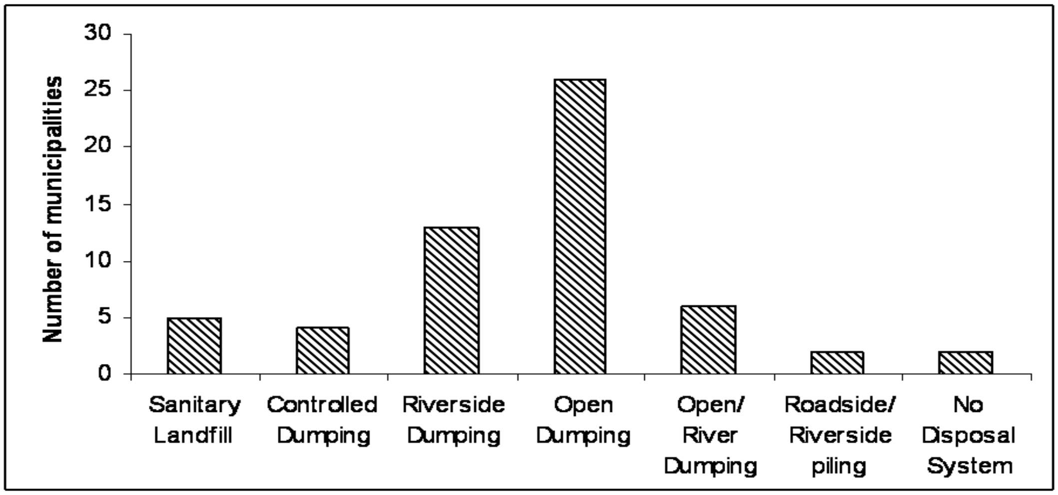


Fig. 5: Current waste disposal methods in the municipalities

Institutional aspects

Increasing responsibilities on solid waste management dictate substantial requirements of human and financial resources. However, the financial constraints and centralized bureaucratic allocation lead to inadequate and poor services. Additionally, due to technical and managerial inefficiencies, the available resources were found often utilized ineffectively. Smaller or relatively newer municipalities were found to not have the separate waste management units. In some cases, two or more units seem to have similar or overlapping responsibilities. For example, many small municipalities such as Khandbari had no solid waste management staff but a large city like Kathmandu had more than 1000 individuals. In addition, Kathmandu was also found to use the services of several private companies and NGOs in waste management. Because of the importance of waste management services for the general public and the unique nature of operating waste management systems, it is essential for all municipalities to have a separate unit to deal with SWM related issues.

Based on the analysis of data provided by municipalities, about 10% of the total municipal budget is spent in SWM. Of the total SWM budget, the municipalities spend nearly 60-70% towards street sweeping/city cleaning, 20-30% on transportation, which shows that more attention is required for door-to-door collection, treatment and safe disposal of solid waste.

Challenges and Future Prospects

As discussed in previous chapters, the municipalities of Nepal are facing many complications and difficulties to achieve their goal of solid waste management. In the recent years, the management problems are becoming complicated and their magnitudes have been increased by many folds. The haphazard disposal of solid waste in densely populated areas, environmentally sensitive areas, riverbanks and heritage sites has made the adverse impacts on the public health and the environment of surroundings which puts a negative externality in anticipated improvement on the quality of life of people. The problems are existed at both management and implementation levels. Most common and frequently cited problems of the solid waste management in the municipalities are listed in Box 1:

The municipalities hitherto do not have sufficient resources to solve the problems, hence municipalities need some assistance and support from the leading center. These helps include both in the forms of hardwares and softwares.

Conclusion and Recommendation

This study aimed at finding out the current status of solid waste management in 58 municipalities of Nepal. The total sample size of 3233 households from 58 municipalities, varying from minimum 50 HHs to 220 HHs gave an average per capita waste generation figure of 0.16 kg per capita per day. Similarly, the average HH waste generation was found as 0.8 kg/day. The total waste collection rate in the 58 municipality was found to be 1283 tons/day. The analysis of waste composition indicated that the highest waste fractions were organic matter followed by plastics, and paper. Effective and efficient solid waste management approach was almost absent in majority of the municipalities.

Box 1: Challenges of SWM in Nepal

- No provision for a separate section to look after Solid Waste Management
- Lack of equipment and technical manpower, capacity building activities
- Lack of empirical evidences and research based data and statistical records as well as the awareness and information and strategic planning
- Inadequate budget;
- Little or no public private participation; and
- Political intervention.

Current waste disposal practices included dumping at either open places or poorly engineered disposal sites. Due to the lack of human and financial resources, and political instability, it has been a challenging task to operate and maintain disposal sites at minimum sanitary standards. The municipalities hitherto do not have sufficient resources to solve the problems, hence municipalities need some assistance and support from the leading center. These helps include both in the forms of hardwares and softwares.

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Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

School Based Solid Waste Management and Recycling Programme in The Ampara District

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ABSTRACT

The Environmental Remediation Programme (ERP), aimed to address the solid waste management related issues in 12 Local Authorities in the Ampara District, is implemented by United Nations Office for Project Services (UNOPS) and funded by the European Union. There was no proper solid waste management system in place in the district until the implementation of ERP. The ERP addresses issues of all elements of well-structured solid waste management systems – waste reduction, segregation, storage of waste, collection, transportation, waste processing and recycling. As awareness creation is a very important at all levels for successful implementation of a new solid waste management system, ERP also conducts awareness creation activities at various levels and the school based waste management and recycling programme is also one of the awareness creation methods of ERP. The school based solid waste management and recycling programme designed educates students on waste reduction, segregation, processing and recycling.

INTRODUCTION

Ampara District is situated in the Eastern Province of Sri Lanka. The Eastern Province is one of the two provinces adversely affected by the three decades lasted war and the December 2004 tsunami devastation. The foresaid two unfortunate events hindered the development; and deter the public from access to services and information. One of the most serious environmental problems in the district is improper solid waste management and disposal. Lack of awareness and poor practices pose significant risk to public health and the environment. It also creates an increasing burden for the national economy. There was no proper waste management system in the area. Solid waste was dumped on either side of roads, at the sea beaches or in low lands; and burnt.

The European Union (EU) funded Environmental Remediation Programme (ERP) is working with twelve local authorities (LA) in the Ampara District to improve the solid waste management practices among the Local authorities and public. The ERP provided facilities, equipment, trained the LA staff on proper SWM and maintenance of facilities; and conducted awareness to the public on 3R concept and proper solid waste management practices. As a part of the awareness creation, ERP conducts school based solid waste management and recycling programmes in selected schools in the twelve local authorities. ERP believes that the awareness creation amongst the school students on SWM and recycling would bring a lasting change on SWM practices in the society in the long run.

ISBN: 978-984-33-7045-7, PI.98 (1-5)

Table 1: Local Authority Wise Population and Waste Generation Data

Local Authority	Population	Waste generation (tons)
ThirukkovilPradasiya Shaba	28,160	6.27
Ampara Urban Council	39,268	7.1
SammanthuraiPradasiya Shaba	54,206	9
Kalmunai Municipal Council	97,024	32.22
AlayadivembuPradasiya Shaba	22,289	3.76
PothuvilPradasiya Shaba	31,995	6
AddalaichenaiPradasiya Shaba	42,761	7.3
UhanaPradasiya Shaba	63,131	3.1
NinthavurPradasiya Shaba	25,652	4.9
DehiyathakandiyaPradasiya Shaba	40,435	9.7
AkkraipattuPradasiya Shaba	37,070	7.9
KaraithivuPradasiya Shaba	19,046	4

METHODOLOGY:

Community awareness is one of the important components of ERP. The awareness activities are conducted in various levels such as community level, village representatives' levels as "community awareness support group levels", local authority staff levels, District and provincial officials' levels and so on. These awareness programmes weredesigned to disseminate information on proper solid waste disposal, 3R concept and source segregation. All these awareness activities were conducted to bring change in people's behaviour on solid waste generation and disposal. Approximately 20% of the waste component in the Ampara District is recyclable waste. Most of these recyclables are thrown away with the waste stream and disposed in the landfills/ dumpsites. A small amount of valuable recyclables like metals and hard plastic (HDP) are collected by the informal recyclable buyers and less valuable recyclables like PET bottles, glass, cardboard, paper and used book are not bought by the recyclable buyers.

ERP decided to create awareness among the school children on segregation and recycling. As the first step of the school recycling programme, the concept of school recycling programme was explained the Director of Education of a particular education zone to get his approval to proceed further. With the permission of the director of education a meeting was arranged for principals and the officials of the Education Office to explain the concept the school recycling and get their approval to implement this in selected schools in the zone. The concept was presented and requested principals who are interested to implement this in his/her school. When the schools are selected, a date and time would be fixed to conduct awareness meeting to teachers, prefects and monitors on the school based recycling programme. In this meeting a PowerPoint presentation is shown with pictures and figures to explain damage caused to the public health and environment by improper waste disposal and importance of source recovery and recycling, what are recyclable waste and the present value per kilogramme of different kinds of recyclables.

Figure 1 Awareness on School based recycling at Al-Marjan Girls' College in Sammanthurai in the Ampara District, Sri Lanka

Figure 2Training teachers on School based solid waste management and recycling

Also, in the same presentation the process of the recyclable collection in the school and sale of recyclable to the recyclable buyer, record maintenance and payment to the students are explained. Following the awareness raising on recycling a flyer on school recycling was issued to every student in the school; and the students were instructed to take this flyers home and explain their parents and neighbors on recycling and recyclable materials; and ask the parents and neighbours not to throw recyclables with waste and to store them at home so that the students could sell them at the school recycling fairs. This school based school recycling awareness programme helps to educate not only the students but also the parents and neighbours on recyclables and recycling.The flyers carry information on the importance of recycling, pricelist of various recyclables and the first day of the recycling fair.The information on market price of recyclables obtained from the recycler every month and the price list I sup dated.

Table 1: List of Materials and Prices

Recyclable materials	Buying price per kilogramme
Paper:	
Cardboard	5
News paper	15
Cartons	5
Mixed paper / used books	5
PET (water/ Soft drink bottles)	15
Iron	40
Copper	250
Plastic chairs/ containers	40
Tin Cans	15
Aluminum	100
Bottles	Varies as per size/type

There are two approaches followed in the School based recycling. One is that on the day of the recycling fair, students bring their waste and directly sell them to the recycler; the transaction is recorded in a School recycling ledger book – for school's reference and also the amount is entered in the individual recycling point card – for students' reference. These recording and record maintaining tasks are done by schools environment club. Relevant training on record keeping and maintenance of record is given to the School environment club. The second option is, a room in the school would be converted as a recycling bank with shelves, space to store recyclables and a scale to weigh the recyclables. Once a week at a particular time recyclable purchasing would be done at the recycling bank. The members of the environment club would be responsible for buying of recyclables at this recycling bank. School students are informed about this activity and t is reminded to them in the assembly. Similar to the approach one, the done or deposited in the students' bank accounts when the amount of their transaction comes equal or more than thousand rupees.

CAPACITY BUILDING AND TRAINING:

In order to do recycling, everyone who wants to involve in recycling needs knowledge on various materials that could be recycled and recyclables that has demand in the local recycling market. Therefore initially ERP trained five teachers from the target schools on schools waste management that includes waste composition study and wastecharacterization. The SBWM training has three phases.The aim is to train school teachers is that it is not possible train all the students in a school. The training for the teachers is a kind of a TOT training. These teachers are expected to create awareness on recycling and recyclable materials to the rest of the teachers and students. The principal of the school will decide a suitable methodology to the awareness programme within the school.

The second phase of the training isschool based waste characterization which is done in the school for one week with the guidance of the trained teachers and the weight of all different waste components is recorded daily. At the end of the week, weight of each waste component generated within the school in the particular week is recorded and the monthly waste generation of each waste component is calculated.

The third phase of the training is done for the same group of teachers. In the third phase of the training, the waste characterization data of each school is analyzed and different options would be given for waste reduction, reuse (composting) and recycling based of the volume of waste generation.

The environmental club students also trained on record maintenance and the clerical duties that they are to perform during recycling fairs/ recycling banks.

School based composting training is also conducted in selected school that opted to go for composting of compostable waste generated within the school.

RESULTS AND DISCUSSION:

The school based recycling programme was inaugurated at Ak/Ayesha Balika School in September 2010 by the European Union Funded Environmental Remediation Programme. The school based recycling programme was implemented as a pilot project at the Ayesha School. The programme was later extended to other schools with the lesson learnt from the pilot project. Now there are 25 schools in the Ampata district with functional recycling programmes.

In SammanthuraiDharusalamMahavidyalaya School, the recycling programme was started in 2012. The principal decided to have one recycling fair per quarter in this school. The principal said that it is not possible to have recycling fairs every month as the school is closed three times a year for holidays and the co- curricular and extracurricular activities are also need to be conducted in the school, so he decided to have once a quarter recycling fair in the school. The first recycling fair was conducted on March 3rd 2012; and around 600 kg of recyclables sold to the recyclable buyer. The second recycling fair was conducted in July 2012; and around 450 kg recyclables were transacted.

The effectiveness of the school recycling programme depends in the interest of the principals. Some school principals wanted this project to their schools but due to their work load or some other reasons they did not pay much attention to the school recycling programme; and at these schools the recycling programme was not very successful. When we approached some other principals to discuss about the school recycling programme, they said that this is an extra burden for them. Therefore the School recycling programme would be successful only if the school principal is concerned about the environment, interested and motivated to have the project at his/her school.

CONCLUSION

The school based solid waste management/recycling programme is introduced first time in the Ampara District by the Environmental Remediation Programme – funded by the European Union. At present this programme is implemented in a limited number of schools; and in the future this model could be replicated in the rest of the schools in the district and schools in other districts in Sri Lanka. This programme is one of the best ways to inculcate proper solid waste management and recycling behavior in the minds of the students; and through the students, the message of segregation of waste, proper solid waste disposal and recycling would reach the community. Also today’s students are members of tomorrow’s community; therefore when students inculcate the practice of segregation and recycling at school, it will be reflected in the future community when the students became grown member of the society.

ISBN: 978-984-33-7045-7, PI.98 (1-5)

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the European Union for generous financing this Enviornemtnal Remediation programme which was a part of the European Ampara Partnership in Ampara District.

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Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Electronic Waste (E- Waste) Management in Bangladesh

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ABSTRACT

Rapid population growth with rapid discarded product due to the increased access of modern technology with increased purchasing power resulted the generation of electronic waste (e-waste). Today e-waste industry is emerging as one of the largest and fastest growing industries all over the world. A sustainable and safe use of e-waste along with its appropriate recycling process can be an important economical driving tool for any country. However, lacking of awareness and irregular management of the same may degrade the surrounding environment and turn out to be unsustainable. In this paper, the present scenario, dumping and recycling practices and policies regarding e-waste management system of Bangladesh have been focused. At present, the electronic market comes to this developing country as a threat rather than the productive means. The illegal and unsafe disposals of discarded items turn more than 30 million of workers of the country including children and women exposed to the heavy metals and hazardous chemicals. As an integral part of the study, the e-waste management systems of different countries of the world those are already acknowledged for managing e-waste since a decade have been emphasised and compared using secondary data sources. Intensive information on e-waste generated by ship breaking industry has also been pointed out. The research has been conducted in anticipation of generating more awareness about one of the growing segment of nation's waste stream and concluded with the recommendations for way forward.

Keywords: e-waste management; dumping practice; recycling process; policies; ship breaking industry;

INTRODUCTION

In today's world, the largest and fastest growing manufacturing industry is 'Electronic industry'. Rapid population growth with rapid discarded product due to the increasing access of modern technology resulted the generation of diverse and complex electronic waste or e-waste (UNEP 2006). E-waste associated with its recycling processes can cause a significant environmental and health hazards. However, in Bangladesh there is a lack of awareness of this burning issue among the Government, NGOs and also in the public sectors. The emerging electronic market of Bangladesh follows the informal and unsafe trend for reusing the waste or breaking them down for parts or throwing them away. This practice eventually turns to a threat for the country's overall human health and surrounding environment. The aim of the research is to focus the present scenario, practices and policies regarding e-waste system of a developing country like Bangladesh along with the recommendations for way forward.

BACKGROUND OF E-WASTE

E-waste, which is the subset of Waste Electrical and Electronic Equipment (WEEE), describes the old, end-of-life disposed electronic appliances such as computers, laptops, entertainment devices, TVs, refrigerators and freezers, mobile phones etc. (WEEE, EU 2002). Most of the current literatures regarding e-waste highlighted three main themes; such as to examine or justify the social and

ISBN: 978-984-33-7045-7, PI.100 (1-6)

environmental perspective (Greenpeace 2007; Smith *et al*. 2006; Toxic Link India 2007) or to focus on the environmental toxicology and health hazards (Wang *et al*. 2011; Muenhor*et al*. 2010; Herat 2008) or to emphasis on the management of e-waste (Kahhat*et al*. 2008a, 2008b; Williams *et al*. 2002). However, in all three approaches, the formation of toxic hazardous waste from effluent is considered as the common outcome of electronic production- consumption-disposal chain (Billah and Lepawsky 2011). More than 1,000 hazardous and non-hazardous components like ferrous material (38%), non-ferrous material (28%), plastic (19%), glass (4%) and others (including wood, rubber, ceramic) (11%) contain in the electric and electronic waste (Wath*et al*. 2010). Some heavy metals like lead, mercury, cadmium, chromium (VI), halogenated constituents (e.g., CFCs), polychlorinated biphenyls, brominated flame retardants (BFRs) can also be found as a substance in those compounds. All these may react as catalyst for the formation of dioxins (DEFRA2004) and in turn act as a harmful ingredient for both environment and human health (Wath*et al*. 2010). The lack of available information regarding the handling of the expired electronics appliances and improper monitoring system relating to dumping does not raise the human health issue only. It can also contaminate the agricultural soil contents with the reduction of annual crop production or can deteriorate the surface and subsurface waterways.The environmental and health impacts with respect to individual toxic ingredients contained in the e-waste product are shown at a glance in thetable.1;

Table.1: Effects of E-waste constituent on health and environment

<table>
<tr><th>E-waste containing products</th><th>Heavy metals & Toxic substance released from e-waste</th><th>Health impacts</th><th>Environmental impacts</th></tr>
<tr><td rowspan="8">Televisions and computer monitors,

Computers and computer peripherals (e.g. Monitors and key boards),

Audio and stereo equipment

VCRs and DVD players,

CFL bulbs,

Video cameras,

Telephone, cellular phones and other wirelessdevices,

Fax and copy machines,

Video game consoles,

Medical and dental equipment etc.</td><td>Lead (PB)</td><td>Damage to central and peripheral nervous systems, blood systems and kidney damage.
Affects brain development of children</td><td rowspan="8">Air pollution,

Water pollution,

Land pollution,

Life threat for wildlife</td></tr>
<tr><td>Cadmium (CD)</td><td>Toxic irreversible effects on human health.
Accumulates in kidney and liver.
Causes neural damage.
Teratogen.</td></tr>
<tr><td>Mercury (Hg)</td><td>Chronic damage to the brain.
Respiratory and skin disorders due to Bio accumulation in fishes.</td></tr>
<tr><td>Chromium (Cr) VI</td><td>Asthmatic bronchitis.
DNA(Deoxy ribonucleic acid) damage</td></tr>
<tr><td>Plastics including PVC(poly vinyl chloride)</td><td>Burning produces dioxin. It causes Reproductive and developmental problems;
Immune system damage;
Interfere with regulatory hormones.</td></tr>
<tr><td>Brominated flame retardants</td><td>Disrupts endocrine system functions</td></tr>
<tr><td>Barium (Ba)</td><td>Short term exposure causes:
Muscle weakness;
Damage to heart, liver and spleen.</td></tr>
<tr><td>Beryllium (Be)</td><td>Carcinogenic (lung cancer)
Inhalation of fumes and dust. Causes chronic beryllium disease or beryllicosis.
Skin diseases such as warts.</td></tr>
</table>

Source: Adopted from (Ghouse*et al*. 2011)

PRESENT SCENARIO OF BANGLADESH

Due to the exponential growth of digital and information technology, the development of new electronic appliances is emerging and becoming not only cheaper, fancier or users' friendly but also getting obsolete so fast. The consumers prefer to buy the new devices rather than repairing the older ones. However, sustainable and safe use of electronic technology can be the economical driving tool for any country. This scenario is identical in all over the world including Bangladesh.

In a developing country like Bangladesh, the e-waste system plays a vital role in the overall economic condition by providing material and labour inputs in a number of formal and informal, legal and illegal sectors (Kulke and Staffeld 2009). At present, around 200,000 urban poor people of the capital of Bangladesh are directly involved in this recovery economy (Billah and Lepawsky 2011) which is about 2% of the city's total population (BBS 2001). But unfortunately, the emerging electronic market comes to this developing country as a threat rather than the productive means. The illegal and unsafe disposals of discarded items turn more than 30 million of workers of the country including children and women exposed to the heavy metals and hazardous chemicals (Afroz*et al*. 2009).Currently, there is no formal recycling sector and sustainable waste management framework in Bangladesh. So, no strict guidelines or rules are there to regulate this popular practice of reusing, recycling and dismantling the e-equipment (Afroz*et al*. 2009).

A study report was published by Environment and Social Development Organization (ESDO) in 2010, based on a survey during September 2009 to June 2010 in Dhaka, capital of Bangladesh to examine the trend of usage of electronic equipment at the end of its life. The study identified the current dumping practice of e-waste in Bangladesh and highlighted the hazard created from its generation at the period of 1971 to 2010. It revealed that roughly around 2.8 million metric tons of generated e-waste is dumped every year in Bangladesh without considering its harmful effects. Again, according to Bangladesh Electrical Merchandise Manufactures Association (BEMMA), each year around 20% to 30% of 3.2 million tonnes of total consumption of e-waste is recycled and the rest of them are released in to the open landfills, farming lands, water bodies and open spaces which eventually contaminate the environment.Ironically, the whereabouts of a large portion of generated e-waste of the country is still remained unknown.Each year more than 15% of child workers die because of the effect of e-waste recycling; whereas more than 83% of the workers are exposed to its harmful health effects (ESDO 2010).According to the report the e-waste generation per year from number of sources can be summarised as showed in table.2;

Table.2: Generated E-Waste from individual sectors per year in Bangladesh

Sector	Generated e-waste in million metric ton/ yr.	Generated e-waste
Ship Breaking Yards	2.5	250000 metric ton/yr
Television Sets	0.17	26000 metric ton/ yr
Computers	0.035	35000 metric ton/ 10 yrs
Mobile Phones	0.005	10504 metric ton/ 21 yrs
CFL Bulbs	0.0005	566.90 metric ton/ 6 yrs
Mercury Bulbs	0.001	1861.32 metric ton/ 10 yrs
Thermometers	0.009	8513.59 metric ton/ 10 yrs
Other Medical &Dental Waste	0.09	93478.25 metric ton/ 10 yrs
Total	2.81	

Source: Adopted from (ESDO 2010)

Hence, the ship breaking industry is playing a dominant role in the country's overall e-waste stream. Among 50,000 child workers who involved in the e-waste collection and recycling systems of the country (Afroz*et al*. 2009), 40% are currently employed in the ship breaking industry.
Another survey had been conducted in October-November 2009, about the current practices of 'Green IT' with special focus on disposal and recycling of mobile phones and batteries by businessmen and individuals in Bangladesh revealed that,in the last 21 years, cell-phone alone has generated 10,504

metric tons of toxic e-waste. Whereas, around 296,302 TV sets are discarded each year which approximately generate e-waste of 170,000 metric tons (Ansari*et al*. 2010).

But it is a paradox where exactly the e-waste story begins and ends (Cook *et al*. 2006). A recent research was performed about the e-waste of Bangladesh in 2010 by Lepawsky and Mather, to identify their edges and boundaries; but the study couldn't trace the significant end waste as residue. Almost every electronic material with its components was found to be bought and sold, assembled, disassembled and reassembled (Lepawsky and Mather 2011). The discarded constituent materials- plastics, glass and metals were also collected, sorted, melted, reused and sold repeatedly by changing hands either domestically or exported to China, India and others. More than 83% of plastic waste generated per day in Dhaka had been found to be recycled, recovered and reprocessed into new plastic products (Kulke and Staffeld 2009). At least 2,500 plastic recycling enterprises has been traced in a small certain area of Lalbagh in Dhaka (Billah and Lepawsky 2011). The expectation of the researchers was to see the piles of waste at the dumpsite to the end; conversely the waste had been found at the production sites. To validate the claim, the authors did fieldwork in another connected country Canada considering the fact that Bangladesh is a recipient of e-waste of Canada (Gregson*et al*. 2010). But the result was similar for both the country that e-waste travels variety of sites along with the multiple recycling and transformation processes. Hence, there is no way to conclude an arbitrary decision of generation and termination phase of e-waste (Lepawsky and Mather 2011). The e-waste imported to Bangladesh from other countries is presented graphically in fig 1;

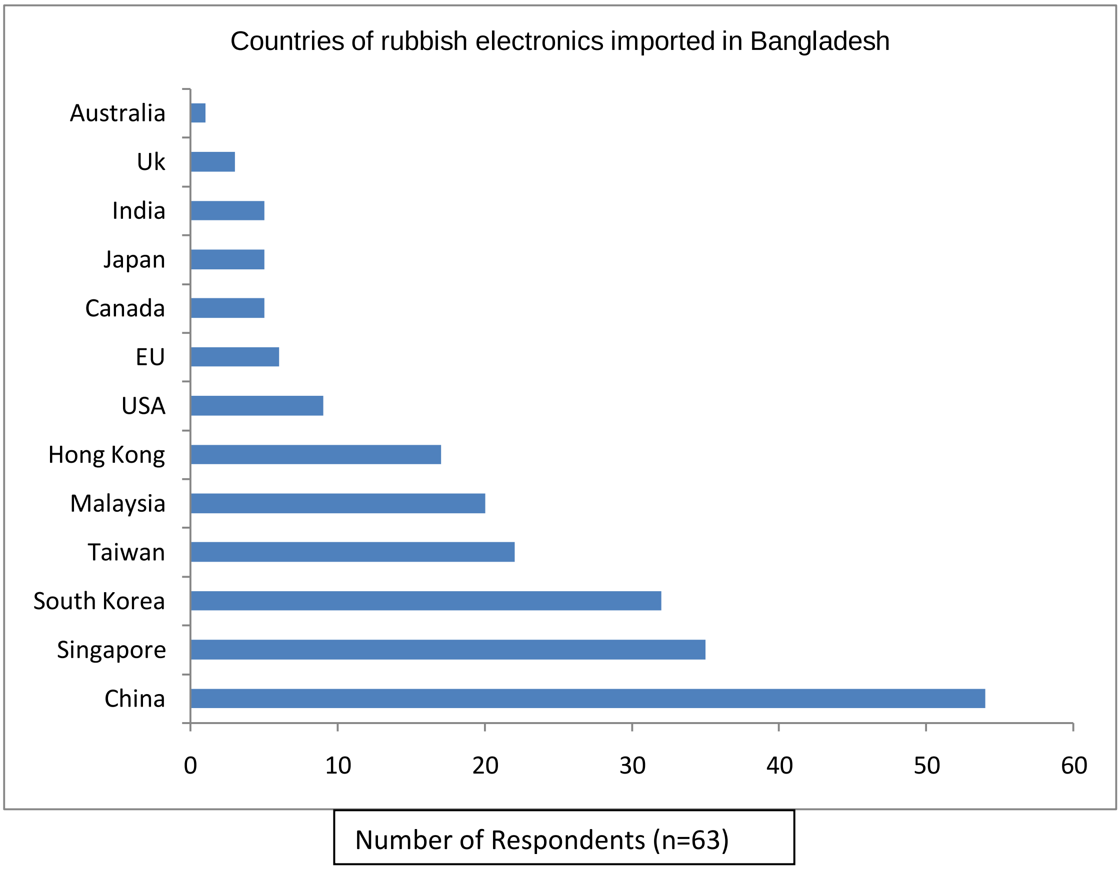

Figure.1: Origin countries of waste electronics imported into Bangladesh

Source: Adopted from (Billah and Lepawsky 2011)

There may be possibilities of any particular respondent to import from multiple source countries. Hence the sum of number of imports exceeds the number of respondents (n=63). The important finding from the graph is that the majority of e-waste imported to Bangladesh is mostly from elsewhere in Asia (Lepawsky and McNabb 2010).

In addition, another finding came from a recent related study that the revenue increases from the first importers to wholesalers and wholesalers to dismantlers (Gregson*et al*. 2010). The profit margin of importers of e-waste is 100 percent or more, whereas the profit of dismantlers often exceed more than 200 percents(Billah and Lepawsky 2011). So, in Bangladesh, e-waste is not only a concern about toxic dumping of discarded materials, but it is also an issue for trading, creating and capturing value in an informal way (Lepawky and McNabb 2010).

POLICY REGIME

The National Environment Policy had adopted in 1992 in Bangladesh where the activities regarding the pollution and destroying the environment was highlighted (Hasan 1998). No specific ordinances for e-waste recycling and management were considered there. Though the Environment Conservation Act of 1995, the Environmental Conservation Rules of 1997 and the Environmental Court Act of 2000 suggested considering all the issues to control, prevent and mitigate pollution for conservation and enhancement of the quality of environment (Sufian and Bala2007). In 2008, the Medical Waste Management Rules emphasised the e-waste management issues of Bangladesh significantly for the first time. Then in November 2009, e-waste issue was also addressed in the draft national 3R (Reduce Reuse and Recycle) strategy.

The high court of Bangladesh noticed the e-waste issue in March, 2009 and handed down the ruling especially to the ship breaking industry, major e-waste generator of the country. The direction of the court was to shut down the operation of ship-breaking yards operating without environmental clearance and to restrict the entrance of ships with hazardous waste without being pre cleaned at source or outside the territory of the country. But unfortunately, no ministries had been observed liaising to ensure conformity to these environmental laws by the court (Ansari *et al*. 2010). And so far, there have been no effective steps made to reduce the e-waste generation or to standardize and regulate the safe recycling, dumping and disposal (ESDO 2010).

CONCLUSION AND RECOMMENDATION

It is difficult to quantify the flow of e-waste locally and globally because of its diversities and chemical complexities. So lacking of awareness and irregular management of this emerging segment of nation's waste stream may cause pollution and degrade the environment. To implement a sustainable solution to the problem the policy makers, users, sellers, producers, importers, exporters along with the stakeholders should go for a common understanding to prepare a comprehensive legislation for hazard free management of e-waste. A system should be developed to handle the issue in such an approach to minimize the adverse environmental and social impacts with the maximization of favourable impacts. From several survey reports, it is evident that the problem regarding e-waste system along with their recycling process cannot be solved in a singledistinct way. However, the optimal solution could be defined depending on the economic perspective including the vital informal and illegal sectors, social and cultural context, the existing operating and regulating framework and the potentials and restrictions of law executions. More quantitative analysis should be revealed in the e-waste recycling sectors to turn it sustainable through fine modelling and tuning. There is also a vibrant need for multi-disciplinary research from diverse field and compare and evaluate the result with different countries like Switzerland which have been already acknowledged for managing e-waste since a decade.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.101 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Study on Waste Generation and Characterization of Three Different Areas in Khulna City

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ABSTRACT

In the rapidly growing cities of developing countries like Bangladesh, urban solid waste management is recently been regarded as one of the most immediate and serious issues for city authorities. The present scenario of house-hold solid waste generation and collection system in three different areas of Khulna city– namely Daulatpur, KUET campus and Fulbarigate is highlighted comparing generation and collection system. The success of solid waste management depends on the real estimation of waste generation. Therefore, the specific objectives of this study are to observed generation, collection and disposal practices of solid waste in the selected areas. The problems of the existing system were identified. Samples from twenty one spots of three selected areas were collected for seven days for two seasons. Samples were collected by going house to house and weight was taken by balance. Then samples were segregated by hand using spoon, hand gloves and masks to avoid health risk. Solid waste generation rate varies from season to season due to availability of daily food vary from season to season. Waste composition is also influenced by external factors, such as geographical location, the population's standard of living, energy source, weather and season of the year. This study represented the outlines of a demonstration project at KUET campus, Fulbarigate and Daulatpur actual situation of solid waste generation and collection system. Food and vegetable waste can be composted to recover waste materials in the form of compost utilization in agriculture.

KEYWORDS: Municipal Solid Waste, Generation Rate, Composition, Collection.

INTRODUCTION

Management of solid wastes continues to remain one of the most neglected areas of urban development in Bangladesh. City authorities spend a large amount of budget on solid wastes management. But, the present level of service in many urban areas is so low that there is a threat to the public health in particular and the environmental quality in general. Several steps are being taken towards improving the situation. An overview of various aspects of the municipal solid waste is provided all domestic wastes in the urban and sub-urban areas of the above areas with emphasis on the generation and composition of house-hold solid waste, collection systems practiced.

OBJECTIVES

The major objectives of this study are outlined as below:

- To field investigate of solid waste management system at KUET campus, Fulbarigate and Daulatpur areas.
- To collect present information on generation by performing a systematic survey in the selected points.
- To find out waste generation rate and characterization of solid waste composition.
- To develop a sustainable collection system.

MATERIALS AND METHODS

At first, selected locations were observed and then discussed to house owner of the family of the selected study areas. The people were agreed to keep solid waste. Field inspection was done to observe the collection practices at KUET campus, Fulbarigate and Daulatpur site. The problems of the existing system were identified. A sweeper was agreed to carry the solid waste from the generation point for the money. Solid waste was segregated by the sweeper to find out the various component of solid waste. Samples were collected from every house and weight was taken by balance. The range of balance was 0 to 5kg.Total 294 samples from twenty one spots of three selected areas were collected and measured for seven days in two seasons. The samples were segregated in precautions by using (hand gloves, masks and noses) spoon. Weight was taken of these segregated components and kept recording the data.

PRESENT STATUS OF STUDY AREAS

Door-to-door collection of waste would take place on a daily basis on either pushcarts or rickshaws. After the waste has been collected from the households and the common areas have been swept, the waste is transported to the site with auto rickshaws. But, in the study areas, these wastes were not collected by the authority, if collected, but hardly. These wastes were disintegrated or discomposed in the open place and causes air pollution, sometimes causes water pollution due to contaminated with ground water. So, protect air and water, no alternative to improve solid waste management system.

Fig. 1: Household Solid Waste Collection in Daulatpur

Fig. 2: Household Solid Waste Collection in KUET campus

Two differences solid waste collection system is shown in two distinct Figures (Fig.1 and Fig.2) from two different sites. Study is unfolded that collection system in only KUET campus was proper way, but, in another two areas were very rough collection system practiced. Two separate dustbins should be used to storage waste for collection on pre-selected time in a day.

RESULTS AND DISCUSSION

A proper survey was performed to find out the real estimation of waste generation rate and characteristics of various component of waste. These survey report's results and discussions are given below:

SOLID WASTE GENERATION

Waste, urban population is expected to produce far more waste per capita than its sub-urban population. This difference between urban and sub-urban waste generation rates the study area where the sub-urban population (Fulbarigate) generates only 0.07 to 0.35 kg per capita per day, while

their urban counterparts (Daulautpur) generate 0.1 to 0.42 kg per capita per day. The quantity of per capita waste generation varies between 0.07 and 0.42kg per day.
All survey data were collected and recorded in Table-1.

Table 1: Quanttities of solid wastes generated in Daulatpur, KUET campus and Fulbarigate

Daulatpur			KUET campus			Fulbarigate		
Family owner name	Average waste generation rate (kg per capita per day)		Source name	Average waste generation rate (kg per capita per day)		Family owner name	Average waste generation rate (kg per capita per day)	
	Rainy season	Winter season		Rainy season	Winter season		Rainy season	Winter season
Sanker Aich H*, 4**	0.296	0.186	9 number dustbin H*, 30**	0.162	0.108	Hafizul Haque L*, 11**	0.140	0.067
Iqbal Hossain H*, 3**	0.386	0.245	5 number dustbin H*, 24**	0.139	0.136	Nurul Haque Hawladar L*, 7**	0.147	0.116
Ruhul-Amin H*, 6**	0.307	0.109	2 number dustbin H*, 5**	0.397	0.370	Iman Ali M*, 10**	0.076	0.027
Laxmi Rani M*, 4**	0.296	0.151	4 number dustbin H*, 4**	0.414	0.254	Md. Jalal Uddin Sarkar M*, 12**	0.071	0.038
Ranjit Das M*, 3**	0.119	0.068	17 number dustbin M*, 24**	0.146	0.129	Nurul Haque H*, 7**	0.203	0.112
Susantha Paul M*, 5**	0.174	0.243	15 number dustbin M*, 15**	0.0791	0.049	Md. Monir Hossain H*, 5**	0.340	0.202
Raju Das L*, 5**	0.320	0.123	**Note:** “*”and “**” indicate family class with respect to income and number of family member respectively. “H”, “M”, “L” and “D_1-D_7” also indicates high, medium, low class family/source and day number of collection data respectively.					
Biren Datta L*, 6**	0.417	0.093						
Joydeb Datta L*, 3**	0.305	0.185						

High income family generates more wastes than lower income family because they earned more and use more necessary things. Middle class family produced small amount of wastes because they use necessary things for long time. Low income society use necessary things. But, these things are not remain long time. So, they generate more waste than middle class family, but less than high class family. But, waste generation less depend on family income. Waste generation associated with season. It varies season to season due to availability of daily food vary from season to season (e.g. various fruit such as mangoes, jackfruit are available in rainy season and various winter’s vegetables are available in winter season). It is clear that waste generation rate is more in rainy season than winter season.

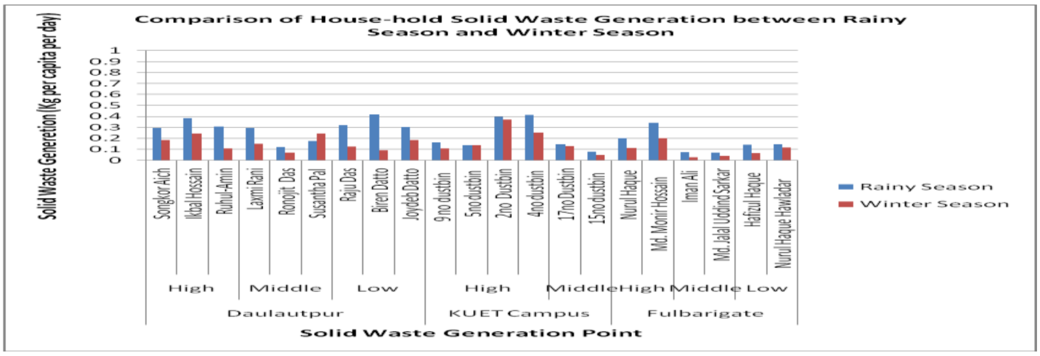

Fig.3: Comparison of House-hold Solid Waste Generation between Rainy Season and Winter Season

In Fig.3 it is clear that solid waste generation variation is varied with respect to the variation of family class.

CHARACTERISTICS OF WASTES

Segregation is an important method of handling municipal solid waste. Segregation at source can be understood clearly by schematic representation. So, segregation is done at the point of generation to estimate actual composition of solid waste. Knowing the composition of the waste allows for defining the strategies for separation, collection and frequency of collection for recycling. Besides, it is important to maintain the facility provided for the collection of waste in order to avoid any nuisances in future. Data were collected from the point of generation in Daulatpur, KUET campus and Fulbarigate and tabulated in Table 2.

Table 2: Approximate composition of solid wastes in KUET campus, Fulbarigate and Daulatpur

Waste Component → Source Name ↓	Season ↓	Weight ↓	Food and Vegetable Waste	Paper Products	Plastics	Metals	Glass and Ceramics	Wood	Garden Wastes	Others
KUET campus	Rainy	Weight (g)	14850.0	850.0	900.0	100.0	200.0	200.0	1150.0	500.0
		% by Weight	79.2	4.5	4.8	0.5	1.1	1.1	6.1	2.7
	Winter	Weight (g)	8960.0	730.0	650.0	-	-	-	150.0	190.0
		% by Weight	83.9	6.8	6.1	-	-	-	1.4	1.8
Fulbarigate	Rainy	Weight (g)	6530.0	510.0	320.0	120.0	170.0	-	815.0	-
		% by Weight	77.1	6.0	3.8	1.4	2.0	-	9.6	-
	Winter	Weight (g)	3200.0	310.0	110.0	400.0	-	-	300.0	-
		% by Weight	74.1	7.2	2.6	9.3	-	-	6.9	-
Daulatpur	Rainy	Weight (g)	10900	400.0	250.0	-	350.0	300.0	1300.0	400.0
		% by Weight	78.4	2.9	1.8	-	2.5	2.2	9.4	2.9
	Winter	Weight (g)	6750.0	560.0	250.0	-	800.0	-	500.0	-
		% by Weight	76.2	6.3	2.8	-	9.0	-	5.6	-

Waste composition is also influenced by external factors, such as geographical location, the population's standard of living, energy source, weather and season of the year. But, season of the year is greatly influenced solid waste composition of the waste. The compositions for municipal solid waste are assumed to be based on wet condition.

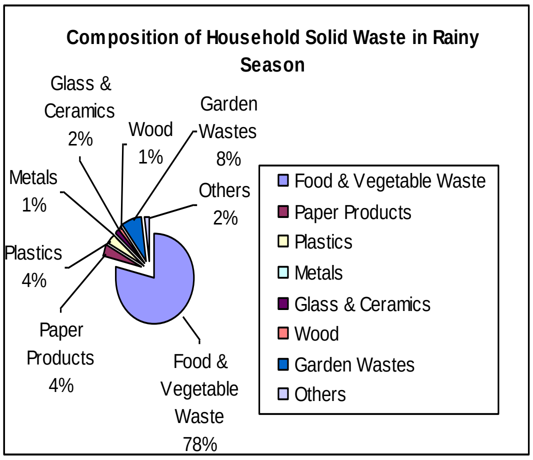

Fig.4:Composition of House-hold Solid Waste in Rainy Season

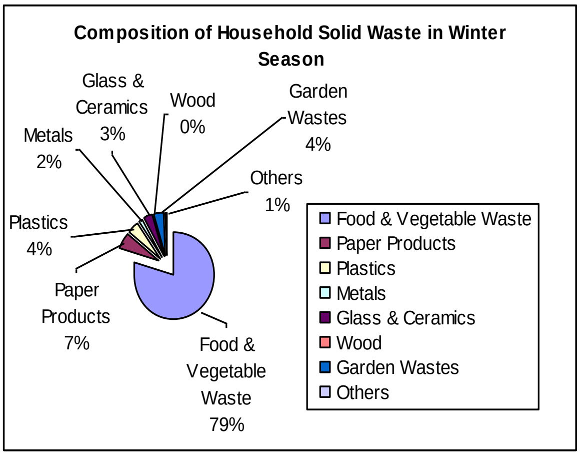

Fig.5:Composition of House-hold Solid Waste in Winter Season

It is quite difficult to segregate the components of the solid waste and find out the actual moisture content. In the rainy season, moisture content of the solid waste is greater than that of summer season. In the pie chart, it is clear that about 75%-80% food and vegetable waste of total waste.

CONCLUSIONS

The present study can be concluded as the followings:

- Average solid waste generation rates are 0.34 kg per day and 0.16 kg per day at Daulatpur in rainy season and winter season respectively.
- Average solid waste generation rates are 0.19 kg per day and 0.13 kg per day at KUET and Fulbarigate in rainy season and winter season respectively.
- A proper characterization system of solid waste was performed.
- It can also help us to understand the influence of socio-economic status and lifestyle on solid waste generation. These results conclude that amount of organic waste is still the highest followed by plastics and paper. However, this information may serve as a reference for further studies in order to observe the behavior of waste generation over family status with respect to income.
- As food and vegetable waste is about 7580% of total waste, so, two separate dustbins would be used to collect food and vegetable waste in one, rest waste in another dustbin.

ACKNOWLEDGEMENT

The author is gratitude to the study area's personnel for their respective contribution to conduct the study.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M. I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.102 (1-7)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Policy Reform for effective Solid Waste Management in Nepal

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ABSTRACT

Nepal is a developing country with a population of 30 million of which 4.5 million or 17 percent lived in urban areas of 58 municipalities including Kathmandu Metropolitan City. The urban areas generate 700,000 tons waste per year. The generation of solid waste has been increasing in urban areas every year owing to changing in life styles of people, development and expansion of trade, commerce and industry. The municipalities are responsible for the management of solid wastes of the urban areas. But the problem is that they do not have technical, managerial and financial capabilities to address the situation. In addition, the systems that they have adopted for the management of solid waste are outdated and inefficient. With this reason the solid waste management is coming up as a great challenge in the country. Therefore, there is an urgent need to address this issue. If not, the urban areas will not be a place for people to live. However, before 1951 Solid waste was not considered as a problem in Nepal. In mid-1963, the increasing urbanization raised the concern on solid waste management. The Government of Nepal established the solid waste management board and took various initiatives on solid waste management from 1981 to 1986. Then, Solid waste management and resource mobilization act, was brought into force in 1987 and established solid waste management and resource mobilization center as an autonomous body and that replaced the solid waste management board. To facilitate its works, solid waste management and resource mobilization regulations and necessary by laws were framed and enforced. The solid waste management policy 1996 has introduced to further clarify its policy on SWM issues which is now in force. Its main objective is to make solid waste management works simple, effective and to minimize the impact of solid waste on environment and public health. The policy has also supported to making local bodies (municipalities) capable of providing efficient and reliable sanitation services and tariff and appropriate technology compatible to the local. The three-year plan 2007 has updated the solid waste management policy 1996 in which stakeholders allowed to involve in SWM issues. The solid waste management act 2011 was passed on 2011/06/15 that aimed to amend and consolidate the laws relating to solid waste management and to arrange for the systematic and effective management of solid waste by minimizing the solid waste at source, re-using, processing or proper disposing of the solid waste. To achieve this goals, new National Solid Waste Management Policy and Strategy 2012 Nepal is now in a process of development on the base of Solid waste management act 2011. We hope this policy will cover all the essential contents of the previous SWM policy and include additional features which will be appropriate and essential to improve present SWM practices in Nepal.

INTRODUCTION

Nepal is one of the landlocked and poor, developing countries of South Asia including world. Urbanization in Nepal is growing at a fast pace, there are 58 municipalities with population of 4.5 million that includes 17% of the total population in the country. The urban areas differ geographically and lay in different development region and ecological zones. Majority of municipalities are found at hilly zone where as terai zone and mountain zone have less number of municipalities. Solid waste has been a major problem in the urban area of the country. With increasing population, generation of waste is gradually increasing.

With the survey conducted by SWMRMC on 2003, it was found that solid waste generated in municipalities are 200-400gm/capita/day. Small towns produce comparatively less number of wastes than large cities. With the change in life style of people, development and expansion of trade, commerce & industries in urban areas, generation of solid waste has been increasing in cities and towns.

Municipalities in the country are not able to cope with this increasing solid waste problem. They don't have proper equipment and skilled main power to provide better SWM service to the public. Collection efficiency ranges between 70 to 90% in major cities, where as in several smaller cities it is below 50%. Still, Solid wastes are dump in the haphazard manner in open space that is increasing the land and water pollution. Service deliver is limited to few markets and residential area where as other areas are neglected due to less number of staffs and vehicles in the municipalities. If we see the annual expenditure of the municipalities, it spends nearly 60-70% towards street sweeping, 20-30% on transportation, and less than 5% on final disposal of waste. Sanitary landfill sites and treatment facilities are developed in few numbers, 5 municipalities have sanitary landfill sites, 3 municipalities has control dumping sites and rest of the other municipalities practice the riverside and open dumping. Private sector is actively supporting few municipalities to carry out solid waste management tasks such as door to door collection, composting and safe disposal of the solid waste.

Major deficiencies seen on municipalities are lack of technical, managerial or financial capabilities to address the situation. Unmanaged solid waste is always a prone to cause adverse impact to human health and environment in the country. Hazardous waste, biomedical waste chemical waste as well as industrial wastes are another problem arising in this field, municipalities don't have a skillful staffs to manage these waste. The rules and regulation are not strong in the country to stop haphazard dumping of these wastes

Therefore, it is important to develop a necessary rules and regulation to reduce this haphazard handling of the solid waste. Different laws were developed under the supervision of Government, but the laws could not provide the proper guidance to the SWM stakeholders. In 2068 February 15, Government of Nepal adopted a newly reform SWM Act 2011. This act covers all the provision that can bring significant changes in the solid waste management.

METHODOLOGY

Literature review and Desk study were the method carried out to figure out and analyze the facts. Different papers related to the solid waste management in context of Nepal were reviewed. Major document were taken from the recent Asian Development Bank Technical Assistant report. Document regarding the earlier legal documents were provided by the Solid Waste Management Technical Support Center, Ministry of Urban Development. All documents are published document from the government of Nepal except the document from the Asian Development Bank.

REFORMS OF SOLID WASTE MANAGEMENT ACTS AND POLICIES IN NEPAL

Prior to 2007 (1951 A.D)

Nepal prior to 2007 BS (1950 AD), Solid waste was mostly organic in nature, and a common practice was to deposit it at the edge of rivers, and rivers would wash away the solid waste. Solid waste was not a subject of priority in early 2007 (1951 A.D). The solid waste was not perceived as a problem previously because they are manageable and under control at the time. Again the urban and city areas were also not populated heavily as in today.

Solid Waste Management Board

As urbanization increases, different cities were formed which raised the demand of solid waste management. Sanitation and hygiene was coming up as common environmental issues with the outbreak of waste born diseases. This made government to appoint a group which can analyze on these issues of Solid waste then government of Nepal established the solid waste management board under the Ministry of Construction, Supply and Transportation. Various initiatives were taken between 1981 AD and 1986 AD.

Solid Waste Management and Resource Mobilization Act, 2044 (1987 AD)

Realizing the need of having legislation on SWM, Solid Waste Management and Resource Mobilization Act, 2044 (1987 AD) was passed and brought into force in 1987 AD. This Act provided for establishment of the Solid Waste Management and Resource Mobilization Center as an autonomous body replacing the Solid Waste Management Board. For the effective implementation of the Act, the Solid Waste Management and Resource Mobilization Regulations and necessary by-laws were framed and some new provisions on solid waste management were incorporated through amendments in the Solid Waste Management and Resource Mobilization Act.

Solid Waste Management Policy, 2053 BS (1996 AD)

The Government of Nepal thereafter issued Solid Waste Management Policy, 2053 BS (1996 AD). The first Solid Waste Management National Policy was formulated in 2053 BS (1996AD) to tackle the emerging solid waste management problems due to urbanization. The policy emphasized on waste management in municipal and urban areas. This policy is still in force. The main objectives of this policy are to make solid waste management simple and effective, to minimize the impact of solid waste on environment and public health, to treat solid waste as resource, to include private sector participation in solid waste management, and to improve public participation by increasing public awareness on sanitation.

The policy include making local bodies capable of providing efficient and reliable sanitation services, operating public awareness program for public participation on sanitation efforts, involving non-government organizations in sanitation activities, developing appropriate technology compatible to the local, social and economic situation and arranging the final disposal of solid waste according to the quantity and nature of waste. The policy emphasizes considering solid waste as resource, promoting re-using and appropriate processing of waste, to make management of solid waste financially sustainable. This policy suggests gradual participation of private sector in suitable components of solid waste management such as collection, storage, transport, transform, re-use and final disposal. The policy also provides for encouraging foreign involvement as well as provision for tax benefits and licensing the industry so that solid waste is considered as a resource. The policy envisaged imposition of tariff and collection thereof. This was followed by framing Environment Protection Act 1996 AD and Local Self-governance Act 1998 AD.

Local Self Governance Act 2055 (1998 AD) and related Regulations

The Local Self Governance Act has made ward committees of Municipalities and VDCs (Village Development Committee) are responsible for managing the waste within of their respective areas. The functions, duties and powers of each Ward Committee under the Village Development Committee include cleaning the roads, ways, bridges, drainage, ponds, lakes, wells, deep water, taps, etc. within the Ward. The Ward Committees have to arrange for disposal of wastes, dirt and rotten materials and to make arrangements to encourage the inhabitants of the Ward for maintaining sanitation.

Three-Year Plan

After a long gap, a three-Year Plan was prepared by the Government of Nepal to update the Solid Waste Management Policy, 2053 BS (1996 AD) with the participation of stakeholders in the management of solid waste. In particular, the updated policy made provisions for managing the industrial waste, medical waste, and hazardous waste of special nature by the concerned institutions generating such waste without adversely impacting public health. It also directed the local bodies (municipalities and village development committees being urbanized), which are located in a specific area appropriate from the viewpoint of geography and transportation, to work under the common umbrella to raise awareness, produce organic fertilizer, construct and manage the landfill site, generate power, from the Municipal solid waste; and involve private sector participation gradually in services such as collection, segregation, reuse, recycle, transpiration and final disposal of solid waste, and promote public-private partnerships in SWM sector.

Environment Policy and Strategy on Periodic Plans of the Government

There is no specific provision in the Environment Policy and Strategy regarding solid waste management. The Present periodic Plan "Three Years Plan 2010-11, 2011-12, 2010-2013 AD" emphasized promoting and extending sanitation facilities through public awareness at the rural and urban areas with the participation and contribution of the local government and users' communities. It has further emphasized IEE (Initial Environment Examination) and Environment Impact Assessment for implementing any infrastructure development project. The plan has, under infrastructure development, targeted to construct 10 landfill sites and conduct feasibility study for another 10 sites. The plan has associated solid waste management with sanitation and infrastructure development activities.

Solid Waste Management Act 2068 BS (2011 AD)

Finally with an objective to amend and consolidate the laws relating to solid waste management and to arrange for the systematic and effective management of solid waste by minimizing solid waste generation at source, re-using & processing the waste and providing for proper disposal of the solid waste. The Govt. of Nepal enacted Municipal solid Waste management Act 2068 BS (2011 AD) effective from 15th June 2011 AD. The objectives of the Act also include maintaining clean and healthy environment by minimizing the adverse effects of solid waste on public health and the environment.

The Local Bodies have been made responsible for construction, operation and management of infrastructures for collection, treatment and final disposal of solid waste, including construction of transfer stations, treatment plants, etc. However, healthcare institutions and industries are made responsible to manage their biomedical and hazardous wastes. A Local Body is authorized to specify the time, place and method for disposal of solid waste and prescribe collection centre for each settlement at such places which is convenient to all. The Local Body is required to manage transportation of waste & provide means of transport of solid waste. The Local Body is expected to encourage reduction, reuse and recycling of solid waste and coordinate with industries for reuse of packing materials for reducing the waste. The Local Body is allowed to construct transfer stations for managing the initially collected solid waste in such a way that it would not cause adverse effect to public health.

The Act makes the Local Body responsible for constructing sanitary landfill sites subject to Environment Protection Laws for management and final disposal of the waste. The Act prohibits management of waste without license and provides for issuance of license and prescribes the procedure for issuance of license to manage the waste. It provides for the involvement of the private sector firms, CBOs and NGOs in solid waste management through competitive bidding. It also provides procedures for bidding, selection of successful bidder, authority of the bidder for collecting tipping fees against solid waste management services. Section 16 authorizes the Local Body to give permission for construction and operation of sanitary landfill site, treatment plant or any other infrastructure subject to Environment Protection and other related laws. A Local Body is authorized to monitor the compliance of the specified standards and cancel any permit if needed.

The Act authorizes for imposition and collection of service fees against solid waste management services and prescribes the basis for fixing such fees (tariff) and procedures for collection of such fees and the usage of the fees. It authorizes the Local Bodies or authorized private operator to suspend or stop the services if any user fails to pay the fee. The Act allows for pecuniary punishment and/or imprisonment for violating the laws. The Act mandates the Local Body to carry out environment protection activities by preparing master plans for the affected area surrounding a landfill site. It authorizes the local bodies for formulation of rules, bye-laws and guidelines, and issue directives. It allows Local Bodies to except foreign assistance.

The Act gives directions on institutional strengthening and capacity building of Local Bodies through technical assistance by SWMTSC under SWM Council. The Act aims to protect and improve public health and environment. The following policy guiding principles, policy statements and strategy made to achieve the Act goals.

National Solid Waste Management Policy and Strategy 2012

Its main objective is to protect public health and environment by improving municipal solid waste management systems and practices. For this, the local bodies as well as citizens are made responsible and accountable in the respective spheres of solid waste management (SWM) within their local jurisdiction. They will work to minimize generation of Municipal Solid Waste (MSW) by motivating industries, commercial establishments and households to reduce waste generation in the first place and make serious efforts to reuse and promote recycling of the waste generated by them. Public private partnerships (PPP) modality will use and encourage community, CBO, NGO & private sector participation in SWM services to make the services efficient and cost effective. SWMTSC will work to build in-house capability of Local Bodies and national institutions to deal with SWM issues effectively. The local bodies will introduce sustainable waste processing technologies that are conducive to local conditions and ensure safe disposal of residual municipal solid wastes as well as treated hazardous, biomedical, chemical and industrial wastes. SWMTSC will work with the local bodies to promote formation of community groups, associations to create public awareness and ensure community participation in managing municipal solid waste. The effort will keep making SWM services self sustaining by levy of user charges and taxes to cover O&M cost of the services and meet cost of capital investments. The promotion of research & development to keeping pace with advancements in SWM sector and for improving level of SWM services will keep continued. The practice will support for the further improvement of SWM practices in Nepal.

The guiding principles of the policy are: SWM services to be all inclusive, Ensure community participation, Zero Waste Target, SWM services to be made self sustaining, Promote CBO, NGO & Private Sector Participation and Promote institutional strengthening, National institution to provide technical support. Its aim is to guide and support to run program effectively.

The role of local bodies, citizens and SWMTSC is provided in the policy. This policy document has included the Implementation strategy which comprise of Public awareness and Community, Capacity Building to local bodies, Preparing national action plan, Assist in preparing Rules & Regulations, Prepare standard, guidelines, manuals etc., Strengthen SWMTSC, Establish SWM Department/cell in Local body, Promote PPP, PSP, NGO and CBO participation, Make SWM services financially sustainable, Monitoring and evaluation and Coordination with all the ministries.

EFFECTIVENESS OF THE POLICIES

This simplistic approach to solid waste management raised concerns with the increase in the amount of solid waste due to growth of population and urbanization. The approach could not work effectively. As a result, the some studies were carried out in the mid-1963 AD. Those studies recommended some short-term and long-term measures for proper SWM. Thereafter, some steps were taken to improve SWM services in the municipalities within the Kathmandu Valley considering the higher amount of waste generation in the area, and a waste management and resource mobilization project was initiated. The plan could not run effectively meeting needs of the solid waste management of the country.

Government of Nepal established the Solid Waste Management Board under the then Ministry of Construction, Supply and Transportation. Various initiatives were taken between 1981 AD and 1986 AD. The initiatives were run on ad hoc basis. There were found big gap between the needs and the initiatives run. The reason is the initiatives lack the policies and programs. As result the initiatives found weak in properly solving the problem of solid waste management in the country. To meet the gap there had been realized the need of having legislation on SWM. As realized, Solid Waste Management and Resource Mobilization Act, 2044 (1987 AD) was passed and brought into force in 1987 AD. This Act provided for establishment of the Solid Waste Management and Resource Mobilization Center as an autonomous body replacing the Solid Waste Management Board. For the effective implementation of the Act, the Solid Waste Management and Resource Mobilization Regulations and necessary by-laws were framed and some new provisions on solid waste management were incorporated through amendments in the Solid Waste Management and Resource Mobilization Act. The act also could not function properly due to lack of technical human resources that need for solid waste management. Besides, the act also found not adequate to progressively increasing solid waste with the reasons of increased urban and city population. The act was mostly centralized, not given any authority to local bodies to regulate the policy and act. It means the local individuals/ family who produced the solid waste was not made them responsible to mange or cooperates to local bodies to manage the waste. Its main reason is that the act lack people's participation.

To solve this problem the Government of Nepal thereafter issued Solid Waste Management Policy, 2053 BS (1996 AD). The policy followed the three-Year Plan was prepared by the Government of Nepal. The plan encouraged the participation of stakeholders in the management of solid waste. The municipalities/ local bodies were made responsible to implement the plan and policies but they could not work properly as planned or meeting needs of solid waste management. Its main reasons are that they lacked the technical knowhow, skilled human resources and financial resources, discipline among the staff, etc. Additional other reasons are the political instability and influence of the political parties/ persons in the municipalities/ local bodies involving in the solid waste management. With all these, plan and policy could not work effectively as planned or expected.

To consolidate the laws relating to solid waste management and to arrange for the systematic and effective management of solid waste by minimizing solid waste generation at source, re-using & processing the waste and providing for proper disposal of the solid waste, recently the Govt. of Nepal enacted Municipal solid Waste management Act 2068 BS (2011 AD) effective from 15th June 2011 AD. The Act focuses on maintaining clean and healthy environment by minimizing the adverse effects of solid waste on public health and the environment. Under this act Solid waste management technical support center (SWMTSC) is established. The centre works as a national leading entity facilitating sustainable solid waste management (SWN) services and compliance to laws and regulations through technical assistance, research and development leading to clean and healthy environment. The centre will provide all these support and assistance to the local bodies to build their capacity and act efficiently in solid waste management. The expectation is that the act will able to meet the present deficiencies and needs of solid waste management in the country.

Looking at the overall steps of the Solid Waste Management process from waste generation to disposal, there are different stakeholders involved in it. National Policy has mandated to reduce the waste that is the role of citizens/waste generators. As SWM Act 2011, have clearly demanded for the waste segregation on the sources, national policy has mentioned it as duty of waste handler to segregate their waste at the origin or source. In case of persons or institutions generating hazardous waste, medical waste, chemical waste or industrial waste, they are themselves responsible for safe storage, transportation, processing and disposal of such waste as per the standards prescribed by Government. Collection is inseparable part of SWM system, directly concern with the waste collector. National Policy have provided the space for the improvement of the collection with the involvement of private sector, local bodies are concern bodies to collect the waste through any means such as street sweepings, collection bins etc. After collection, Waste needs to transport to the allocated site for safe disposal. Local bodies are the responsible person to provide the proper transportation facilities. For the treatment and land filling process, Municipalities are the authorized to develop their own landfill site and waste treatment. Solid waste management technical support center provides the technical support in every steps of the waste management as per the demand of the local bodies. The emerging issues that national policy tries to highlights are Planning & Budgeting for Solid Waste Management, Implementation strategy, Lack of in-house capabilities and technical know-how, Segregation of Waste, Enhancement of collection efficiency, Safe disposal of solid waste, Collection of service charge and Lack of public awareness.

CONCLUSION

Solid waste management is one of the demanded services in the urban area. Clean, green, and healthy city and urban areas are the beauties of the country. These are keys to good environment. For this, the SWMTSC will be fully equipped and capable with the skilled human resources to provide the technical, research and development services to the local bodies. And then, the local bodies should be able to implement the plan and programs as expected by the Act. Then only there will be effective and successful meeting the needs of SWM services of the country. All three (SWMTSC, local bodies and people) will work well cooperating each other and will meet the needs of SWM in the country. The newly made national SWM policy have fulfilled all the drawback of the previous SWM policy. It has clearly guided the local bodies, citizen/waste generator and government which is essential for the understanding their responsibilities and work promptly on any arising SWM issue. Therefore, the newly made policy have justified the SWM Act 2011 and provided a right track for improvement of SWM in the country.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.104 (1-7)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Role of Management Information System in Solid Waste Managemenet

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ABSTRACT

Management information system (MIS) plays a critical role in the planning and operation of solid waste management services. In most of the cases in Sri Lanka, especially in Ampara, virtual decisions are taken in order to implement effective solid waste management services, which is one of the major disadvantages in monitoring, planning and operations of solid waste management system. Therefore, management information system was developed to examine solid waste management in Ampara district, Sri Lanka. One of the primary reasons of importance of the Solid waste management information system (SWMIS) is that several solid waste activities are combined and produced several reports in order to monitor and plan operations of solid waste management system. Integrated solid waste management system is evaluated not only in terms of economic benefit but also in terms of public participation through solid waste management information system (SWMIS.)

INTRODUCTION

Solid waste management governed by local authority is a major problem in Ampara district. It struggles to find solution due to lack of proper information management system. The information management system developed by United Nations Office for Project Services (UNOPS) with the financial support of European Union (EU) plays a key role in managing entire solid waste management issues of Ampara District in Sri Lanka. Several International organizations intent to support local authorities but they failed to continue due to lack of enough reliable information and its management. Data collection and processing of household and waste management data are critical to determine qualitative product. Reliability or consistency and completeness will be ensured through proper solid waste information management system.

Information management system is a method which helps managers running a specific project, program or a company. It collects data which may be “financial” or “operational activities” and then process it and produce information to the managers which helps them running the company or program. Solid Waste Management information system is management of information to operate solid waste management programme that supports to take decisions.

Most of the Local Authorities (LAs) face chronic deficit in managing data that makes local authority to miss several opportunities. Local authorities hardly produce and process data due to lack of information management system. Integrated information management system will assist local authority to keep record on all the services delivered to local authority and income generated through existing practices. It could also be a base for the development to be carried out by the local authority. Moreover, Commissioner of local government and Assistant commissioner of local government could access information available in the local authority.

It is aimed at establishing an efficient and effective implementation of Management Information System and ensuring sustainability of the facilities that are delivered under EU funded project. As a part of their roles and responsibilities, LAs in coordination with other stakeholders will conduct regular audit to assess the level of services extended to the public and other stakeholders. The process of developing information management system and tools/forms to be used in the actual development of the system will help relevant stakeholders understand elements of management information system.

METHODOLOGY

Data Collection

Data was collected from household, private and public institutions and analyzed and processed in order to accept database requirement. Information generated from actual operation of the services was collected regularly and stored in the computer. Socio economic information relevant to solid waste management was also collected and stored. These data are then processed to provide information in a useful form for subsequent utilization. The processed information was stored in magnetic media and printed on paper for use in planning and operational management. Data was processed with the support of Microsoft Excel and then transferred to the MIS system developed by UNOPS.

System Analysis

Household data and Local authority data are key to the system. Some local authorities collect waste and dispose the same, at the same time some other local authorities collect process and dispose waste. There are group of local authorities that transfer waste to Karathivu waste transfer station and Karathivu local authorities transport waste and finally Addalaichchenai local authority dispose waste. This process is extremely complex in terms of management. However, the system is common to all the local authorities but some functions are disabled based on the local authority waste management system.

The performance of a solid waste management system is a function of the amount and quality of resources allocated to carry out the services, as well as on the socioeconomic development and physical characteristics of the service area. The performance can be expressed mathematically as follows:

$$O = f(I, D) \quad (1)$$

where:

- O= the performance of the service,
- I = the resource inputs to the service, and
- D = the socioeconomic development and physical characteristics of the service area.

The variables related to the socioeconomic development and physical characteristics of the service area are normally cannot be controlled by the authority. For instance, the width of a street could not be changed to allow passage of solid waste collection vehicles. Instead, the authority must modify its collection fleet to existing conditions in order to perform the required services.

On the other hand, the variables associated with resource inputs should be controlled by the authority. In fact, the success of a solid waste management system depends largely on how wisely available resources are utilized. Consequently, in order to improve the performance of its services, the local authority should allocate available resources optimally.

Decisions on operational management are usually made based on the level of socioeconomic development, physical characteristics of the service area, and a predetermined total resource input. In a small local authority in Sri Lanka, the resource input is generally dictated by the central, provincial government and donor organizations. Under these conditions, the authority must operate the system in a manner that maximum performance is achieved. Based on the information presented in the equation, this becomes an optimization problem; that is, O is to be maximized, having I and D as constants. Therefore, the authority must select a set of collection, processing, and disposal methods, among various alternatives, such that O is optimized.

In waste management planning, the desired performance (O) is generally fixed as a future goal of the plan, with the estimated level of socioeconomic development and physical characteristics of the service area (D), and the level of resources required to achieve the goal (I) at a minimum cost. Thus, the problem becomes one of optimization of I having O and D fixed at a certain time. The minimization of I is, therefore, a decision criterion used in the planning process.

In addition to these criteria for evaluation, a ratio of the service performance to the resource input or vice versa (i.e., O/I or I/O) can also be used for evaluating the efficiency of solid waste management systems. In order to make these evaluation processes possible and analytical, the variables in the equation must be determined and measured. These variables are generally called as indicators. The indicators are typically divided into: service performance (used to describe O); resource input (used to describe I); efficiency (O/I or I/O); and socioeconomic and physical conditions (used to describe D)

RESULTS

System Development

Local authority staffs do not have enough capacity to manage complex database; therefore simple database using Microsoft access has been developed in order to solve basic solid waste management problems in the district. Front end of the database is form and back end of it is table. Both front and back ends are connected in order to capture data. Modifications made in the front end do not affect back and vice-versa. Data entered through front end will be stored in back end.

User Authentication

User Authentication interface shows form that provides privileges to the users to access the database. The database could be accessed by two types of people such as administrators and users. Solid Waste Management Information System (SWMIS) itself consists of user account that could be users or administrators who have authority to access database. Administrators have authority to make all the changes in the system and use the same. User has limited authority to access the database. User will be able to handle front end and generate reports. Only users and administrators who have privilege can access the database. If both user name and password are empty, it will show “user name cannot be empty. If the user name is available but password is empty, then it will show “Password cannot be empty”. If username and password does not match, it will show invalid account. After login the database, switchboard will show whether it is administrator or user. Single authentication is applicable in the system.

Switch Board

Switch board facilitates to skip one set of interface to other. The Switch board shows European Union funded project is being implemented by UNOPS. It shows interface that consists of several solid waste management system interfaces in which user will be working to feed data and generate reports. It consists of Solid waste collection, Solid waste distribution, household data, household billing, recycled / mixture production, on call services, Reports, Settings and exit. Waste collection consists of waste collection information. Icon waste transportation provides options to feed information connected to waste transportation from adjacent local authorities such as Sammanthurai, Karaithivu, Kalmunai and Ninthavur. Waste distribution provides opportunity to feed information related to compost, recyclables and residuals. Household data interface accepts household information. Household billing interface is to bill household who receives solid waste management services. Recyclable mixture production interface is to feed data about the production borne from solid waste management facility and keep track on sales information. On call service interface is to provide options to feed additional waste collected from other sources. Setting interface provides facility to change pre-defined criteria. Report interface is to view and print reports of solid waste management reports. Exit provides facility to exit from the system.

Solid Waste Collection Interface

Solid Waste Collection Interface is a path that helps feeding data about waste collection information. Name of local authority will appear at the top cell. Date could be typed or selected from the icon that will appear at the right side of the cell. Collection date cell will accept only numerical field. Tractor number is already listed in the programme. By selecting specific tractor number plate, the user could feed number of trips of the tractor. If a particular Tractor is not available in the drop down menu, system will not accept new tractor at this interface. Numerical value needs to be added in the number of Trips cell. If the text is in the field, total amount spent could be calculated and it will show error. An average expense of the load is already calculated in the programme; therefore total amount spent to collect waste will be computed by the programme. By clicking the save button, the specific information could be saved in the system. Then, saved information will display below, which could be seen by dragging scroll bar. If there are any needs in changing information fed in the system, it could be done by clicking ID of the particular record that brings waste collection detail interface.

Waste Distribution Interface

Waste Distribution interface supports to record processed waste that is to transfer composting cell, landfill or recycling store. Information could be fed either in Kgs or loads. Save button will be used to save information which will appear below that helps user to verify the data. If it is required to make changes in the record, it could be done by clicking ID of the particular record. However, administrator could view all the changes made in the system.

Household Detail Interface

Household detail interface represents household data that is the key to the solid waste management system. Property owner is mapped in order to monitor his/her distribution and property. Household data is already inserted in the database. New household data could be inserted through the interface mentioned below. Main objective of the interface is to keep track household data specially property owners and their details. Residents' information is also included in the database to keep track on the waste generators. Local authority provides four main services such as solid waste, water supply, public utility services and welfare services. All the services are being delivered will be tracked in the system. Those who supports for solid waste management services will have easy access to other services. By clicking save button, information fed in could be stored. It also provides provisions to search household information. If it is required to make changes in the record entered, it could be done by clicking ID of the particular record. However ID cannot be changed but other information could be changed. Once property owner accepts to receive solid waste management service, permission will be given to break away from the system. Only administrator could make changes based in solid waste management services delivery.

Household Billing Interface

Household billing Interface provides facility to bill household data and store information of household paid. Those who receive solid waste management services have to pay for the services obtaining from local authority. Household could be searched using HH code, NIC number, Advanced search. HH code is unique to each household. If anybody knows HH code of particular household, the beneficiary could be loaded using load button and then bill could be generated to the particular person. NIC number could be used in similar way. Advanced search could also be used in order to find household information. Prior to generate bill, date and time of the computer need to be ensured. Bill will be generated to the households whom receive solid waste management services. Particular GN Division will be selected to print bills. Then name of the household could be loaded using HH code, NIC number or advanced search. Unless household is loaded, "add starting balance" button will be inactive. After loading the household, starting balance could be added by clicking ID of the particular record.

Make payment dialog box will appear to add payment. HH Code, Property Owner, economic level, and billing period will be inactive therefore it cannot be changed at this end by both administrators and users. Having entered entry date and amount, make payment will be selected. System will calculate household billing balance and produce household billing dialog box that shows outstanding period, outstanding amount, billing period, household credit balance and net payable amount. If anybody wants to make payment, it could be done by selecting make payment button. After generating bills, starting balance needs to be added by selecting add starting balance button. When next bill is generated it will be accounted and bill will show amount to be paid in the system.

There will be separate account for each household. Those who make one year advance payment will be given 10% discount. Bills will be generated for every six month which are first six month and last six months. Discount will not be returned in the form of money but it will be credited to the account of household.

Recyclable Item and Compost Production Interface

It shows the interface of recyclable Item / Compost production in the drop down Menu. In built name of the local authority is placed in the database. Production date of the product is to select from the calendar button. Production type consists of compost, plastic, paper / cardboard, metal, glass, mixed item and others. Then Kg of the recyclable product will be inserted from and saved by selecting the save button. System will show operational cost of the product which will be calculated automatically. It provides options to record all the items produced and sold. It could be possible by clicking sales button. If the user has entered wrong information, data could not be edited by selecting ID of the particular record; however no changes could be done but it could be cancelled. Later new data could be entered in order to rectify the errors. User log would record all the changes made in this regard. Control system is in-cooperated in order to prevent entering false information.

On Call Services

On call services shows on call services that provides opportunity to obtain additional services. Call date and collection date needs to be entered because both dates may be different. Garbage collection date cannot be earlier than call date. Services could be given to the households who are in the administrative area of the Local Authority. Number of trips will be entered manually and means of the transportation could be from local authority vehicle or private vehicle.

Household Advanced Search

Household Advanced search helps users to find details of household information. Main focus in the database is given to property owner. It is also possible to use scrolling bar in order to find household information. If residence is typed in the cell of property owner’s name, it will not search the data in the database. Therefore property owner’s name is compulsory in finding records.

Household Complains

Household could complain about solid waste management services, which could be tracked through database. Search Household button could be used to load information. Particular household could be selected using scrolling bar or by find button. It could also be loaded by clicking ID of particular household in the Household detail form. Household could lodge complain against the solid waste management services by selecting Household complaints button. Date of complains and description of complaint will be entered in the form. Save button will save the entered information. Having addressed complains, user could feed the information by selecting ID of the particular complains through the form mentioned below.

Settings

Settings could be accessed only by administrator to change basic criteria of the system. It consists of four options such as vehicle entry, Change user-fee, and Change operations rate and user account. Vehicle entry will give provision to add number of tractor or truck being used for solid waste management programme. User fee may change every year therefore the database has provision to change whenever it is required. It is also possible to use number of category with different user-fee charge. Change user-fee options provide such facility to modify user-fee. Kalumnai, Sammanthurai, Karathivu, Ninthavur, Addalaichchenai falls under one cluster and combined solid waste management services are being provided by UNOPS with the financial assistance of European Union. Tipping fee is divided into two categories such as in coming and outgoing waste. This set of interface is applicable only to cluster setup. Those who get services need to pay tipping fee that could be modified every year based on the services.

User Accounts

Only authorized user could use the system, that prevent abusing system as system itself consists of list of users. If wrong information entered in the system, it will show invalid account.

Reports

This interface facilitates to generate reports from the data entered in the system. There are five major types of reports such as waste collection, waste processing, transfer and transportation, waste disposal; Institutional arrangements will be generated from the database. Transfer and transportation report is not applicable to all the local authorities except Karaithivu Local Authority. Waste disposal report will provide Kg of waste and Load of waste transferred to the landfill. That will help us understand efficiency of waste processing and efficiency of the landfill operation. Institutional arrangement will provide financial efficiency and operational efficiency of the solid waste management system. It consists of userfee log, household complaints and service log. All the reports are further divided into daily, monthly and yearly reports as stipulated above. If we further click the box in front of the “Daily Waste Collection Report”, Report will be produced for the data entered in the system.

Monthly waste collection report could be generated by selecting the button at the front. It will request additional information of starting and ending date. The report could be printed by clicking the print button at the bottom. Yearly report could also be generated in this manner.

CONCLUSION

A large amount of data is used for planning, designing, and operating municipal solid waste collection, processing, and disposal services. Due to the diversity of situations throughout the world, and in many cases within a particular country, it would be difficult to design a single Management Information System (MIS) that would be capable of satisfying the needs of all solid waste management functions. Through understanding of the system and local context made it possible to develop a SWMIS tailored to the local context.

Microsoft access was used to produce management information system. Having completed detail study on waste management process and capacity of the local authority, draft plan to computerize system was developed. Sets of user friendly interface were introduced in order to simplify the system as computer skills of local authority staff were limited. The information management system is to keep track on records on waste collection, compost generation, collected recyclable, sold compost, sold recyclable, amount of waste directed to landfill, service charge record, unit operational cost, conversion from kg to number of load, load to kg solid waste weight information. Moreover, it acts as a governance tool of local authority which facilitates to take key decisions towards sustainability. It consists of flexibility to accept new criteria and capable of expanding, as more resources are made available.

ACKNOWLEDGEMENT

I would like to thank EU and UNOPS for giving opportunity to write and publish this paper for the international audience. Some of the programming code is written for better understanding. I would like to thank local authority and other stakeholders who supported and provided information as per requirements.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.105 (1-4)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Driving Force of Sustainable Solid Waste Management, User Fee Collection, Sri Lankan Case Study

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ABSTRACT

Environmental Remediation Project of United Nations Office for Project Services (UNOPS) funded by European Union (EU) provides solutions for the long running solid waste management problems in Ampara District. Objective of the research paper is to analyze impact of demand based solid waste management services and introduce service charge / user fee for waste disposal. User Fee is a the fee collected by the local authorities from households, business shops and other establishments as payment for receiving waste management services on a regular basis. It provided additional financial support for the solid waste management services. Households need to feel that they pay for the services of the solid waste management. It will facilitate to establish clean and tidy environment then this could be model to other local authorities in the country.

INTRODUCTION

Waste collection in Ampara district is a fast growing social, environmental, political and economic problem. Burning and waste disposal at lagoon and public places were a common practices. It was observed deficit financial situation and commitment of local authority were key problem in providing better solid waste management services. Objective of the programme is to build capability of the local authority to generate revenue for the solid waste management program and set up the corresponding system of user fee collection that is simple, efficient and effective to improve waste collection performance of the local authority.

Environmental remediation programme (ERP) of United Nations office for project services, funded by European Union facilitates to provide sustainable solution for the solid waste management problem in Ampara district, Sri Lanka. Karaithivu local authority is selected to elaborate implementation of user fee collection system that is driving force of sustainable solid waste management.

User-fee is a payment that needs to be made by service recipients of solid waste collection system in Karaithivu Pradeshiya Sabha that is specifically from household, business enterprises, institutions and other stakeholders. It is newly introduced in Sri Lanka but it is widely being practiced in many developed and developing countries.

Research analyses legal provisions in the local authority ordinance and highlights different interpretation of same legal terms. The paper demonstrates implementation strategies and control system of usrfee collection system. Solid Waste Management Information System (SWMIS) is a supporting tool to ensure efficient solid waste management services and effective userfee collection services.

LEGAL BASIS FOR USER-FEE COLLECTION

Local authority is an autonomous and self-financing institution (clause 4.1.1.4 of gazette extraordinary of the democratic socialist republic of Sri Lanka - 18.12.2009). Therefore it is not rational to anticipate funds from the provincial council. The local authority ordinance also provides opportunity to charge user-fee legal basis and enactment of by law by council approval. Act numbered 15 of 1987

Pradeshiya Sabha ordinance and clause 109 itself indicated that power to implement service charge is vested to the local authority. The national solid waste management policy Statement No 18 (granting policy provisions to ensure self-financing for waste management by effective revenue generation mechanisms for LAs) of the National Solid Waste Management Policy for which the approval has been granted by the Cabinet of Ministers in 2007 provides following strategies to aim at the User Fee.

Strategy No 18.1- Levy a load based service charge from generators of waste with a short term action to introduce a financial structure for levying a User Fee and with a long term action to develop a financial structure for levying a User Fee with incentives for segregation.

Gazette of the Democratic Socialist Republic of Sri Lanka No. 1769 dated July 27, 2012 has published By-Laws on Solid Waste Management for the regulation, supervision, inspection and control of segregation, storage, collection, transfer, transportation, processing, treatment and disposal of “solid waste” generated in public places, private premises, at streets, thoroughfares within ther local authority area limits. The by-law includes provision to collect user fee for solid waste management. Provision for violation and penalties is also mentioned in the by-law.

Therefore it is possible to introduce such service charges or userfee in order to provide additional financial support. It not only increases financial stability but also service performance of solid waste management system.

DISCUSSION

Considering economic condition of the waste generators, flexible charges are introduced for waste management system in the local authority areas. Charges mentioned in the below table 1 are very low considering Sri Lankan economic level. Per capita income of Sri Lanka is about US$ 2000. (Sri Lanka Socio-Economic Data 2011, Central Bank of Sri Lanka). These charges are implemented in Karaitivu, Alayadivembu, Pottuvil and Thirukkovil local authority in Ampara district. Here Karaitivu local authority is taken as an example to show detail. Following Diagram, figure 1 shows total expenses of solid waste collection in Karaithivu Pradeshiya Sabha with respect to the financial year. The graph shows that waste collection expenses were negative as until 2011. Soon after the introduction of user-fee, it started to overcome the budget deficit and earned saving. However with the time, the amount of saving is to use as capital investment to improve solid waste collection services and later it will introduce suitable options to reduce waste generation from household and other entity.

Table1: Userfee charges

Description	Userfee / Service charge
Samudthi recipients (Household below poverty line)	LKR 30
Residential premises	LKR 50
Residential Multistoried building/tenements	LKR 75
Commercial establishments	LKR 100

The process of user-fee collection system installation has undergone the following implementation process:

Improvement of waste collection frequency and increase of waste collection coverage: Waste collection system has direct impact on user-fee collection system. Therefore it is vital to ensure efficient solid waste collection system.

Local authority by law is developed to support collection of userfee for the service provided by the local authorities based on the provision available in the local authority ordinance.

Establishment of the data base for households and business establishments in the local authority: Considering capacity of the local authority, it is not realistic to handle enormous data manually. Therefore it is vital to introduce database that handles more than one million data at a time and calculate net payable of service recipients. Moreover designed solid waste management information system is able to generate user fee bills and reports.

Design a user fee accounting system, a household-based financial account: Solid waste management information system consists of userfee accounting system and develops total due and balance sheet.

Train local authority staff on the new user fee scheme: As the userfee collection system is new to Sri Lanka it was prerequisite to train relevant staff to handle solid waste management information system of the local authority.

Community awareness for the user fee billing and fee collection: Leaflets highlighting legal provisions were prepared and distributed to all the service recipients. Incentive mechanism that encourages voluntary payment is also elaborated in the leaflets.

Actual distribution of billing, collection and recording of fees: Two types of bills are provided to households of which computerized billing takes place in two cycles that is first six months and next six months. Purpose of providing two billing cycle is to induce multiple months payments. Pradeshiya Sabha (PS 1) bill that consists of three carbon copies are also provided in addition to the computerized bills. There are white, blue, green and pink bills and delivered to clients, accounts unit, solid waste management units and auditing units.

Public reporting on user fee collection and disbursements: Reports will be generated through database and presented to the all the community in the areas in order to build trust and accountability. Reporting system seeks suggestions from public to provide better services.

LKR 220,240 is collected through userfee system from 2241 households. 2618 bills are printed and 2241 bills are distributed. It shows 86% of households are willing to pay userfee and receive services. Solid waste collection is a common practice prior to the intervention of environmental remediation project though it was not implemented in acceptable manner therefore initial idea was to establish proper solid waste collection system using additional money drawn by the userfee. Fine will be charged to stakeholders who violate collection service regulation.

Figure 1: SWM Expenses

Main advantage of the user fee is that generators are provided with a direct financial incentive to reduce their waste. Userfee charge is based on amount of waste delivered to waste collection services. Now it is time for waste generators to decide purchasing pattern in order to reduce waste generation. There can also be significant cost saving and reduction in the management and administration of workforce. Fund raised from user fee could be retained for development of infrastructure associated with solid waste management. Household or clients could pre-arrange or preset their payment schedule. The payment could be monthly, quarterly or yearly. At the moment flat rate is implemented regardless of level of services as it is an introduction stage however it will be reviewed and charge will be based on the level of service.

User pay seems to be consistent with the arguments that polluters (including entrepreneur and consumers) should be made responsible for externalities when possible. It does not have conflict with any of the policies and major programs of ministry of local government. User fee would encourage shifts towards the 3Rs by individuals and corporate entities.

User fee systems would be simple and cost-effective to administrate, and ideally it could be integrated with existing national, provincial and municipal financial, regulatory and institutional structures. In Ampara Sri Lanka, it is integrated with solid waste management unit of local authorities. Generated revenue is retained by local authority to support the overall waste management system. Due to implementation of use fee, waste generators could end up with illegal dumpsite therefore law enforcement team was established by the government with the support of environmental Remediation Programme to avoid littering of waste. These problems are addressed through public education and law enforcement. Stiff fines against those caught dumping illegally shall be introduced.

CONCLUSION

Important part in the waste management is waste collection and its disposal. Charging userfee drives local authority to collect solid waste as per the schedule. Local authority keep eye on the vehicle maintenance to make sure regular waste collection. Local authorities received disposal facilities through Environmental Remediation Programme and received fund trough userfee.

At the moment nominal rate is introduced as userfee to different economic group. However some area receives daily collection services and other area receives once a week collection services. Charges will be further extended based on frequency of collection services.

ACKNOWLEDGEMENT

I would like to thank EU and UNOPS for giving opportunity to write and publish this paper for the international audience. Some of the programming code is written for better understanding. I would like to thank local authority and other stakeholders who supported and provided information as per requirements. The original and 1 copy of your paper should be submitted to the Secretary of the Seminar Organizing Committee. Write acknowledgment, if any, here in brief.

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ISBN: 978-984-33-7045-7, PI.116 (1-7)

Proceedings of the WasteSafe 2013 – 3rd International Conference on Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Integrated and Eco-Friendly Approach of Waste Management: An Environmental Case Study of Dhaka City in Bangladesh

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ABSTRACT

Waste is an unavoidable by product of human activities and Improper management of this waste is one of the main causes of environmental pollution. Waste generation increases with population expansion and economic development. The sight of a dustbin overflowing and the stench rising from it are all too familiar sights of the old part of the Dhaka city. The municipal agencies are unable to handle the increasing amount of municipal solid waste, which into the uncollected waste being spread on roads and in other public areas leading to tremendous pollution and destruction of land and negative impact on human health. In this paper we will try to come up with acceptable integrated approach to solve the environmental problems and to reduce the quantity of solid waste disposed off on land. This paper will also highlight the present status of municipal solid waste management in Dhaka city including environmental issues. It is also envisaged to expose the solid waste generation rate, its composition, collection systems, and areas of responsibilities (public / private sector), transfer and treatment sites and waste disposal systems used.

Keywords: *Waste, Environmental pollution, municipal agencies, negative impact, waste disposal.*

INTRODUCTION

The generation of solid waste has become an increasingly important global issue over the last decade due to the escalating growth in world population and large increase in waste production (M. A. Warith,2003). Improper management of solid waste is one of the main causes of environmental pollution and degradation in Dhaka city, which is our main concern. Waste Management has emerged as one of the greatest challenges faced by Dhaka city corporation authority. DCC is facing serious problems in providing a satisfactory service to the city dwellers with its limited resources and a poor management plan. An inadequate information base (regarding quantity, type and characteristics of wastes), poor operation and maintenance of service facilities and above all lack of civic awareness on the part of a section of the population are adding up to the deteriorating environmental situation(Faisal Ibney Hai,2004). Waste generation increases with population expansion and economic development. Improperly managed solid waste poses a risk to human health and the environment. Uncontrolled dumping and improper waste handling causes a variety of problems, including contaminating water, attracting insects and rodents, and increasing flooding due to blocked drainage canals or gullies. In addition, it may result in safety hazards from fires or explosions. Improper waste management also increases greenhouse gas (GHG) emissions, which contribute to climate change. So, it is important to assess the pollution level for the protection of environment and natural resources that requires sustainable interventions in the Dhaka city. Therefore, a study on the environmental impact assessment in the surroundings of Dhaka city on the basis of relevant environmental parameters and made an EIA report based on it. So, the overall objectives of this study were:

1. To evaluate the existing environmental condition in Dhaka city.
2. To gather information regarding waste generation, collection, handling, hauling, treatment and disposal of waste.

3. To adapt/undertake the protective measures to reduce the adverse impact of waste on human environment and natural ecosystem.
4. To build up the awareness program for strengthen the waste management system.

Figure 1: the location map of the Waste dumping site

A REVIEW ON EXISTING ENVIRONMENTAL CONDITIONS IN DHAKA CITY

Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the developing world. Dhaka is one of the most polluted cities in the world (according to an UNFPA report'2001). Municipal waste is one of the major issues but air and water pollution are also responsible to make the city pollute.

Solid wastes are basically of two types (a) organic wastes, which include vegetables, fruits, food staff from households, hotels and restaurants, and (b) hard wastes, such as pieces of wood, metals, glass, plastics and polythene materials, paper, rubber, cloths and textile factory waste and construction materials. Household waste is an aggregate of all substance from a household ready for disposal, which is about 1718 tons /day at a percentage of 49.08 %. There are over 1,000 small and large industries in the Dhaka metropolitan area generating a significant amount of toxic and hazardous wastes and contributing to environmental degradation in and around Dhaka City. These industries include chemicals, textiles, dyeing, printing, tannery, iron and steel, metal, plastic, rubber, and tobacco. A total of about 722 tons and 835 tons of Commercial & Industrial Waste generated per day from Dhaka city. It is estimated that 20 percent of the whole hospital wastes (255 tons, 7.29 % of total solid waste generated per day) generated in the city is infectious and hazardous. Waste is collected from small bowls (plastic or metal) or plastic bins provided for each bed and emptied into larger containers. These containers are then conveyed by pushcart to the nearest municipal bin for dumping. (Reza 2005)

More than 3 million people do not have legal access to water supply in Dhaka City. Quality of water is poor and the incidence of water-borne diseases such as diarrhea, cholera, dysentery, jaundice, typhoid etc. is very high. Due to indiscriminate discharge of wastewater the water bodies within Dhaka City are polluted. About 45 % of populations are connected to separate or combined sewerage system and 11% of populations are connected to septic tank. Rest of the population discharges wastewater directly or indirectly to water bodies (Report on SWM; DCC' 2005). The river of Buriganga contains soluble chromium, which causes cancer and for that leather industries in Hazaribagh are mainly responsible, most of which are situated along the river. The water bodies often are loaded with human excreta, decomposable kitchen wastes, other non-decomposable wastes and industrial effluents.

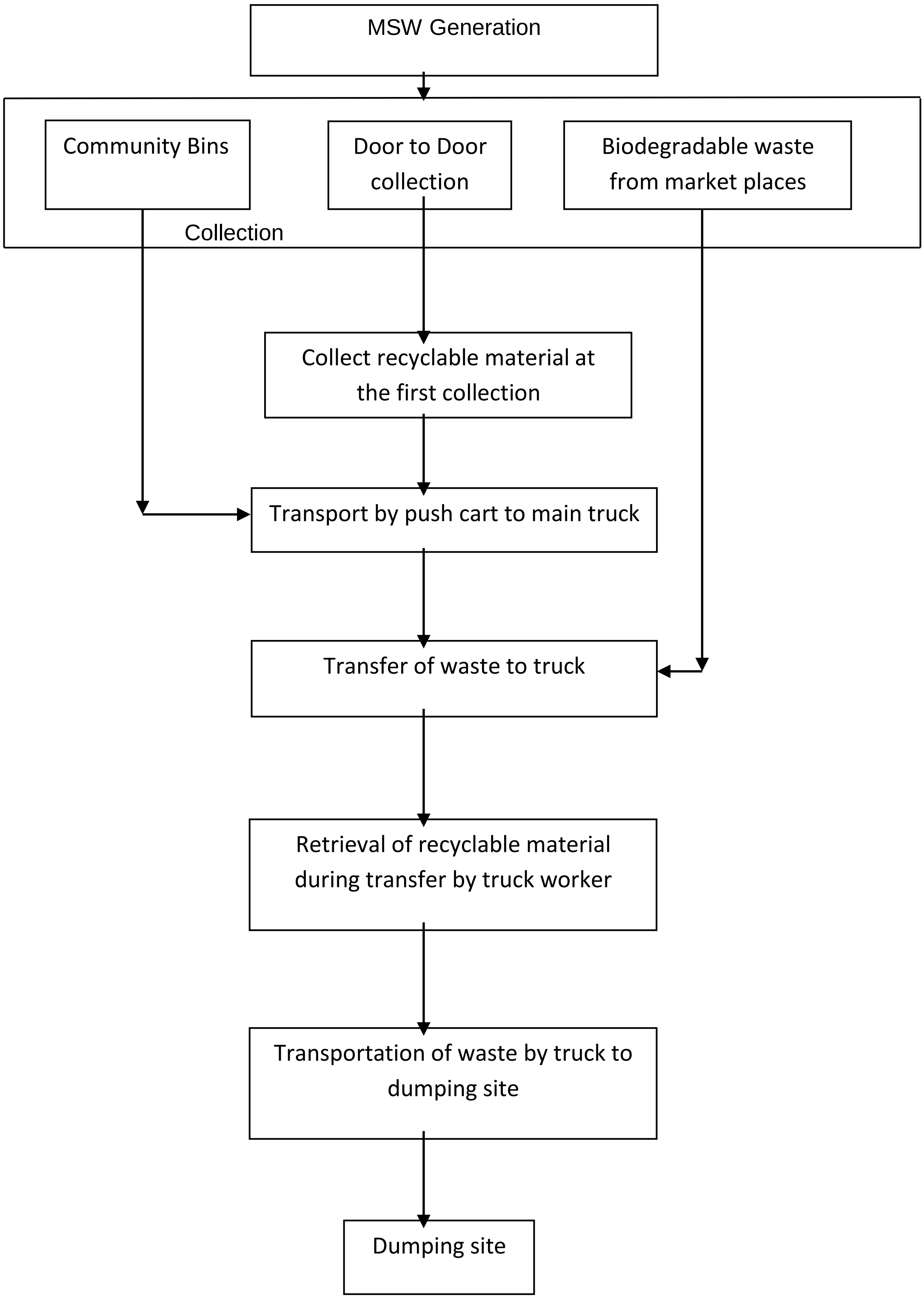

Figure 2: Current Solid waste management practice in Dhaka city

STUDY METHODOLOGY

The study used both primary and secondary data. Primary data collected from officials and general people of Dhaka City Corporation. The methods used for this study are a combination of observation by case studies and questionnaire survey. Relevant data for this study were collected directly from the field by using a questionnaire and depthinterview. The sample size was 100 respondents (Residential respondents 50, Commercial 25, Service Sector 25) for the questionnaire survey. The key part of the questionnaire inquires the perception on the general people who received the service. The methods adopted for the present study also make extensive use of secondary material analysis to build up and support the objectives of the study. The data obtained through the field survey was analysed as input for EIA. The relative importance among various environmental parametes was conducted by pairwise comparison. The pairwise comparison method is applied to reduce individual judgment errors by requiring multiple pairwise comparisons of relative values. An Environmental Impact Value (EIV) was calculated based on the weightage and maginitude of the concerened parameter and an EIA report was prepared.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

An environmental impact assessment (EIA) is an assessment of the possible positive or negative impact that a current situation may have on the environment, together consisting of the environmental, social and economic aspects. The purpose of EIA is to ensure the protection and conservation of the environment and natural resources including human health aspects against uncontrolled development. The long-term objective is to ensure a sustainable economic development that meets present needs without compromising future generation’s ability to meet their own needs. EIA is an important tool in the integrated environmental management approach.

METHODOLOGY FOR EIA

Considering the situation of our country, a simple methodology was taken for Environmental Impact Assessment of the environment of the Dhaka city. The methodology used for EIA in Dhaka city is Environmental Evaluation System (EES). Relative importance of the parameters is selected based on ‘LGED guideline, 1992’. The environmental parameters are grouped into four categories which are: Physical resources, Ecological resources, Human use values and Quality of life values. The environmental impact was assessed by Environmental Impact Values (EIVs) which may be defined mathematically as equation (1):

$$\mathrm{EIV} = \sum_{i=1}^{n} Vi\ Wi \qquad (1)$$

Where V_i is the relative change in the value of environmental quality of parameter i with respect to existing situation. W_i is the relative importance or weight of parameter i, and n is the total number of environmental parameter related to the project. The computation of EIV of solid waste needs determination of V_i, the value representing the magnitude of alteration of the environmental parameters, and W_i, the value representing relative weight or importance of the respective parameters.

Table 1: Environmental Impact value of Dhaka city

Environmental Parameters	Relative importance value	Degree of impact	Relative impact		EIV
			POSITIVE	NEGETIVE	
Physical resources					**-55**
Dust pollution	6	-3		-3	-18
Obstruction to water flow	6	-3		-4	-18
Regional hydrology/Flooding	4	-1		-1	-4
Drainage congestion/ water logging	5	-4		-5	-20
Land use	5	+1	+1		+5
Ecological Resources					**-62**
Fisheries	6	-4		-4	-24
Flora & Fauna	4	-2		-2	-8
Wetland habitant	4	-2		-2	-8
Forest	2	-1		-1	-2
Eutrophication	1	0	0		0
Aquatic biology	4	-3		-3	-12
Sewerage	4	-2		-3	-8
Human use value					**+48**
Employment opportunity	8	+4	+4		+32
Commercial and service facilities	6	+3	+3		+18
Industrial activities	3	+2	+2		+6
Landscape	2	-1			-2
Navigation	3	0	0	-1	0
Irrigation facilities	3	0	0		0
Flood control	3	-2		-2	-6
Quality of life values					**+11**
Public health	6	-4		-4	-24
Disposal of garbage	7	+5	+5		+35
Total Environmental Impact Value (EIV)					**-58**

MAGNITUDE OF ENVIRONMENTAL PARAMETERS

The beneficial and adverse changes in environmental parameters resulting from solid waste, usually expressed in qualitative terms are plotted in a scale to quantify the environmental alterations in Table 1. The changes of environmental parameters are measured with respect to background conditions. The adverse changes have been given values -1, -2,-3,-4,-5 to represent very low, low, modarate, high and very high negative impacts respectively. Similarly +1, +2, +3, +4, +5 represent very low, low, modarate,high and very high positive impacts respectively. A value from the scale representing effect of the project on each parameter was taken to compute the EIV of the Dhaka city for solid waste.

IMPORTANCE OF THE RELATIVE ENVIRONMENTAL PARAMETERS

The importance of a parameter varies from country to country depending on the environmental concerns of the country. All environmental parameters influenced by the solid waste are not of equal importance or weight. EES methodology is based on the assignment of an importance unit to each parameter by judgment of professional experts consists of chemists, biologists, civil engineers, environmental engineers, agricultural scientists, social scientists and urban planners. The judgments complete the pair wise comparisons that are needed at this stage, and are entered in a pair wise comparison matrix. The data in the matrix can be used to generate a good estimate of the criteria weights (Nydick et al. 1992). The weights provide a measure of the relative importance of each criterion.

RESULT AND DISCUSSION

Values are indicating the magnitude of environmental changes influenced by the solid waste. All these impacts were summed up to obtain the total EIV of -58. Despite of some human interest related factors as positive impacts on physico-ecological environment made the total EIV negative. Based on the interviews it was found that the environmental parameters gave the highest negative value of -62. Employment opportunities earned positive degree of impact because people living here are so poor that they are satisfied to earn rather than remaining unemployed although the working condition is totally adverse.

RECOMMENDATIONS

The concerned authority like RAJUK, DCC, DWASA etc. should take the immediate and long term measures to overcome the existing problems.
Following recommendations should be taken into considerations:

- ◊ Preparation of legislation, (by laws, rules, regulations) should be involved for Waste reduction
- ◊ There have to be provision for involving interested NGO's, private sector and general public to participate in waste management
- ◊ Formulate the policy for community-based program for strong awareness creation undertaking to win the commitments
- ◊ Involvement of the community in the system of safe household waste management
- ◊ Composting plant should be installed
- ◊ Institutional strengthening should be built for recycling sector where it is a way of managing household waste
- ◊ Informal recyclers have to be encouraged by providing them space to produce their materials
- ◊ Sustainable solid waste management should be assisted through generation of electricity, gas, fertilizer, ceramic product etc
- ◊ Landfill should be designed in such a way that it can sustain for long time and manage waste properly
- ◊ Public awareness program where attention have to be given for reusable household waste

CONCLUSION

Urban solid waste issues represent major problems in developing countries, so infrastructure and technology should be improved to overcome barriers to the safe collection and disposal of urban waste. Effective solid management system is needed to ensure better human health and safety of workers involving in the process of waste disposal. So NGOs can contribute for initiating a environment friendly system, demonstrating new concepts, providing technical training and knowledge to others. In addition to these prerequisites, an effective system of solid waste management must be economically sustainable also.

A community based projects have a demonstrated effect for managing solid wastes and the success of this approach depends largely on identifying and addressing the community's needs. Although Dhaka is a capital city, in spite of being a large number of residences are not completely aware of the health hazard and solid waste related problems. The households are not disposing their waste in bins or a recommended place. Therefore, it is important to launch a long-term awareness program that people can be motivated for enhancing their existing environmental conditions willingly where media can play an integral role for building up this program. Apart from the media, Government Should has taken the policy as soft and hard measures for implementing the system which is environmentally sustainable.

ACKNOWLEDGMENT

The authors would like to thank the authority and workers of DCC and the local people of Uttara area.

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ISBN: 978-984-33-7045-7, PI.122 (1-8)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

3R (Reduce, Reuse and Recycle) Action Plan for the City Corporations in Bangladesh: Paradigm shift of Waste Management to Resource Management

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Abstract

Minimizing the use of resources in the manufacture, distribution and use of products consumed by society with maximum reuse, recycling and recovery has embodied as a concept of 3Rs (**R**educe, **R**euse and **R**ecycle). In recent days, the 3Rs principle has started to gain more attention due to the depletion of natural resources and increase of pollution level in the environment. The perspective of waste management has been changed. It is not viewed as a problem but as an opportunity. There is a paradigm shift in thinking about waste 'not merely as a nuisance but as a resource' and the shift of waste management from 'contain and disposal' to 'resource management'. In this mission, in 2010 Government of Bangladesh has formulated National 3R strategy for waste management. It is further endorsed by the Local Government Ministry for implementation by the City Corporations and the Municipalities.

The 3R strategy sets the goal of waste reduction, reuse and recycling and minimizing waste disposal in open dumps, rivers, flood plains and landfills by 2015 and promotes recycling of waste through mandatory segregation of waste at source as well as creates a market for recycled products and provides incentives for recycling of wastes. It recognizes waste as a resource and advocates for segregation of waste at source, encourages emission reducing technology through private sector investment and tapping the potential of CDM provisions, promotes "polluters pay" principle as well as cleaner production and Environmental Management System (EMS), and supports the participation of the informal sectors who are engaged in the recycling of various materials.

The National 3R strategy directs the local government authorities to develop their own action plans with setting up of quantifiable targets and pursue organic waste recycling through composting, bio-gas and refused derived fuel. With this directives, action plan for 3Rs has been prepared in consultation with the City Corporations and other relevant stakeholders in line with their development agenda, time-line and budgetary provision. The main emphasis has been given on the socialization of 3R through partnership building among the stakeholders to bring the 3R activities into practice in society. This action plan has been prepared based on the prevailing activities and future programs undertaken by different ministries and agencies. A target has been set with gradual incremental percentage of attainment based on the human and financial resources of the City Corporations. Capacity building, awareness development and political commitment are the main drivers of the action plan. This paper will share some of the good practices which are incorporated along with the targeted activities that are recommended in the action plan for the promotion and implementation of 3R through establishing a recycling oriented society in Bangladesh.

Keywords: Waste management, National 3R strategy, Action plan.

1.0 Introduction

Rising waste volumes and increasing complexity of waste streams have become major and growing public health and environmental problems. Due to the growth of population and the changing lifestyles and consumption patterns of people; not only the quantity of waste generation is increasing, the quality and composition of waste is also changing particularly more and more hazardous and toxic waste are adding into the waste stream. To address the problem, waste has to be collected separately and more specific treatment is needed. This needs the mobilization of resources such as human, equipment and finance. It has to be viewed not only as a problem but also as an opportunity. There should be a paradigm shift in thinking about waste 'not merely as a nuisance but as a resource' and the shift of waste management 'from contain and disposal to resource management'.

In recent days, the 3Rs principle has started gaining more attention due to the depletion of natural resources and increase of pollution level in the environment. 3Rs is an approach that can promote the efficient use of resources, harmonizing both environmental and economic concerns through making efforts on waste reduction, reuse and recycling.

Figure 1 and Figure 2 describes the changes in the flow of resources in the production to consumption and final disposal through both unsustainable pattern of economy and sustainable resource-efficient economy with 3Rs. The first diagram shows a 'one way' economy in which resource extraction, production, consumption and final disposal are open ended with little effort in resource-savings making environment at risk. The second diagram is a shift of End of Pipe to 3R a 'closed loop' of resource management in the production-consumption-disposal cycle with maximum utilization of resources and minimal waste production by reusing and recycling of by-products.

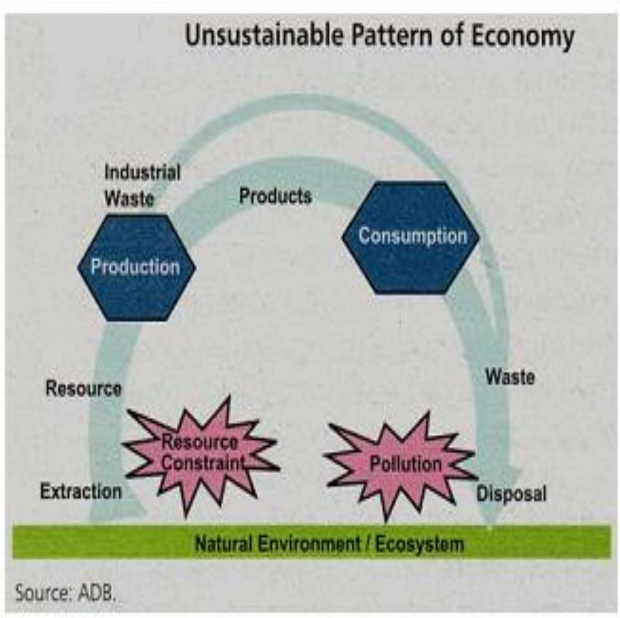

Fig 1: Unsustainable pattern of Economy

Fig 2: Sustainable Resource-Efficient Economy with 3Rs

2.0: Background of 3R initiative

The importance of 3R is emphasized in many global agendas and action plans. Agenda 21 highlights to change consumption and production patterns for sustainable development. The Johannesburg Plan of Implementation (JPOI) adopted at the 2002 World Summit on Sustainable Development stipulated that all countries should promote sustainable consumption and production to facilitate global sustainable development. It has laid emphasis on developing waste management systems, with the highest priority placed on waste prevention and minimization, reuse and recycling and environmentally sound disposal facilities. The thirtieth G8 Summit at Sea Island Georgia, US (June 2004) and the follow-up 3R Ministerial Meeting in Tokyo (April 2005) have directly or indirectly emphasized the critical need for reorienting production and consumption patterns through the effective implementation of 3R principles. At the G8 summit, G8 countries agreed to launch the 3R Initiative in 2004 with the objectives of reducing barriers to the international flow of goods and materials for recycling and remanufacturing and building capacity for the 3Rs in the developing countries. The 3R Initiative towards a ‘Sound Material Cycle Society’ was formally launched at the 3R Ministerial meeting in Tokyo. Since the late 1990s, China has been adopting ‘Circular Economy Policy’ with a shift of its strategies for environmental management from the end-of-pipe approach to integrated life cycle management. Activities of the 3R Initiative in Asia included a series of inter-governmental meetings and expert meeting with an outcome of adopting ‘The Kobe action Plan’. The Kobe action plan has given emphasis to prioritize the 3Rs in the national development strategy. In 2009, the National 3R strategy Development Project has been implemented as a collaborative capacity development programme in six Asian countries including Bangladesh with the support of Ministry of Environment of Japan and United Nations Centre for Regional Development (UNCRD).

3.0 Review of the National 3R (Reduce, Reuse and Recycling) strategy for waste management

Department of Environment has formulated the National 3R (Reduce, Reuse and Recycle) strategy for Bangladesh having a series of national consultation meetings with the concern ministries and other potential stakeholders. The strategy has been introduced with an intention to meet the challenges related with the continuous increase in waste generation and resource demand, intends to raise the priority of environmentally sound waste management and resource efficiency as well as increase institutional capacity. This strategy has been ratified by the Government of Bangladesh (GOB) in 2010. The strategy sets the goal of waste reduction, reuse and recycling and minimizing waste disposal in open dumps, rivers, flood plains and landfills by 2015 and promotes recycling of waste through mandatory segregation of waste at source as well as creates a market for recycled products and provides incentives for recycling of wastes.

- It recognizes waste as a resource and advocates for segregation of waste at source.
- The strategy encourages emission reducing technology and tapping the potential of CDM provisions.
- It encourages the private sector investment
- It promotes “polluters pay” principle as well as cleaner production and Environmental Management System (EMS).
- It supports the participation of the informal sectors who are engaged in the recycling of various materials.
- To promote 3R principles, the strategy recommends:
    - Raising public awareness,
    - Employing appropriate technology,
    - Setting up a 3R secretariat at Department of Environment (DoE)
    - Involving all stakeholder groups through Public-Private Partnership (PPP)
    - Funding through Clean Development Mechanism (CDM)
    - Segregation of waste at source and special treatment for hazardous waste.

It also defines the roles of government agencies, citizens, private sector agencies, NGOs and Media. The National 3R strategy directs the local government authorities to develop their own action plans with setting up of quantifiable targets and pursue organic waste recycling through composting, bio-gas and refused derived fuel.

4.0 Existing situation of recycling in Bangladesh

The process of recycling in Bangladesh is very much in practice informally without control of any statutory body. Recycling provides jobs for waste pickers, business for traders and commercial activities for the owners of certain mills and factories who use wastes as raw materials for producing saleable items. In many cases the recycling saves foreign exchange from importing the things that can be produced locally from wastes.

Recycling is mainly done through unorganized sector, an informal network of waste pickers (both from primary disposal points as well as intermediate/final disposal areas), door-to-door collectors, primary and secondary dealers, and finally the recycling industries. Recyclables (plastic, metal, glass, paper etc.) are mainly recycled informally by small and medium sized industries using local and inefficient technologies in an unhealthy working condition. They lack of modern affordable technology, knowhow, incentives and proper infrastructures. Solid waste management, poverty and recycling are closely linked. Recycling is mainly economics driven as it is a source of livelihood for many unemployed both man and woman. Significant number of women and children are involved in waste picking.

In Bangladesh, recovery and recycling occurs in three phases. In the first phase, the waste generators separate waste which has higher market value such as newspaper, bottles, and plastic containers and sell them to street hawkers. In the second phase, the scavengers are rummage through the wastes near the bins for collecting recyclable materials of low market value such as broken glass, cans, polythene which are discarded by households. The final phase is the collection of recyclable materials by the waste pickers from the waste vehicles immediately after unloading at dumpsites. Scavenging from an economic and social point of view, it economizes on resource use, reduces burden of waste disposal and contributes to environmental conservation. However, they work in wastes in a risky environment without due consideration to their occupational health and safety.

5.0 Source segregation and 3R project in Bangladesh

There is virtually no organized and planned source segregation in any part of Bangladesh. Segregation, if at all, is driven by economic factors except for healthcare waste in a limited scale due to regulatory requirements. Sorting is mostly done by unorganized sector (scavengers and rag pickers) and rarely done by waste generators. The efficiency of segregation is quite low as the unorganized sector tends to segregate only those waste materials which have relatively higher economic return in the recycling market. This segregation and sorting takes place in a very unsafe and hazardous condition. Despite the absence of organized segregation system, quite substantial amount of plastic, metal, paper, glass etc. are collected and recycled. A large number of people ranging from rag pickers to primary dealers, secondary dealers and recycling industries earn their living out of waste recycling.

In contrast, organic waste, which constitutes the largest portion in the waste stream, is often disposed of rather than being segregated and converted into compost, bio-gas etc. Composting is done by the private sectors from waste segregated at the plant. As no national targets have been set up to promote waste minimization, recycling and recovery, the city corporations or municipalities have taken initiative for waste reduction through composting. However, demand and marketability of compost is found a big problem which forced to shut down of some of the composting plants.

Availability of funds to support waste segregation and recycling is a challenging issue. Municipalities are barely able to maintain the basic waste collection and disposal services, heavily subsidized by the government.

Pilot and demonstration projects could play a significant role in complementing the national 3R strategies and policies by motivating the general public, the private sector, and the other key stakeholders on the beneficial aspects and impacts of the 3Rs.

ISBN: 978-984-33-7045-7, PI.122 (1-8)

3R pilot project in Bangladesh

Ministry of Environment and Forest (MOEF) using the Climate Change Trust Fund initiated a demonstration project of 3R (First phase) in 4 communities in Dhaka and 2 communities in Chittagong. The main purpose of the project is to create awareness on source segregation and recycling of waste and reduction of emission of Green House Gases from waste. To address 100 tons of waste of 50,000 families, 70 thousand bins of three different color (Green= Organic, Yellow= Recyclable inorganic and Red= Hazardous) for Dhaka and 50 thousand for Chittagong has been distributed. 180 tricycle vans for Dhaka and 100 for Chittagong with three separate compartments have been made to collect three types of waste. For recycling of waste, in Dhaka a compost plant of 15 ton capacity and in Chittagong 10 ton capacity has been designed.

Fig 3: Source-segregation in three colored bins

Fig 4: Three Chambered Waste Collection vans for separate collection

6.0 Development of Action Plan for 3R

The development of action plan for 3R is essential for effective waste management. This action plan is the road map for the municipalities for sustainable waste management. The National 3R strategy directs the relevant institutions e.g. local government bodies, industries, NGOs, trade bodies such as Chamber of Commerce and Industries to develop their own action plans for achieving National 3R goal in their respective areas. The key issues that are considered for the formulation of Action Plan:

1. Identification of priority subsectors for 3R in waste sector
2. Setting up of quantifiable targets
3. Setting up time line
4. Mobilization of fund to realize the 3R activities
5. Review and updating of targets
6. Assessment and achievements of the actions

6.1 Objectives of the action plan

- To develop a network of stakeholders such as national, local governments, academia, scientific and research community, the private sector, media community, NGOs and the informal sectors for gradual implementation of the components of 3R strategies
- Promote awareness among the general public including school children on the beneficial aspects of the 3Rs
- Gradual implementation of the 3R activities such as source segregation, waste reduction and recycling activities
- To put 3R into practice and creating a recycling oriented society
- To address the issues of sustainable production, consumption and waste minimization through 3R approach

6.2 Key issues of developing action plan

6.2.1: **Role of relevant stakeholders**: Individual, households, community/neighborhood (clubs), Policy makers (ward councilors/officials), business community (SMEs, manufacturers), informal sectors (Waste pickers, secondary buyers), private sector, CBOs/NGOs, research and academic organizations etc. are the potential stakeholders for developing and implementing 3R action plan.

Stakeholders	Roles and Responsibilities
Ministry of Environment	In order to promote and institutionalize effective 3R strategies/policies Ministry of Environment must provide an appropriate political and economic platform in line with the needs and demands of the local community, businesses and the private sector. Develop policies and guidelines with an objective to reducing waste production, reusing materials, and recycling waste for sustainable waste management. Act as 3R Focal point to guide the promotion and implementation of 3R strategies.
Local government authorities (City Corporations/ Municipalities)	The local government authorities could implement the national 3R strategies by initiating a range of projects and activities in collaboration with international partners and donors. Arrange required infrastructure facilities/ finances to implement the strategy. Take initiative for the market of recyclable products Accommodate the informal sector in 3R activities
Donor communities	Bi-lateral/multi-lateral donors can provide both financial and technical resources to promote 3Rs by supporting a wide range of 3R related projects (Pilot/demonstration)
NGOs	NGOs can play an effective role in implementing 3R projects and can also act as advocates for the 3R promotion (awareness creation to secure community participation, community mobilization in the implementation of the strategy) Bridge the ground-based activities such as behavioral change in source segregation, develop green purchasing habits etc.
Private sector	Involvement in recycling activities Investment in 3R related projects Promotion of 3R through CSR
Local Communities	The consent and participation of the local community is essential. Do source-segregation at household Co-operate municipalities to carry our 3R activities
Informal sector	Play supportive role to promote separation and collection of waste at primary level Work in partnership with private sector, NGOs to promote 3R Improve their working condition to reduce health hazards Form co-operatives and establish rights to get justified price Help to phase out children as waste pickers
Small and Medium Enterprises (SMEs)	SMEs using recyclables as raw materials work closely with informal sector and create demand for recyclable materials Adopt cleaner technology and produce environment friendly products Improve health and safety of the workers
Media	Coverage in print and electronic media of 3R activities Organize mass awareness raising campaign Publicity of good practices of 3R
Scientific, research and academic institutions	Research institutions both scientific and academic could conduct research programmes to develop and transfer environmentally sound technologies for the 3Rs. They could play the leading role in introducing and disseminating cleaner production technologies to industries, governments and communities through training , education programmes and other extension and outreach programmes.

6.2.2 Awareness, understanding and involvement of 3R in society: Raising awareness of citizens is essential factor to introduce source separation and reduce amount of waste. Proper introduction of source segregation and 3R cannot be realized without citizen's support. Tools for behavioral change in source segregation of waste (Leaflets, stickers, electronic and print media support, billboards etc.), Promotion of 3R activities (TV commercial on SS, 3R songs), Environmental Education on 3R at school (Waste Bank), PR goods (Cap/T-shirt), 3R fair (Waste Market), Logo/branding etc. can be adopted.

6.2.3 3R Socialization: Partnership building between stakeholders

3R is essentially multi-sectoral. Local Government, Environment, health, education, information, agriculture and other relevant ministries or agencies should work together for the promotion and implementation of 3R activities. NGOs, private sector and social organizations etc. should facilitate to bridging the work with the communities. According to 3R strategy, a 3R wing under the Ministry of Environment with subsequent Inter-ministerial committee, Technology Advisory Group and 3R secretariat has been established to guide the promotion and implementation of 3R strategy. However, to bring the 3R activities into practice in society, there should be participation from all actors and participation which could be ensured through formation of three 3R groups such as 3R promoters (official stakeholder network), 3R supporters (community based volunteer network) and 3R volunteers (young generation volunteer network). In addition, there should be establishment of 3R units in the City Corporations who will promote and implement 3R activities. Mass media (Newspaper, Electronic media) should be joining on a regular basis for promoting the 3R activities. A combined 3R networks involving all stakeholders has been proposed in Figure 5.

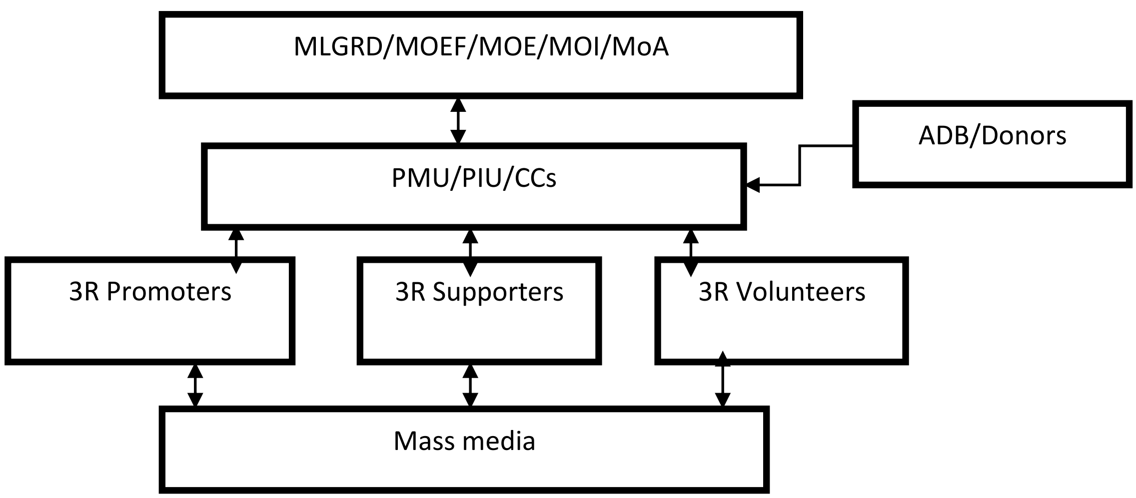

Fig 5: 3R Networks between stakeholders

[3R Promoters: Government Organizations, University and research institutions, private companies etc.
3R Supporters: Community groups, self-motivated citizen, women club, youth club etc.
3R Volunteers: Students etc.]

7.0 Components of 3R Action Plan

A Detailed Action plan has been prepared for each City Corporation based on the following guiding components:

<u>Target setting</u>:

- Waste segregation at source: At least 1000 Households each year
- Waste to be recycled by composting or bio-gas at least 20 % by 2013 on an incremental basis based on capacity.
- Waste to be disposed of at final disposal site is reduced at least 20% by 2013 on an incremental basis based on capacity.

Targeted activities:

- Identifying pilot wards
- Distribution household garbage bins and collection vans (organic and inorganic)
- Produce source-separation instruction tools
- Environmental education and public relation activities
- Implementation of source separation
- Development of Material Recovery Facility (MRF)
- Construction of compost plant
- Compost production and sell

Time line:
Short-term (Year 2013-2015)
Mid-term (2016-2018)
Long-term (2019-2021)
Budget:
City Corporations, Municipalities, Donor Agencies

8.0 Conclusion:

The action plan for 3R prepared for the City Corporations/Municipalities has been based on the prevailing activities and future programs taken by different ministries and agencies. The guiding principles of the National 3R strategy have been followed in preparation of the action plan. A target has been set with gradual incremental percentage of attainment in consultation with the City Corporations based on their human and financial resources. Capacity building, awareness development and political commitment are the important drivers to make the action plan workable. The ultimate goal of the Action Plan is to establish a recycling oriented society where sustainable production and consumption are realized which can be achieved through gradual implementation of the targets set in the 3R Action Plan.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.127 (1-8)

Proceedings of the WasteSafe 2013 – 3rd International Conference on Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Mathematical Model Showing The Benefit-Cost Ratio Per Unit Mass for the Solid Waste Management of Dhaka City

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ABSTRACT

Dhaka, the capital of Bangladesh, is generating more than 5000 tons of solid wastes per day. The Dhaka City Corporation, the responsible authority, is only dumping these wastes or simply burning it down without treating them further as a very useful source of energy. The research objective is to bring an engineering solution of the present problem. A Massive Integrated Bio-plant is designed, based on that a mathematical model showing benefit-cost ratio of it. The method has been formulated using an integer linear problem. The proposed model includes: trucks for transportation of waste, replacement trucks and their depots, incineration with energy recovery, dumping site, plastic plant, bio-gas plant, fertilizer plant etc. The obtained result is the benefit-cost ratio per mass derived from the cost owing to investment and management cost, operational costs from the use of replacement trucks, benefit from energy generation from various plants.

KEYWORDS

Solid Waste Management, Mathematical Model, Benefit-Cost Ratio, Massive Integrated Bio-plant.

INTRODUCTION

The protection of the environment and natural resources is increasingly becoming very important through environmentally sustainable waste management program. Therefore following the part of waste managers, a sustainable approach to the waste management and to integrate strategies that will produce the best practicable option becomes necessary. This is a very challenging task since it involves taking into account economic, technical, regulatory, and environmental issues (see Costi et al [1]). Waste management can become more complex if social and political considerations are also into account.

It is not very ago, Dhaka, the capital of Bangladesh possessed an image as a city of green and water bodies. Within last few decades this serene and tranquil city has been transformed into one the most polluted and crowded cities in the world. Dhaka City Corporation (DCC) is responsible for managing the city. The juristic of DCC area is 360 km^2 and accommodates over 15 million people. It is projected that the population would be more than 20 million by the year 2015. Right now it is the 9th largest cities in the world and 28th among the mostly densely populated cities in the world (23029/km^2).

People around Dhaka city gathered here for better jobs and livelihood because Dhaka is called the city of opportunity for the people of Bangladesh. This huge amount of population is generating massive amount of wastes which DCC is dealing with. Unfortunately most of these wastes are dumped in the landfill areas and then burnt. If utilized in the engineering way with proper technology under the supervision of experts, these wastes can be recycled, reused and can be used to generate electricity, biogases and various different products.

This is the high time to plan a massive project that can stand parallel and uphold the gas and electricity scarcity. The developed countries like ANNEX countries which include UK, Germany, and USA etc. have already developed the technology of building massive integrated bio-gas plant which is used for multiple ways of generating various products and useful energy. Unfortunately the people of Bangladesh are being deprived of enjoying such facilitations even though they are producing massive wastes and uselessly throwing them away. People of Dhaka city largely depends on gas and electricity for cooking and other activities. As the population increases the problem will also rise and it can be easily predicted that one day there will be nothing to spare for these poor citizens of Dhaka!

RESEARCH OBJECTIVES

The establishment of the mathematical model is on a massive integrated bio-plant. The work focuses on the construction and design of a schematic of one such plant. The study will also illustrate a detailed description of the mathematical model that can be used as tools for decision makers in the day to day planning and management of integrated program of solid waste collection, incineration, recycling, treatment and disposal.

METHODOLOGY

Schematic Diagram of the Massive Integrated Bio-plant

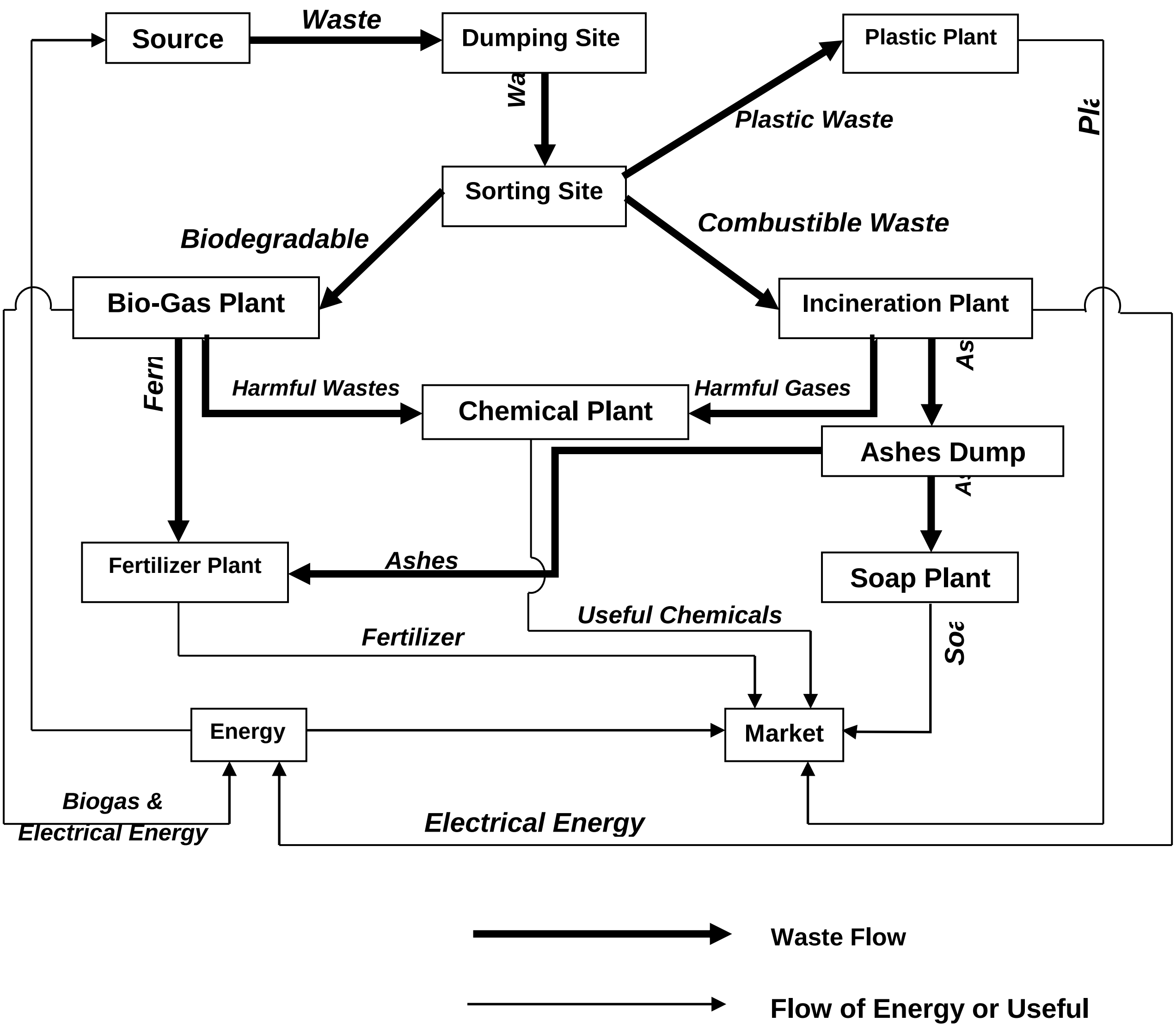

Figure 01: Schematic Design of a Massive Integrated Bio Plant

Working Principle of the Massive Integrated Bio-plant

Wastes generated by the sources are dumped in the dumping sites. These wastes after some treatment are sent to the sorting sites where three categories of wastes are separted; namely the biodegradable wastes, combustible wastes and plastic wastes.

Biodegradable wastes are those wastes which has got the putrefying ability like garbage. Therefore these wastes are transferred to Bio Plant. Combustible wastes are the wastes which have high heating value, low humidity, moderate activation energy and which are easily burnt; like paper, leaves, bits of wood, straw etc. are taken to the incineration plant for combustion or burning. Plastic Wastes like ployvinyl chloride (PVC), low-density polyethene (LDPE), polypropylene (PP), polystyrene (PS) are taken to the plastic plants, mainly for recycling after series of treatments.

Biogas plant produces bio methane and electrical energy as the useful products, which are directly or indirectly passed back to the source or market. This plant also produces harmful wastes especially gases which are treated in the chemical plant before it is released to the environment or send back to the market.The ferments produced in the biogas plants are transported to the fertilizer plant where they are converted to low priced fertilizer which is back to the market.

The purpose of incineration plant is to treat combustible waste. The electrical energy produced is back to the source directly or indirectly. The harmful gases produced are treated in the nearby chemical plant before it is released to the environment and useful chemical to the market. The ashes produced are dumped to the ash dump sites where the types of ashes are classified. One part ashes are transported to the fertilizer plant and the other part is transported to the soap plant.

Plastic plants take care of the plastics wastes most of which are recycled back to the market. The soap plants are plants where different soaps are manufactured. There may be different brands of soaps that can be manufactured by certain specific type of ashes. The chemical plants are those where harmful wastes are converted to useful product and human friendly chemicals so that there would be no adverse effect of these chemicals on the environment.

Mathematical Model Formation

The model is formulated as an integer linear program (see Wolsey [14]). It has been presented as a decision making tool for solid waste planners in decisions concerning the overall management of solid waste. Several treatment plants and facilities along with the waste collection component has been considered within the proposed model: trucks for the transportation of waste; replacement trucks and their depots; incinerators with energy recovery; dumping site; several plants for recycling useful products and energy etc. The user may prefer to measure the transportation costs in terms of costs per mass made from the waste source; in that case the model is more appropriate.

The objective function of the model describes tipping fees, total investment and maintenance costs, costs for buying or hiring trucks, transportation costs as well as operational costs from the use of replacement trucks. The benefits from energy generation, compost, and recycling are also incorporated in the objective function. Apart from the transportation costs, installation and operational costs for plants and landfills, and benefits from different plants, the objective function also includes truck purchase costs as well as costs due to the presence of replacement trucks depots. Special attention has been given to deciding the number and the type of trucks that are used to transport a given type of waste from the waste collection points to the plants or landfills. Replacement trucks are also considered with the observation of possible breakdowns of the operational trucks. Moreover, instead of measuring the amount of waste using the number of trucks used multiplied by their capacities, continuous variables can be introduced to measure directly the amount of waste that goes to the plants and landfills.

Assumptions

The mathematical model is based on the following assumptions:

1. The waste handling operations in the mathematical model are to be executed daily.

2. Each plant or site is considered to have the benefit-cost ratio more than 1 and is justified to invest for the proposed model.

3. It is assumed that each plant or site is giving more rate of return than minimum acceptable rate of return (MARR).

4. Waste source and the dumping site are located at the centers of the waste generating areas.

5. The dumping site and the sorting site is considered to be at the same location.

6. The incinerator and the ash dump site is also considered at the same location.

Schematic Model for Mathematical Formation

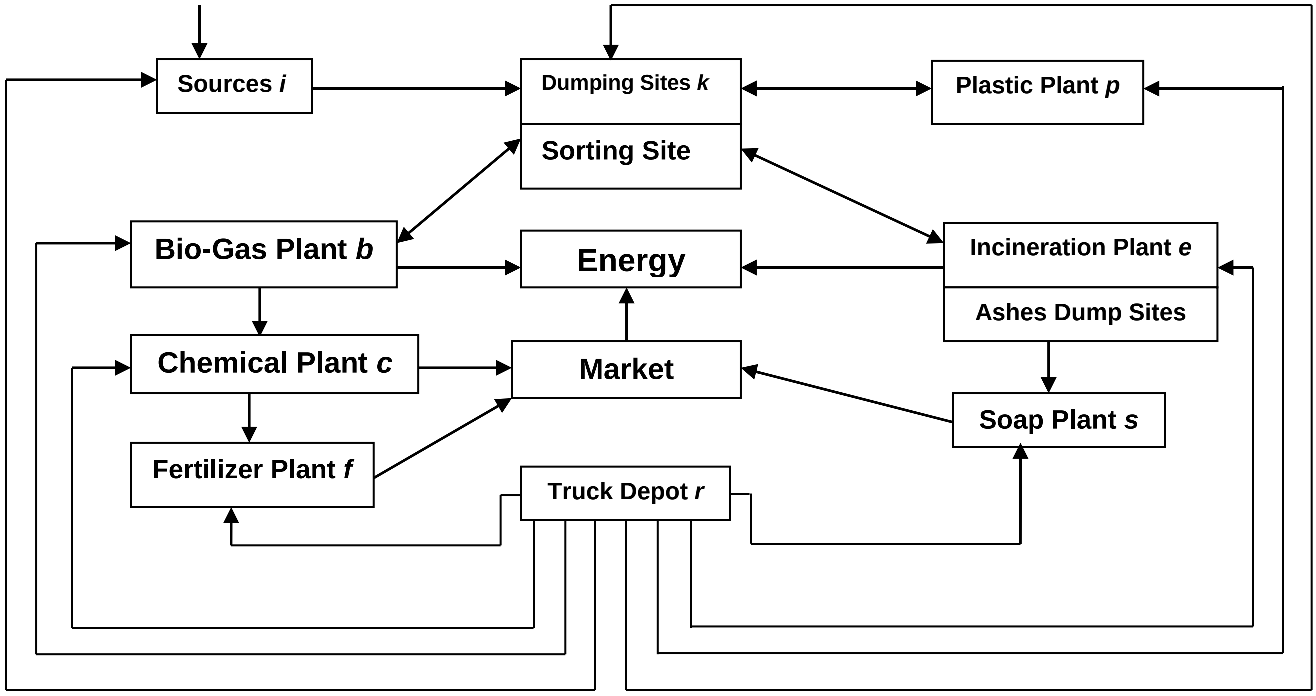

Figure 02: A Schematic Diagram of the Massive Integrated Bio plant according to the assumptions

Indices

i = 1, 2…	I: location of waste source
b = 1, 2…	B: location of biogas plant
c = 1, 2…	C: location of chemical plant
e = 1, 2…	E: location of incineration plant
f = 1, 2…	F: location of fertilization plant
k = 1, 2…	K: location of dumping site
p = 1, 2…	P: location of plastic plant
r = 1, 2…	R: location of truck depot
s = 1, 2…	S: location of soap plant
l = 1, 2…	L: truck type
g = 1, 2…	G: waste Type

Variables

Φ_{kbg}, Φ_{keg}, Φ_{kpg}: respectively amount of waste (in tons) of type *g* collected everyday by trucks of type *l* from dumping site *k* to a biogas plant at *b*, to an incinerator at *e* and to a Plastic Plant *p*.

x_{kbg}, x_{kpg}, x_{keg}: respectively the number of trucks of type *l* used every day to carry waste of type *g* dumping site *k* to a biogas plant at *b*, to a Plastic Plant *p* and to an incinerator at *e*.

ω_{bkg}, ω_{ekg}, ω_{pkg}: respectively amount of waste (in tons) of type *g* collected everyday by trucks of type *l* from a bio-gas plant at *b*, an incinerator at *e*, to a Plastic Plant *p* to the Damping Site *k.*

y_{ikg}, y_{bkg}, y_{ekg}, y_{pkg}: the number of trucks of type *l* used every day to carry waste of type *g* from a source *i*, biogas plant at *b*, an incinerator at *e*, to a plastic plant *p* to a dumping site *k*.

n_{rb}, n_{rc}, n_{re}, n_{rf}, n_{rk}, n_{rp}, n_{rs}: respectively number of trucks of type *l* used every day from a replacement trucks depot at *r* to a biogas plant at *b*, to a chemical plant at *c*, to an incinerator at *e*, to a fertilizer plant at *f*, to a dumping site at *k*, to a plastic plant *p* and to a soap plant at *s*.

z_b, z_c, z_e, z_f, z_k, z_p, z_{rs}, z_r : 0-1 variables indicating respectively, the presence of biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, to a plastic plant *p*, a soap plant at *s* and a truck depot at *r*.

w_b, w_c, w_e, w_f, w_k, w_p, w_s : amount of waste transported everyday respectively, to a biogas plant at *b*, to a chemical plant at *c*, to an incinerator at *e*, to a fertilizer plant at *f*, to a dumping site at *k*, to a plastic plant *p* and to a soap plant at *s*.

T_l: The number of trucks of type *l* used every day.

$(RT)_l$: The number of replacement trucks of type *l* required every day.

Input Data/Parameter

α_l : capacity (in tons) of a truck of type *l*.

m_{rb}, m_{rc}, m_{re}, m_{rf}, m_{rk}, m_{rp}, m_{rs}, m_{ri}: respectively the cost of moving a truck of type *l* from a replacement trucks depot at *r* to a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, a plastic plant *p*, a soap plant at *s* and a waste source at *i*.

u_{kb}, u_{kp}, u_{ke}: respectively transportation cost per unit of waste carried by a truck of type *l* from a dumping site at *k* to biogas plant at *b*, to a plastic plant *p* and to an incinerator at *e*.

d_{ik},d_{bk}, d_{ek}, d_{pk} : respectively transportation cost per unit of waste carried by a truck of type *l* from a waste source at *i*, a biogas plant at *b*, an incinerator at *e* and a plastic plant at *p* to a dumping site at *k*.

β_b, β_c, β_e, β_f, β_p, β_s : revenue respectively, per unit of waste at bio-gas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f* , a plastic plant at *p* and a soap plant at *s*.

f_l: the cost of buying a new truck of type *l*, $l = 1 ..., L$.

ρ_b, ρ_c, ρ_e, ρ_f, ρ_p, ρ_s : fraction (%) of unrecovered waste respectively, at biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, to a plastic plant *p* and a soap plant at *s*.

δ_b, δ_c, δ_e, δ_f, δ_k, δ_p, δ_s, δ_r : respectively installation cost incurred in opening a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, to a plastic plant *p*, a soap plant at *s* and a replacement trucks depot at *r*.

γ_b, γ_c, γ_e, γ_f, γ_k, γ_p, γ_s : respectively variable cost incurred in handling a unit of waste at a biogas plant at *b*, a chemical plant at *c*, an incinerator at *e*, a fertilizer plant at *f*, a dumping site at *k*, a plastic plant at *p* and a soap plant at *s*.

RESULTS/FINDINGS

The objective function represents the overall daily waste management costs. The first component, V_1 *(z, w, Φ, ω)*, gives the investment and waste handling expenses as well as transportation costs per unit mass. The second component, $V_2(n,z)$, gives expenses owing to the use of replacement trucks. The third component, $V_3(x,y,n)$, is the total cost incurred for buying all the trucks of various kinds and capacities. In this function we have the installation cost parameters δ, and the variable cost parameters γ. The variables Φ and ω have been defined before. The component $Bn\ (w)$ is the income and revenues earned from per unit waste from different plants. The benefit-cost ratio per unit mass can then be derived dividing the benefit by the total cost, V, which is the summation of all the cost components V_1, V_2 and V_3. The model works on daily basis.

The component V_1 will show the overall cost for installation, transportations and other variable cost (e.g. maintenance).

$$\begin{aligned} V_1(z, w, \Phi, \omega) = [&\Sigma_b(\delta_b z_b + \gamma_b w_b) + \Sigma_c(\delta_c z_c + \gamma_c w_c) + \Sigma_e(\delta_e z_e + \gamma_e w_e) + \Sigma_f(\delta_f z_f + \gamma_f w_f) \\ &+ \Sigma_k(\delta_k z_k + \gamma_k w_k) + \Sigma_s(\delta_s z_s + \gamma_s w_s) + \Sigma_p(\delta_p z_p + \gamma_p w_p)] + \alpha_l[\Sigma_{glkb} u_{kb} \Phi_{kbg} \\ &+ \Sigma_{glkp} u_{kp} \Phi_{kpg} + \Sigma_{glke} u_{ke} \Phi_{keg} + \Sigma_{glik} d_{ik} \omega_{ikg} + \Sigma_{glbk} d_{bk} \omega_{bkg} \\ &+ \Sigma_{glek} d_{ek} \omega_{ekg} + \Sigma_{glpk} d_{pk} \omega_{pkg}] \end{aligned} \quad (1)$$

The component V_2 concerns the total costs owing to the presence of replacement trucks (or standby trucks).

$$\begin{aligned} V_2(n,z) = &\Sigma_{ril}(m_{ri} n_{ri}) + \Sigma_{rbl}(m_{rb} n_{rb}) + \Sigma_{rcl}(m_{rc} n_{rc}) + \Sigma_{rel}(m_{re} n_{re}) + \Sigma_{rfl}(m_{rf} n_{rf}) \\ &+ \Sigma_{rkl}(m_{rk} n_{rk}) + \Sigma_{rsl}(m_{rs} n_{rs}) + \Sigma_{rpl}(m_{rp} n_{rp}) + \Sigma_r(\delta_r z_r) \end{aligned} \quad (2)$$

The component V_3 gives the total cost for buying all trucks required in the daily management of waste.

$$V_3(x,y,n) = \Sigma_l f_l [T_l + (RT)_l] \quad (3)$$

The component Bn gives the benefits at the plants owing to the production of electric energy, compost, recycled materials and other revenues of the useful part per unit waste.

$$\begin{aligned} Bn(w) = &\Sigma_b \beta_b(1 - \rho_b) w_b + \Sigma_c \beta_c(1 - \rho_c) w_c + \Sigma_e \beta_e(1 - \rho_e) w_e \\ &+ \Sigma_f \beta_f(1 - \rho_f) w_f + \Sigma_p \beta_p(1 - \rho_p) w_p + \Sigma_s \beta_s(1 - \rho_s) w_s \end{aligned} \quad (4)$$

Total Cost:

$$V = V_1 + V_2 + V_3 \quad (5)$$

The benefit-cost ratio per unit trip:

$$\text{Benefit: Total Cost} = Bn/V \quad (6)$$

DISCUSSIONS

Limitations of the Mathematical Model

Some of the limitations of the model are as follows:

1. Although regulatory, technical, and environmental constraints are not comprehensively considered in these models, it is assumed that they can be handled in details without affecting the results of the model.

2. In our model we neglect the traffic jam in Dhaka city. If this would be considered the model would be more realistic.

3. In reality the united sites like the dumping site, sorting site, incinerator, and the ash dumping site may not exists at the same place. In that case the mathematical models need to be modified.

4. As this is a massive project design and requires a huge amount of money to start with. As it needs time to construct, time to time modification of the design might result a better benefit. This means it is not the final model and has a lot of scopes to be modified.

5. Selection of suitable locations for such a massive project might give a bit of trouble for the investors. They may not risk their money on the basis of these models only.

6. Some of the plant in the design might give lesser benefit-cost ratio and should be discarded. But in our model we assume the individual plant has got the benefit cost ratio more than one, so that the mathematical models could be established.

7. During transportation there is some loss of the waste due to littering or scattering.

Application of the Mathematical Model

1. The mathematical model can be simulated in AMPL modeling system with a compatible solver CPLEX (see ILOG AMPL CPLEX System [10]). This powerful algebraic modeling language solves problems in linear, non-linear, and integer programming etc.

2. The model can be used as important tools for planners in solid waste management in an urban environment.

3. The model may as well be adapted for use in other areas of application like industrial warehouse location and product distributions among industry agents.

CONCLUSIONS

The study illustrates a schematic design of a massive integrated bio plant. The plant concerns with following plants: biogas plants, plastic plants, incinerators, fertilizer plants, soap plants and chemical plants. These plants work in parallel with dumping sites, truck depots and the waste source. The model works on daily basis and the revenues from these plants are considered as benefit; the total cost includes the installation cost, variable cost, maintenance cost, tipping cost, transportation cost and the cost for buying trucks. Based on the devise a mathematical model is developed showing the benefit-cost ratio per unit mass. The mathematical formula is derived applying the linear integer program.

The formula only works under certain assumptions and limitations. The performance can be further studied using a powerful algebraic programming AMPL and CPLEX. In that case the overall management of solid waste may be more easily accessible to solid waste planner in decision making. Although implementation of this mathematical model is expensive, risky and time consuming; there are various ways this model can be modified and made suitable in real life.

ACKNOWLEDGEMENTS

My special thanks to all the Professors of my university, officers working in Dhaka City Corporation (DCC) and Local Government Engineering Department (LGED). Finally I thank my family whose love has kept me going through the project; my friends in IUT and colleagues in my office deserve thanks too.

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Solid Waste Management in the Developing Countries
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SITE SELECTION FOR WASTE DISPOSAL FOR DHAKA CITY CORPORATION (DCC) AREA USING GIS

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ABSTRACT

Waste disposal is an important part of waste management system, which requires much attention to avoid environmental pollution. In context of Bangladesh waste disposal and management is in bad shape in urban area, since urban inhabitants generate huge amount of municipal solid waste daily and population density is high. Only major cities have some sort of garbage disposal system. In the major cities like Dhaka city in Bangladesh, the amount of waste generated in 1985 was 1040 tons/day, while in 1990 it was 1776 tons/day and in 1998 was 2398 tons/day. The gradual increase of waste generation continued and in 1999, it was 3500 tons/day and in 2002 was 4000 tons/day. As a part of improper waste management system selection of solid waste disposal sites for this city does not consider the environmental factors. Because selection of disposal sites is not located considering residential area, clinic/hospital, educational institution, drainage network, socio cultural and religious institution. In this article, major portion of the data required for the study have been collected from RAJUK. GIS based shape files of DCC ward, land use map and structures map have been collected from DAP (Detailed Area Plan, 2010). Different datasets have been compiled in the Arc GIS 9.2 software and using the 'Spatial Analyst' tool, analysis has been conducted to find out the suitable waste disposal site. In this article, demographic status of the area which are selected for the waste disposal site and accessibility of those sites have been analyzed to attain the suitability assessment of proposed waste disposal sites.

INTRODUCTION

Urban solid waste management is considered as one of the most immediate and serious environmental problems confronting municipal authorities in developing countries like Bangladesh. The rapid growth of population and urbanization decreases the non-renewable resources and disposal of effluent and toxic waste indiscriminately are some of the major environmental issues posing threats to the existence of human being. The most common problems associated with improper management of solid waste include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (*Rahman* et al. 2008). Waste disposing is an important part of waste management system, which requires much attention to avoid environmental pollution. In context of Bangladesh waste disposal and management is in bad shape in urban area, since urban inhabitants generate huge amount of municipal solid waste daily and population density is high.

At present, Dhaka city is generating 4000 tons of solid waste per day with a per capita generation 0.5 kg/day. According to joint study of JICA and DCC, if the present growth of population and city development continue, waste generation will also increase and by 2010, waste generation in Dhaka city will be 10,000 tons/day, which might be reached to 40,000 tons/day by 2025 (*Yusuf* 2004).This view obviously exhibits the excessive waste generation rate of the Dhaka city. But there are not enough landfill sites for disposing the waste and the existing landfill sites will be filled up within one and half year only. Then it will be created huge crisis.

A suitable disposal site must have environmental safety criteria and attributes that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment while it is operating. Criteria for site selection include natural physical characteristics as well as socioeconomic, ecological and land-use factors. The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or other associated features, which help in selection of sites. Site selection procedures can benefit from the appropriate use of GIS. The use of GIS in selection process will reduce the time and enhance the accuracy.

OBJECTIVE

The objectives are the main guidance of any study or project to go through for achieving some specific goals. Fixation of objectives makes any study or project more systematic and to continue on the right track towards the goal. The main objectives of the study are-

1. To draw up some suitable solid waste disposal sites using GIS technique in DCC area.
2. To assess the feasibility of the proposed sites (accessibility to the site, vacant area, demographic characteristics)

CONTEXT OF DCC

About 50% waste is collected by DCC, another 15% is recycled and other 35% is discarded into streets, drains, canals and open spaces.

- DCC sweeps roads & drains daily.
- Accumulate wastes from roadside.
- Cleaners collect & transfer to the nearest dustbin/container.
- DCC's truck dump to the dumping depots.
- Dressing by bulldozers, tire dozers, pay loaders & excavators.

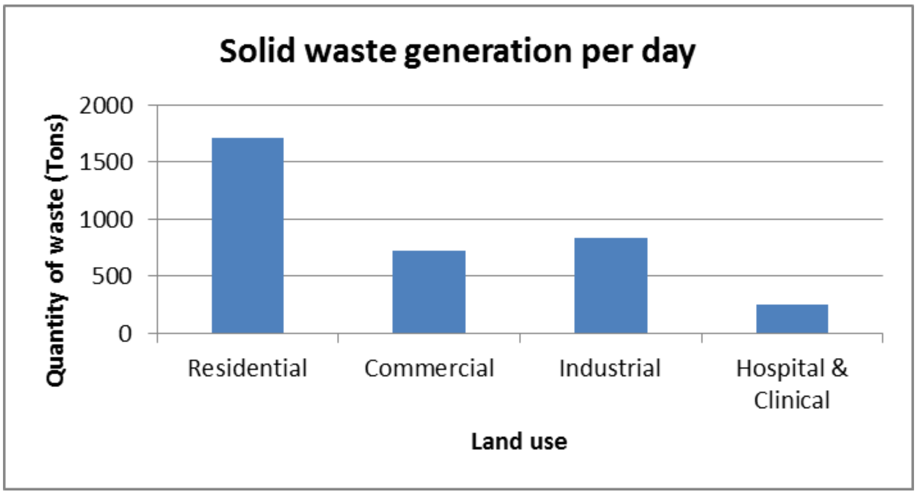

Figure 1: Solid waste generation per day in DCC area

Impact of solid waste disposal on environment-

- Open air dumping creates unhygienic and poses enormous threat to the people.
- Causes aesthetic problem and nuisance due to nauseating pungent odor.
- Promotes spreading of diseases.
- The situation further aggravated by the indiscriminate disposal of Hospital and Clinical Waste.
- Presence of extremely high level of Total and Facial coli form.
- Pollute water bodies.
- Carbon dioxide and Methane produced from solid waste are extremely harmful to the environment.
- Gases are produced in the landfills through aerobic and anaerobic decomposition of organic compounds, which are threat to the environment (*Zahur* 2007).

METHODOLOGY

Methodology describes the design of a research procedure. It does not indicate a set of method taken to conduct a research but also refers to rationale and logical assumptions considered by the researchers in a particular study. Methodology does not refer to research or any specific analysis technique; rather it refers to anything that has been incorporated logically to fulfill the objectives of the study. Here both of the method and methodology have been described. Description of the data sources, data collection and organization of the collected data are given here.

Problem identification and literature review: A contemporary issue of the lack of waste disposal site has been illustrated in background of the study. On the basis of the problem, proposals of new feasible waste disposal sites with specific objectives have been initiated. An extensive literature review has been performed for generating the ideas, understanding regarding the location criteria for selecting the waste disposal site. The use of GIS software for site selection has also been adapted for the simplicity in the project work.

Data collection: The data for this study has been collected from only secondary sources. Major portion of the data have been collected from RAJUK. GIS based shape file of DCC ward, land use map and structures map shape files have been collected from DAP (Detailed Area Map, 2010). Proposals and recommendation of relevant thesis, journal will be used in this research for the analysis purpose. Demographic characteristics of the wards have also been collected to facilitate the project work.

Data compilation and analysis: To fulfill the first objective, different datasets have been compiled in the Arc GIS 9.2 software and using the 'Spatial Analyst' tool, analysis has been conducted to find out the suitable waste disposal site. For the logical output, different datasets have been weighted at different status following their existing significance. Datasets have been compiled through ArcGIS 9.2, Microsoft Access and Microsoft Excel to illustrate some maps, charts and figures. Demographic status of the area which are selected for the waste disposal site and accessibility of those sites have been analyzed to attain the 2ndobjective.

Proposals and recommendation: The proposals and recommendations of this study have been formulated based on the analyzed data. These have been clarified by different charts, maps and theory output conducted in the analysis stage.

STUDY AREA PROFILE

DCC has been selected as a study area in which an attempt has been made to select the suitable waste disposal site. Existing land fill site will be filled up within one and half year only. So on an urgent basis, some new sites should be selected for DCC area. There are 90 wards under the jurisdiction of Dhaka City Corporation among which 89 wards have been selected in order to carry out this research. The researchers could not include Ward no. 01 because of data unavailability.

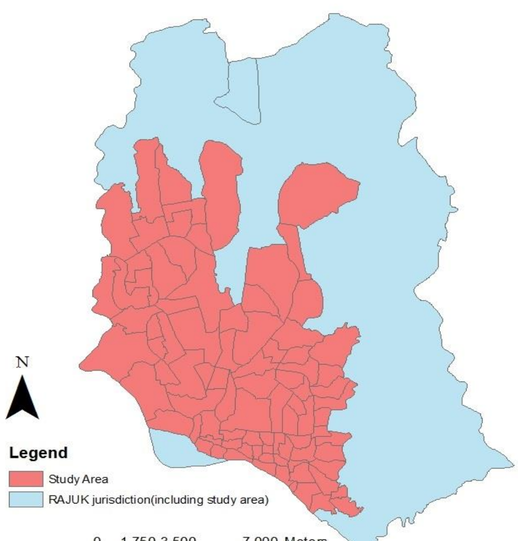

Figure 2: Location of Study area

The total study area has an area of about 30,869 acres (124.98 sq. km) and its population is about 6,890,885 persons with average density of 169 persons per acre (DAP 2010).

There are two sites where solid waste from Dhaka city is dumped and both waste sites are managed by DCC. According to DCC official, at present DCC is now dumping larger quantities of waste in Matuail dumpsite and a small quantities in the Amin Bazar dumpsite. Crude dumping is practiced in both dumpsites of DCC. Government provided permission to acquire 72 acres land for Matuail dumpsite. Unfortunately, DCC got the possession of the 50.83 acres land only, while compensation of 21.17 acres land was not paid that's why DCC didn't get the possession of that land. According to DCC, Matuail solid waste dumpsite at Demra is already filled up and will be possible to dump maximum one and half year only. DCC is trying to extend Matuail waste dumpsite by another 50 acres of land which is under process of approval. Besides this, DCC is also trying to acquire another patch of 53 acres land in Amin Bazar. This process is also stopped due to negligence of RAJUK and DOE (*Yusuf* 2004).

Matuail and Gabtoli both dumpsites are mere practice crude dumping and there is no system of leachate collection. Leachate infiltrate and can cause ground water contamination. Moreover leachate drainage to neighboring to neighboring water bodies such as wetland where fish cultivation is in progress and through food chain city citizen could be affected and can create a great health concern for city dwellers due to unsustainable practice of solid waste management (*Yusuf* 2004).

ANALYSIS

Before starting the project work, a coordinate system named 'BTM (Bangladesh Transverse Mercator)' has been projected to fit the data in the real world situation. The whole work is divided into 4 steps to facilitate the project work.

Step 1: Inputting datasets

First, it has to add the 3 shape file into Arc GIS 9.2 of DCC ward, Land use and existing landfill site. DCC ward shape file and Land use shape file are in the format of polygon feature and existing landfill site is in the format of point feature. So the final map including all those shape files is on the following-

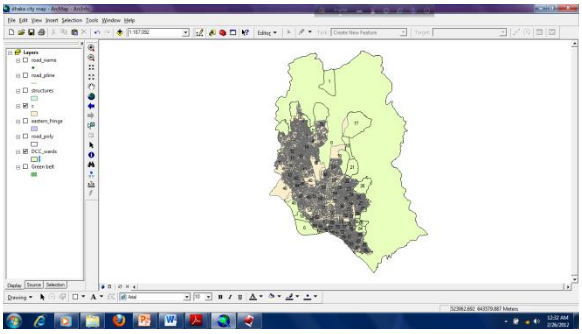

Figure 3: Input all the datasets in GIS software

Land use shape file has been transformed into education and research, health facility, vacant area, planned residential, recreational area and water body shape files. Then the new created shape files (polygon feature) have been converted into point features to ease the function of software.

Step 2: Deriving datasets

Deriving dataset from the input datasets is the next step in the suitability model. Following datasets of land use have to derive using 'Spatial Analyst' tool.

- Distance from existing landfill sites
- Distance from education and Research
- Distance from health facility
- Distance from vacant land
- Distance from planned residential

- Distance from recreational sites
- Distance from water body
- Distance from restricted area

Eight raster maps from 8 land uses have been created. And in all maps, the output cell size is fixed to 30*30 pixels.

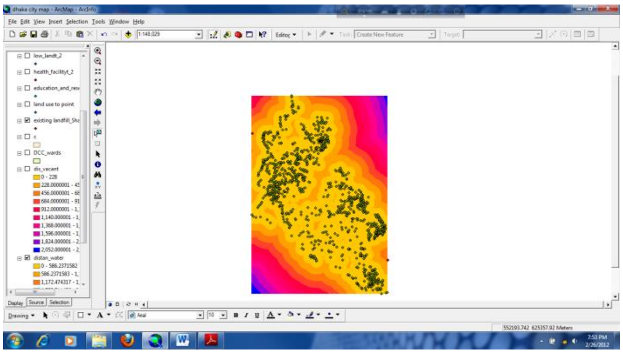

Figure 4: Distance raster map

Step 3: Reclassifying datasets

It is now required the datasets to find out the best location for waste disposal site. The next step is to combine them to find out where the potential locations can be found. In order to combine the datasets, a common scale must be set first. It is necessary to reclassify the datasets to a common scale, within the range 1-10, giving higher values to attribute within each dataset that are more suitable for locating the waste disposal site.

- Reclassify Distance from existing landfill sites
- Reclassify Distance from education and Research
- Reclassify Distance from health facility
- Reclassify Distance from planned residential
- Reclassify Distance from recreational sites
- Reclassify Distance from water body
- Reclassify Distance from restricted area
- Reclassify Distance from vacant land

It is preferable to locate the new site away from the existing sites to spread out their location throughout the DCC area. All other land uses except vacant land are best suited if the proposed waste disposal site will be far from them. The farthest distance from those land uses will get the value of 10 and according to it, the lowest distance will get the value of 1. By doing this, it can be easily determined that which areas are far from and which areas are nearer to those land uses. In case of vacant land, the farthest distance from it will get the value of 1 and the lowest distance will take the value of 10.

In all cases, 'Equal Interval' is chosen as classification method. And the total number of classes is 10.
Spatial Analyst ⟶ Reclassify

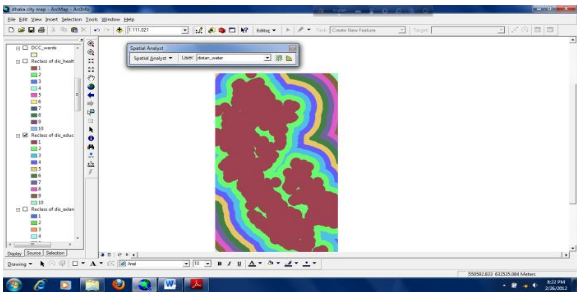

Figure 5: Final reclassify raster map

A total of 8 reclassification map have been prepared from the 8 raster map. Then those maps have taken into the final steps to find out the final output.

Step 4: Weighting and combining datasets

After applying the common scale in the datasets where higher values are given to those attributes that are considered more suitable within each dataset, it is the final step to combine them to find the most suitable locations. Now it has to weight all datasets giving each a percentage influence. The higher the percentage, the more influence a particular dataset will have in the suitability model.

The percentage of each dataset is given below (each percentage is divided by 100 to normalize the value)-Reclassify Distance from existing landfill sites- 0.05 (5%), Reclassify Distance from education and Research- 0.2 (20%), Reclassify Distance from health facility- 0.2 (20%), Reclassify Distance from planned residential- 0.1 (10%), Reclassify Distance from recreational sites- 0.02 (2%), Reclassify Distance from water body- 0.2 (20%), Reclassify Distance from restricted area- 0.08 (8%) and Reclassify Distance from vacant land- 0.15 (15%)
Spatial Analyst ⟶ Raster Calculator

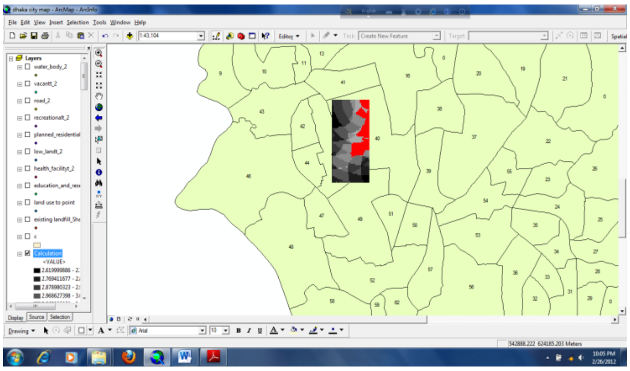

Figure 6: Map generation after Raster calculation

The output raster datasets show the location (red colored) according to the criteria which were set in the suitability model. Now it is necessary to assess the locations. This should be done in the field, as well as examining the demographic data of those areas.

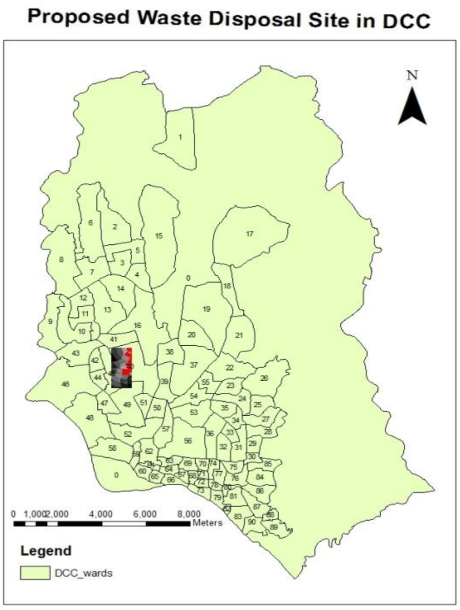

Figure 7: Map showing proposed waste disposal site in DCC area

It has been shown the final locations for waste disposal site for DCC area in the above map. By using the 'Spatial Analyst' tool with some logical criteria, it has come into solution about the proposed site.

SUITABILITY ASSESSMENT OF THE SITE

This portion of the study has gone through to assess the existing suitability of the proposed site according to their location. It has been tried to find out their suitability considering the demographic statistics and accessibility to that site.

This location is merging with two wards 40 and 45. Ward no 40 and 45 mainly cover the 'Mohammadpur area'. The total area of ward no 40 and 45 is about 846 acre and 346 acre respectively. Density of the two wards is very much low with respect to the density of DCC area which is calculated from the projected population of 2010 (BBS 2001). There are some vacant spaces in ward no 40 but in a low scale.

Table 1: Demographic statistics of 40 and 45 ward

Ward	Area in acre	Area in hectare	Projected Population (2010)	Density per acre
40	845.9	342.47	96142	114
45	346.27	140.19	61926	179

There has been accessibility in this location by roadway. So it creates no problem from the aspect of transportation planning mainly for the waste carrying vehicles. Accessibility to that location is also significant which can be easily depicted from the following figure.

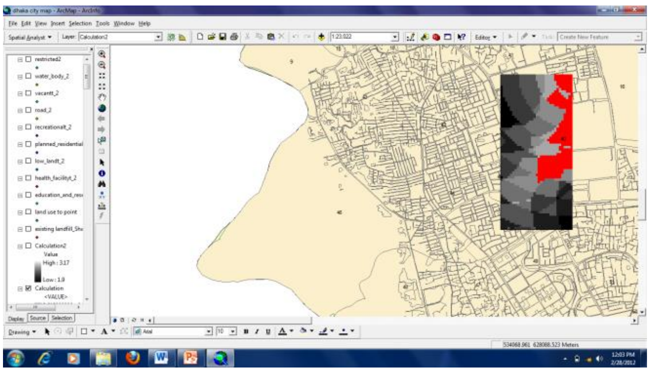

Figure 8: Road network in the proposed sites

RECOMMENDATION

Some proposals have been recommended along with the site selection are in the following:

- Effective transportation planning is required in the new sites mainly enough space for turning, unloading etc. for the waste carrying vehicles.
- Proper OHS (occupational health and safety) measures should be taken for the people who are involved in this work.
- It will be recommended for proper solid waste management (such as Leachate management) in the new sites, may be in cooperation with government and non-government organizations such as JICA.
- There should be some provision for composting and incineration which reduce the waste in a large scale. Composting is very much significant from the aspect of environment.
- It is highly recommended for the green belts around the proposed waste disposal site which will obstruct the views and as well as reduce spreading of pungent odor.
- Outcome of this study will be used for further studies by the government or other concerned authority.

CONCLUSION

This study used GIS integrated standard methodology for the selection of sites, which are suitable for the disposal of solid wastes. This methodology incorporates a large number of factors which are essential to identify the sites. In fact, many other parameters are required for this study, but the most important parameters have been taken into consideration. Thus with the use of these technologies management of municipal waste will no longer be a problem for city administrators.

ACKNOWLEDGEMENT

This study has been conducted under the MURP course titled 'GIS in Environmental Modeling' offered by Civil Engineering Department, BUET taken by Dr. Md. Mafizur Rahman, Professor, Department of Civil Engineering and Director ITN, BUET.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.134 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Impacts of Community Awareness Interventions in Solid Waste Management System

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Abstract

This paper looks at the case of ERP from the perspective of institutional development for sustainability of improved SWM. It describes and analyses the experiences gained in the process of evolving innovative approaches and strategies for implementation of a Solid Waste Management Project in the eastern region of Sri Lanka. The project is distinguished by the external assistance component and multi-stakeholder engagement covering financial assistance, implementation and monitoring by UNOPS and EU. It formed part of a larger programme towards Tsunami Recovery and Reconstruction through Environmental Remediation. Further this paper describes the visible outcome of the tools and methods used in the community awareness activities at different perspective: Increase in collection routes, reduced travel time of the collection vehicles, timeliness of the collection vehicle according to the schedule, increase in household waste collection, improvement in handling and disposing of solid waste segregation of solid waste at source etc.

Introduction

The community awareness programme in solid waste management in the twelve local authority areas conducted successfully achieving the targets. The development objective of the community awareness programme is aimed at target communities in general and different in particular , to increase their understanding and heighten their awareness regarding effective management of their wastes , increase their active involvement in implementing the improved collection system , promote and influence their behaviour with regard to practicing 3Rs (reduce , reuse , recycle)

In Collaboration with the office of Assistant Commissioner of Local Government (ACLG) and twelve Local authorities in Ampara district, United Nations Office for Project Services (UNOPS), with the funding from the European Union (EU), is implementing the Environmental Remediation Program (ERP) in the Ampara district to assist the local authorities (LAs), communities and key stakeholders in strengthening the natural resources and environment base. The overall objective of ERP is to contribute to community development and recovery in the Tsunami affected District of Ampara through the improvement of the environment for the District. The three main components of ERP are:

- Solid waste collection and management (SWM)
- Drainage construction in flood prone urban areas
- Environment restoration through planting of trees in coastal and tsunami affected areas and along roadsides

The scope and activities of the solid waste management component covers four key areas namely:

- SWM facilities construction and operations

- Governance and Institutional Development
- Capacity Development and awareness building
- Business Development and Marketing.

Capacity Development & Community Awareness Building interventions covers the awareness building for community and capacity building of Local authority's staff inordor to improve their skill , knowledge and practices in SWM related tasks , thus we hope this intervention would lead to contribute Environmental Education and Campaigns as mentioned in the advertisement.

The CA Program has been organized in terms of five major activities which are interrelated and consistent with the specific objectives aforementioned. These are:

- Establishing an improved waste collection system.
- Awareness raising and knowledge building on good waste management practices.
- Establishing Mechanisms for Sustained Implementation of Improved Collection System.
- Increasing Awareness among the General Public.
- Developing Resource Materials for Awareness Campaign.

Objectives & Outcomes

Objective:

The development objective of the proposed CA program is directed at communities in general and different stakeholders in particular to increase their understanding and heighten their awareness in

- Effectively managing their wastes,
- Increase their involvement in implementing the improved collection system,
- Promote and influence behaviour in practicing the 3Rs;
- Reduce, Re-use and Recycle activities,
- increase participation to promote effective SWM.

The expected outcome is a clean environment resulting from changed behaviours and attitudes engineered through the process of awareness creation. More specifically, the following outcomes are expected to be observable:

1. Improved collection system in place with increase in the collection routes, reduced travel time, and consistency and on time collection of wastes according to a defined schedule

2. Visible cleanliness in the areas; reduced if not totally eliminated dumping of garbage along the streets

3. Increased volume in household wastes collected and increased participation rate

4. Demonstrated good knowledge and practice of the proper handling of wastes

5. Expressed understanding of health implications of good and bad SWM practices

6. Demonstrated practice in waste segregation and improved levels of recycling

7. Conducted activities applying SWM practices

8. Demonstrated for SWM activities through positive decisions / actions

9. Institutional mechanisms established for LA commitment and , and stakeholder participation

10. LA and community acceptance and participation in the fee for service mechanism

Implementation

The Community Awareness Program (CA Program) in Solid Waste Management (SWM) in the Local Authorities has been facilitated by Resources

Development Consultant – a service provider in collaboration with all respective local authorities and continuous consultation with ACLG. During the implementation LA staff were involved in participating the events and the relevant government officials were included when necessary. Grama Niladharies involved in setting up the SWM –SG to mobilize and conduct the awareness programs.

The CA Program was targeted towards the communities and other stakeholders to create awareness in managing their Solid Waste (SW), increased participation and involvement in the LAs' Collection System, and changing their attitudes and behaviours in practicing the 3Rs – Reduce, Re-use and Re-cycle.

The specific objectives of the CA Program are:

a. To establish an improved waste collection and disposal system in the five target LA areas

b. To establish mechanisms for the sustained implementation of improved waste collection and disposal systems

c. To facilitate awareness creation among target communities and other stakeholders, enabling them to adopt and continuously practice good SWM

d. To increase awareness among the general public on the benefits of effective SWM systems and motive them to adopt such SWM practices.

e. To develop appropriate resource materials for use in the awareness raising initiatives

In order to achieve the above objectives the following activities were undertaken:

1: Establishing an Improved Waste Collection System

Interaction Meetings with the Community, Orientation Awareness Sessions, Monitoring Visits in the Collection Routes, Monthly Meetings with LAs and SWM officials, Meetings with GN Heads, Mobile Caravan and HH/Neighbourhood Awareness Campaigns have had equal impact in establishing the Improved Collection System. Regular Monitoring Visits had a great impact that compelled the collectors to adhere to schedule and the routes and is being continued and the system has improved in comparison to period prior to the implementation of the Project extending the Collection to interior areas also.

2: Awareness Raising and Knowledge Building on Good Waste Management Practices

Awareness Building Sessions and Follow-up Activities that were well planned and conducted, assisted in bringing about a change in the attitudes of both SW generators – HHs, Shop owners, Market vendors etc. as well as the Collection Staff in adopting Good Waste Management Practices. The HHs and other SW generators are now packing their SW in bags or other containers and hand them over to the collectors on their scheduled day. The bulky materials like Banana Stumps and Tree Cuttings are sliced and bundled before handing over. As a result, the roads and lanes are very clean and no more SW heaps are observed.

3: Establish Mechanisms for the sustained implementation of improved collection systems.

Regular Meetings with the LA officials inducing them to take more responsibility on SWM and to have certain strict policies on SWM such as to have fixed vehicles for SW collection without diverting them for other works and to have a stand-by for any break downs have resulted in maintaining their schedules and routes. The Support Groups have started having regular meetings and organize their own Awareness Campaigns as well as are organizing clean-up campaigns promoting better SWM practices in their localities. Also they interact with SWM Unit staff at the LAs to sort out problems and issues related to SWM in their areas. These will certainly sustainability of the whole system.

4. Increasing Awareness among the General Public

The Leaflets, Book Markers, stickers, collection schedule cards etc. having the message on improved SWM and conservation of environment have made a positive change of attitude among school children as well as the teachers. Some schools have now started delivering some messages in their assembly on SWM and Environment. Radio News Plugs and Paper Articles have created awareness among the public on the changes that have taken place and continue to take place on SWM and the importance and benefits by keeping the Environment Clean. The Permanent Sign Boards and Permanent Banners that have been established will remind the public the importance of Improved SWM practices and keeping their environment clean and to sustain this program. The Phasing-out Workshops gave an opportunity for all stakeholder representatives and LA to interact openly and to place their proposals in improving the SWM system in their LA area with specific recommendations.

5. Developing Resource Materials for Awareness Creation

Considerable time was spent to develop customized materials like PowerPoint presentation were used in order to have an efficient outreach among the different audiences suck as school children, government officials, market vendors, bank officers etc.

Impacts

1. **Increase in Collection Routes:** Generally there is an increase in the collection routes in all LA areas.

2. **Reduced Travel Time of the Collection Vehicles**: Time taken for the Collection Vehicles has been reduced due to the better SWM practices adopted by HHs such as proper bagging and handing over. The time spent on sweeping waste by the collectors is saved, the use of Siren indicates the arrival of the Collection Vehicle so that the HHs are ready by the time the vehicle arrives at their collection point which reduces the travel time of the Collection Vehicle.

3. **Timeliness of the Collection Vehicle according to the Schedule:** The HHs and the Collection staff are aware of the Collection Day and Approximate Time. The time and schedule are generally maintained except for some special reason when the Collection Vehicle is deployed for other uses.

4. **Attitude and behavioural change of Collectors and Households**: The relationship between the collectors and the HH was not always happy prior to the CA Program. Due to continued monitoring and persuasion the situation has changed remarkably and the HH have started to even assist the collectors in loading when necessary. The HH have realized the difficult nature of the collectors duty as well as the collectors have started persuading HH to bag and bundle their SW. Thus the CA Program has achieved one of its important roles in changing the attitudes and behavior of both the parties.

5. **Increase in HH waste collection:** Due to the CA Program and increase in the collection routes, there is a significant increase in SW collected.

6. Improvement in Handling and Handing over of SW: Cutting and Bundling of SW like Banana trunks and other bulky materials now practiced by the HHs have improved the SW collection and Handing.

7. Segregation of SW at source: The CA Program assisted the UNOPS intervention under ERP in establishing the practice of 'Waste Segregation at Source' through the awareness programs. Now the HHs are willing to segregate their wastes.

8. Fee for Service: Awareness about fee for service provided to the community and the households were convinced to pay the fee for service. Households are from 4 LA are already started to pay their fee for the solid waste management services. This helps LAs to manage with their extra expenditures occurred in SWM related activities.

9. Visual Cleanliness: There is significant change in visual cleanliness along not only the main roads and public places but also in the interior roads where there is a reduction in litter and garbage heaps.

Sustainability

The community and other stakeholders have realized the importance of proper handling of SW. However like any other Programme, SWM Awareness Programme needs backstopping and the LAs can use the services of the SWM Groups that has been established. Therefore SWM groups are being formed and strengthened in LA, mainly facilitate the SWM related issued between community and LA officials. The SWM is expected to meet monthly to discuss the areas of improvements from both Community and LA side.

Women play a determining role in waste management and they form important channels of communication. Representation of women members including housewife's consider when the SWMAC were set up. In many situations women are the first to be affected by a deterioration of the environment and are most willing to participate in projects that improve their living conditions.

The LA s are equipped with enough transportation and equipment facilities to undertake the efficient collection and all staff are in different level in SWM system are provided on the job an class room trainings . Thus they will provide the needful SWM services in future.

Conclusion

Clean environment is fundamental to human happiness and wellbeing. It is a universally rewarding experience that contributes to both health and wealth – in short, improved quality of life. Notwithstanding this social valuation and recognition, human action in modern times has tended to contribute to dirty the environment. This is immediately visible in urban areas primarily because of the issue of solid waste management. Whereas a faith in resilience and adaptation seems comforting, people are beginning to increasingly realize that it is rather unlikely to occur for an exceedingly long time to come. The various immediate consequences of dirty environment experienced by individuals and groups across society together with the knowledge of similar occurrences elsewhere in the world have crystallized a social resolve to deal with the SWM problem for the benefit of all present and future generations. Regardless of the enormity and complexity of the problem, however, the new resolve shifts the historical reliance on the government and rules and regulations to do it all.

Given there are limits to the effectiveness of government action, could other major players such as business and civil society fill the gap? Under what conditions are they feasible? Or, could external assistance armed as it does with expertise, international experiences, financial and organizational clout, do the needful? Would it be a booster for local institutions to gain vitality and stamina (and thus contributing to sustainability), or lock them all in a dependency syndrome?

ISBN: 978-984-33-7045-7, PI.134 (1-6)

Acknowledgement

The authors wish to express their gratitude to the European Union for generously financing this Environmental Remediation programme which was a part of the European Ampara Partnership in Ampara District.

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Abbreviations:

ACLG	Assistant Commissioner of Local Government
CA	Community Awareness
CAP	Community Awareness Program
CBO	Community Based Organization
ERP	Environmental Remediation Programme
EU	European Union
GN	Grama Niladari
GND	Grama Niladari Division
HH	Household
LA	Local Authority
PS	Pradeshiya Sabha
SW	Solid Waste
SWM	Solid Waste Management
SWM-SG	Solid Waste Management Group
UNOPS	United Nation Office for Project Service

M. Alamgir, I.M. Rafizul, S.M.T. Islam, M. I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.141 (1-11)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

A Case Study on Solid Waste Management and Possible Betterment Strategies

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ABSTRACT

Solid Waste Management (SWM) at different industries (both production based and service based) was deeply researched since last several decades. Education Industry (both public and private) is one of the significant service providing sector consists of students, teachers, administrative staffs and other stakeholders. This study emphasizes on the existing SWM practices; its adverse future consequence; some easy adaptive, low cost, and profit generating strategies to improve the upcoming environmental condition at an educational/research based organization. For this study, Chittagong University of Engineering and Technology (CUET) was selected which is situated in a semi-urban area and out of Chittagong City Corporation (CCC) cordon line, naturally the routine SWM operation by CCC is not available there. In the first stage of study, the traditional practices were visually traced and critically define the specific categories of Solid Waste (SW) produced in the study area and its detrimental effects on environment (mainly on air, water and soil).In the second stage, a rational study was held on how the existing SWM could be improved in terms of social acceptance, economical viability and nullification of environmental pollution. Proposed sustainable waste to wealth approach shows a possible roadmap to survive against SW disaster at a symbolic educational organization specially situated in the rural or semi-urban areas in Bangladesh.

Keywords: Semi-Urban Solid Waste Management, Education Industry, Waste Classification, 3R's Principle, Sustainable Development

INTRODUCTION

The Word "Waste" is commonly thought of as no economic or monetary value and is widely assumed to be inevitable. A Paradigm Shift in thinking about the definition of so called waste is essential for a transition to more resource efficient societies. A collective term for garbage, refuse, rubbish, and trash, each term representing a definite category of SW materials according to the classification established by the National Solid Waste Management Association (NSWMA),USA. It includes solid or semi-solid, non-soluble material such as agricultural refuse, demolition waste, industrial waste, mining residues, municipal garbage, and sewage sludge [15]. CUET is the only Engineering University in Chittagong and one of the leading technology based research organization in Bangladesh. The University is taking shape in about 163 acres land [16] and situated in a semi-urban area about 25 km away from City [17] which is not under the Chittagong City Corporation (CCC) Cordon Area (Please see the Map). Naturally, SWM (SWM) of this area does not perform by CCC Authority but dealt by the society with the partial supports of University management. Waste Management (WM) involves (i) development of an insight into the impact of waste generation, collection, transportation and disposal methods adopted by local community/society on the environment and (ii) adoption of new methods to reduce its adverse effect [1]. As a part of this view, it may be highly appreciated to assess the existing WM practices at a particular zone of society (i.e., CUET campus) for develop a noble WM roadmap with some governing parameters (study area, categories of wastes produced and tentative low cost and easy adaptive solution with waste to energy approach) which fulfill three inclusive fundamentals (society, economy and environment) of Sustainable Development (SD).

EXISTING ORGANIZATIONS WORKING WITH SWM

Duel sided printing is a very effective SW reducing option. To write short message or a cell phone number or to photocopy a small document it's not wise to use a full-size (A4, Legal) paper [10]. Sorting at source (home sorting) is driven by the existing markets for recyclable materials and the link between the house holder and the waste collector [11]. In 2007, a pilot project on source separation of SW was initiated by Waste Concern in Sector #5 of the Uttara Model Town of Dhaka city where the population was estimated to be 105,913 and every day 51.16 tons of waste was generated [3]. In India, centralized sorting was already successfully adopted [13]. Take-back provision motivates the producer to design the product with recyclability of the materials in mind and especially to reduce the content of toxic materials that may be difficult to dispose [6]. In 2006, Bangladesh saved around US$ 4.73 million by recovering and recycling 3420 tons of lead and Government has recently enacted an order on used Lead Acid Batteries Recycling and Management. Under this act, annually 660,000 nos. batteries will be recycled and 3,300 ton hard lead will be reclaimed from used batteries results resource conservation by reducing consumption of fresh lead [3]. Recollection of PET Bottles by monetary transaction might be very effective in the study area.

Waste Concern established a Recycling Training Center in 2005 in Katchpur, Narayangang, under the Sustainable Environment Management Program (SEMP), Ministry of Environment and Forest (MoEF) for technology demonstration and training on waste recycling and energy conservation for the officials, staffs, students, researchers from both the Government and private sectors [7]. CUET authority may think about the training facilities under Centre for Environmental Science and Engineering (CESE) for sustainable SWM so that after attain in short, medium and long term training session, they may take part in the SWM. Recycling of medical waste is not viable due to the potential health risks [8]. Capacity building and WM education programs needed for effective implementation of Medical Waste Treatment [9]. PRISM, a local NGO has initiated Biomedical Waste Collection and Disposal service to 75 private clinics including government hospitals in Dhaka city by the support of duckweed ponds [3]. It's may be one good solution for the waste generated by CUET medical center. Recycling of plastic waste is very potential for growing business world in terms of economic and environmental points of view. In 2005, 45% of plastic waste was recycled by informal sector saving approximately US$ 350 million. In Dhaka City Corporation (DCC) area, 3315 tons of SW was generated per day of year 2005 where 4.15% is plastic borne and 50,214 tons of plastic waste is disposed in the city at the rate of 137.57 tons/day. Although 51% of total plastic waste is recycled in DCC area, health safety and environmental issues of this informal sector are not properly looked after which needs attention [3]. The recycling of e-waste is required to be regulated due to presence of hazardous constituents (radioactivity) in the components of waste electrical and electronic assemblies which may hamper soil texture, fertility and ecosystem if through abruptly here and there [3]. The informal sector operations comprising the feriwallahs, waste pickers, Tokai, buyers and manufactures are essential to the WM chain in semi-urban areas like CUET, yet the services provided by this sector is poorly understood or acknowledged [2].

Composting is a means of recapturing value from waste through the utilization of natural biodegradation process to convert organic materials into soil additives. It has the potential to reduce the cost of waste disposal, minimize large scale public health risk, and produce a clean and readily marketable finished product (as fish feed) and help to increase the recovery rate of recyclable materials [3]. Both of the power generation and biogas plant from rice husk comparatively cost effective from other methods. In 2007, Dream's Power Ltd, a Kapasia, Gazipur based private company with the financial assistance of World Bank and technical expertise from India installed a biogas plant to generate electricity where Government power supply are absent and rice-husks are abundant and un-utilized. At present about 500 households / shops are the beneficiaries of the project [3]. CUET may follow such kind of alternative energy producing options with some little modifications. In 1998, American International School Dhaka at Baridhara (AISD) initiated a rooftop compost plant with the technical supports from Waste Concern, where organic waste from class rooms, offices, dining hall and kitchen is coming to the compost plant. The recyclables are kept in the separate bins and later sold to dealers [3]. Several establishments at the study area such as school, collage, university, academic building, staff quarter, student's hall may adopt this profitable strategy. Integrate some parameters, CUET may ensure the feasibility of such kind of biogas plant by community/household based from the SW producing in the region. (Please see Figure No-01, 02 and 03).

MOTIVATION

It is estimated that approximately 13,332 tons of waste is produced per day in the urban and semi-urban areas of Bangladesh, which is over 4.86 million tons annually; this amount will grow up to 47,000 tons/day and close to 17.2 million tons per year by 2025 [2]. Waste collection rate ranges from 44.30-76.47% in major urban and semi-urban areas where per capita waste generation rate is 0.41 kg/capita/day and waste collection efficiency varies from 37% to 77% with an average of 55%. Waste reduction is the most cost effective way of SWM for prevents unpleasant and unhygienic surroundings [3]. In Uttara Model Town, by utilizing 3Rs practices the community recycles 2 truck full loads everyday and as a result can save Taka 9,490,000 per year [4]. Development and transfer of environmentally sound technologies for SWM (3Rs) and Integrated SWM (ISWM) are applicable in the context of existing socio-economic and climatic condition of study area through collaboration among stakeholders such as national/local governments, private sectors, consumers, manufactures, informal sectors and research bodies. CUET should adopt appropriate, affordable and suitable technology for sustainable SWM [2].

METHODOLOGY

In the first stage of work, existing practices were visually traced and critically define the specific categories of SW produced in the study area and its detrimental effects on environment (mainly on air, water and soil). In the second stage, a rational study was held on how the existing SWM could be improved in terms of social acceptance, economical viability and nullification of environmental pollution. Proposed sustainable waste to wealth approach shows a possible roadmap to survive against SW disaster at a symbolic educational organization specially situated in the semi-urban area in Bangladesh.

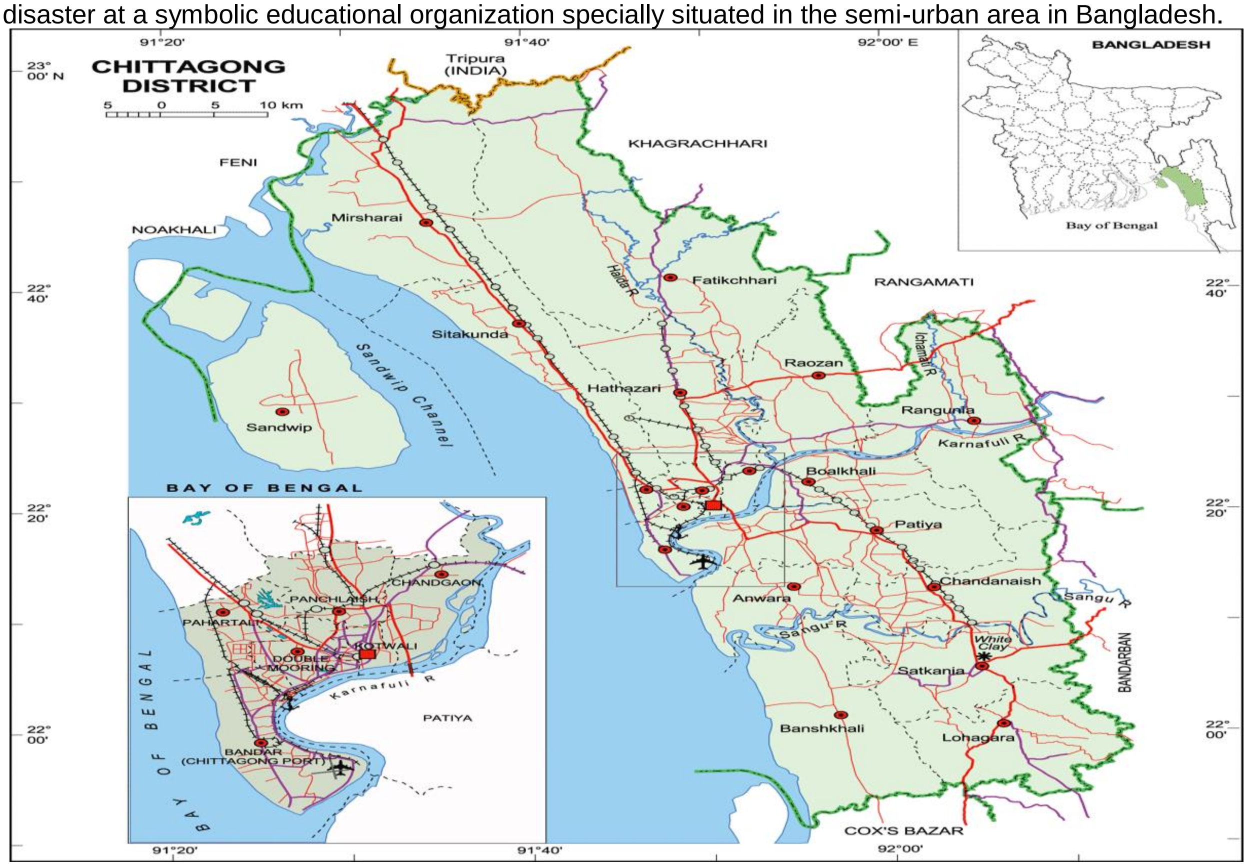

Figure-01: Map of Chittagong District with existing Upazilas at the Sub-Urban Zone [14]

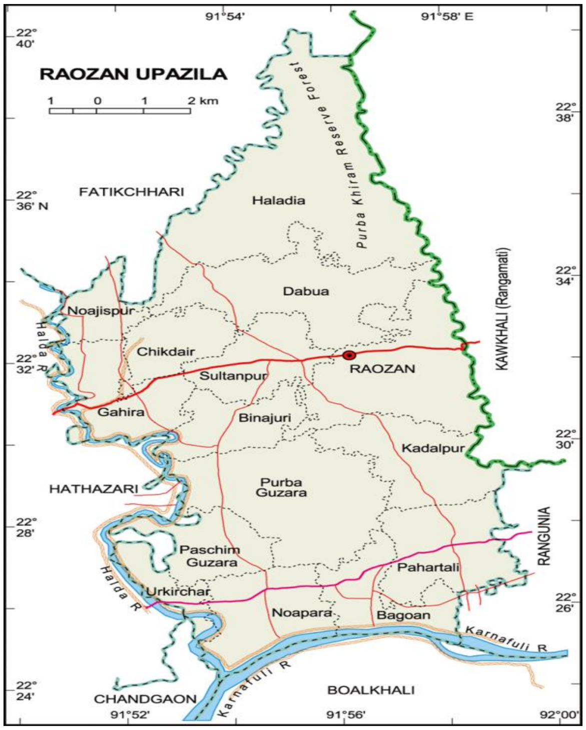

Figure-02: Pahartali Union at Raujan Upazila [12]

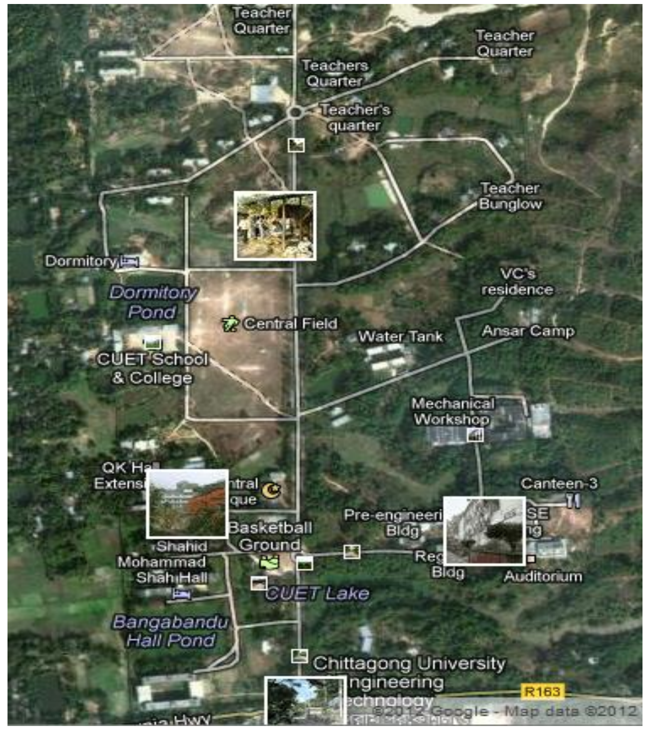

Figure-03: Study Area at Pahartali Union [6]

SW CHARACTERIZATION AT THE STUDY AREA

The study area is a community consists of public residents (i.e., Staff Quarter, Students Hall) and official establishments (i.e., Administrative Building, Library, and Academic Buildings), which generates almost all sorts of SW regularly. All the real life examples of SWs are collected and sorted based on walk down surveying and visual screening methods. Emphasizing issues are (i) tough to predict the actual volume of waste production (ii) concentration of waste proportion is heterogeneous and (iii) individual waste needs different treatment. Some of the dominant real life pictures of SWs at study area are shown below-------


Bamboo Pieces


Demolished Concrete


Old Furnishers


Damaged Toner


Unused Study Materials


Broken Plastic Scale


Unused Rubber Pieces


Refused Latex Piece


Biscuit Packet (Plastic)


Custard Cake Packet


Damaged Bronze Crest


Old Wooden Nameplate


Ice-Cream/Coffee Cup


Refused Plastic Folder


Marker Pen Box


Tissue Packet (Plastic)


Damaged PET Bottle


Refused Cloth Pieces


Unused Coconut Shell


Broken One time Plate


Broken Tube Light


Unused Cement Bag


Dumped Jute Bag


Refused Wooden Pieces


Chips Packet (Plastic)


Broken Glass Piece


Refused Partex Block


Broken Tiles Piece





Unus

ed Emery Paper

Damaged Sanitary Items

Refused Plastic Ropes

Empty Cigarette Pack


Refused Sweet Meat Box


Broken Electric Holder



Damaged Painting and Washing Accessories


Damaged Measuring Tape


Empty Match Box



Refused Plain Paper and News Paper




Broken CD/DVD Box   Unused Packaging Puff   Damaged PVC Pipe   Other Plastic Borne Wastes

PRESENT SWM IN THE STUDY AREA

SW of the study area such as dry leaves, plastic packet, wrapper, and stationary product (wastage paper, pen etc) are collected by that lower level employee and then most of them are gathered in a place and fired openly. Due to the traditional dumping system, all of the SWs are treated as same category. Therefore no sorting occurs and cumulatively burning them which cause air pollution by black smokes and flying solid particles. Sometimes street waste collector or “Tokai” collected some of the plastic (PET bottle), chips packet, biscuit packet, in a significant volume. They are selling the collected SW to the local vendors in terms of weight. E-wastes (such as non repairable keyboard, toner with residual ink, mouse, mobile cover, keypad, lithium battery, mobile or computer chipset or IC) are dumping here and there abruptly. There is no landfill site available at study area for disposal of hazardous medical waste or e-waste. CUET should aware about it and formulate a plan of healthier disposal to achieve an environment friendly SWM system. Generally, demolished concrete is dumped in the low land which decreases underground water recharge. There is no facility in CUET for treatment or recycling of hazardous wastes.

Blockage of Drainage System due to Poor SWM   Waste Overflows from Bin   Street Sweeping

Some of the irrigation land in the campus compound, where cultivation occurred regularly. Of this significant volume of agricultural waste (such as rice-husk) generated in the campus area, most of them are used as domestic fuel in an inefficient manner. There is no authentic policy or guidelines on efficient use of agricultural waste for production of energy or fertilizer. There is no guideline or rules available for SWM in the CUET residential area. Current approach to SWM system in CUET is conventional i.e. end of pipe system. Its mainly emphasizes on collection and disposal and not on reuse and reduction. ‘We dump – They (waste worker) collect’ is the general attitude that had been cultivated among the stakeholders over a long period. CUET does not have any functional record keeping method to assess the day-wise and street-wise volumes of waste handled. Without adequate record keeping and realistic databases it is difficult to improve the quality of planning and delivery of basic SWM services in the study area.

Figure-04: Waste Collection Bucket at Students Hall, Canteen, CUET Library and Academic Building

A few numbers of waste bin and waste collection buckets situated in the study area mainly in front of 3 canteens**,** library, academic building, and student's hall and in residential area which are effectively used by the inhabitants. Waste bins are mostly packed by the waste and the waste worker are clean up them with in regular interval. Due to overflow of waste, some of the waste bin is not clearly visible. Engineering Division of the University is responsible for the implementation, operation and maintenance and of WM activities. A few environment oriented organization (Green for Peace) in CUET promotes the SWM operation by student's participation. They arrange a number of waste buckets; put it in front of library, canteen and maintaining its operation. CUET also declares a specific day in every year named "Cleanliness for Green Environment" to buildup awareness for sustainable environment in the study area.

BAMBOO PIECES, OLD FURNISHERS, WOODEN NAMEPLATE, REFUSED WOODEN PIECES AND REFUSED PARTEX BLOCK	→ ABRUPTLY DUMPING HERE AND THERE; SOMETIMES COLLECT TOGETHER AND BURNING.	→ CAUSES AIR AND SOIL POLLUTION
DEMOLISHED CONCRETE	→ DIRECTLY DUMPING TO THE EXITING LOW LAND	→ PREVENT UG WATER RECHARGE AND BLOCK DRAINAGE
DAMAGED TONER, BROKEN CD/DVD WITH BOX, MOBILE BATTERIES, LITHIUM BATTERIES, CHIP/IC OF PC/MOBILE	→ ABRUPTLY DUMPING HERE AND THERE; SOMETIMES COLLECT TOGETHER AND BURNING.	→ INTENSE AIR AND SOIL DEGRADATION
UNUSED STUDY MATERIALS (I.E., BROKEN PLASTIC SCALE/ REFUSED PLASTIC FOLDER/ INKLESS BALL PEN ETC)	→ ABRUPTLY DUMPING HERE AND THERE; SOMETIMES COLLECT TOGETHER AND BURNING.	→ CAUSES AIR AND SOIL POLLUTION
BROKEN ELECTRIC HOLDER, PLUG, SWITCH & CABLE ETC	→ DIRECT DUMPING & COLLECTIVELY OPEN AIR BURNING	→ AIR, SOIL POLLUTION
REFUSED RUBBER, LATEX PIECE & EMERY PAPER	→ DIRECT DUMPING & COLLECTIVELY OPEN AIR BURNING	→ AIR & SOIL POLLUTION
DAMAGED PLASTIC BORNE SANITARY ITEMS	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING	→ AIR, SOIL POLLUTION
PLASTIC BORNE BISCUIT PACKET, CUSTARD CAKE PACKET, CHIPS PACKET, TISSUE PACKET, PET BOTTLE AND OTHER PLASTIC SW	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING	→ AIR & SOIL POLLUTION, BLOCK DRAINAGE & UG RECHARGE
DAMAGED METALLIC CREST/SOUVENIR	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO HAWKER	→ AIR, SOIL POLLUTION
EMPTY CIGARETTE PACKET, MATCH BOX, SWEET MEAT BOX, MARKER PEN BOX ETC	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO HAWKERS	→ INSIGNIFICANT INCOME FROM SELLING, AIR POLLUTION BY BURNING & SOIL DEGRADATION
ICE-CREAM/COFFEE CUP	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO THE HAWKERS	→ AIR & SOIL POLLUTION
REFUSED PLASTIC ROPES	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO HAWKERS	→ AIR AND SOIL POLLUTION
DAMAGED PAINTING & WASHING ACCESSORIES	→ DIRECT DUMPING, COLLECTIVELY BURNING OR SELLING	→ HUGE AIR, SOIL POLLUTION
DAMAGED MEASURING STEEL TAPE	→ ABRUPTLY DUMPING HERE & THERE WITHOUT ANY PRECAUTION	→ CAUSES INJURY TO WORKERS
REFUSED PLAIN PAPER & NEWS PAPER	→ DIRECT DUMPING, COLLECTIVELY BURNING OR SELLING TO HAWKERS	→ AIR, SOIL POLLUTION
AGRICULTURAL WASTE (RICE HUSKS & DRY LEAVES)	→ USED AS FIREWOOD (LAKRI) FOR COOKING AND ANIMAL FEED	→ CAUSES BLACK SMOKE
HOUSEHOLD GARBAGE & REFUSED CLOTH PIECES	→ DIRECT DUMPING, ANIMAL FEED; BURNING OR SELLING	→ CAUSES AIR & SOIL POLLUTION
UNUSED COCONUT SHELL	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO THE HAWKERS	→ AIR, SOIL POLLUTION
BROKEN ONE TIME PLATES & PACKAGING PUFF (SHOLA)	→ DIRECT DUMPING, COLLECTIVELY BURNING OR SELLING	→ AIR & SOIL POLLUTION
BROKEN TUBE LIGHT AND GLASS PIECES, BROKEN TILES PIECES	→ DIRECT DUMPING, SELLING TO HAWKERS	→ SOIL DEGRADATION
EMPTY ALUMINUM CAN OF SOFT DRINKS, BODY SPRAY & AEROSOL	→ DIRECT DUMPING, SELLING TO HAWKERS	→ HUGE AIR & SOIL POLLUTION
REFUSED CEMENT BAGS & JUTE BAGS	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO HAWKER	→ AIR, SOIL POLLUTION
DAMAGED PLASTIC & PVC PIPE	→ DIRECT DUMPING, COLLECTIVELY OPEN AIR BURNING OR SELLING TO THE HAWKERS	→ AIR & SOIL POLLUTION
MEDICAL HAZARDOUS WASTE	→ DIRECT DUMPING, COLLECTIVELY BURNING OR SELLING TO THE HAWKERS	→ INTENSE AIR & SOIL POLLUTION

Figure-05: Traditional SWM Practices and its Future Consequences at the Study Area

POSSIBLE BETTERMENT STRATEGIES

CUET may try to establish the 3 bin (Red, Yellow and Green) in front of every Department so that stuffs, teachers and students could easily use it and put the waste at the appropriate bin. CUET may follow 3Rs principle of SWM. They can simply reduce SW production by reuse or use again and again as long as possible. For Example: use the mineral water pet bottle for containing milk, oil, water, juice or any other beverage items. Use of maximum value added product may help to reduce SW generation. For Example: Use of a modern multimedia mobile phone which contains phone facilities, internet modem, MP3 Player, MP4 Player, Radio, Chatting, email and browsing etc. CUET inhabitants should buy maximum expired date mentioning product and therefore no need to buy such kind of product again before the expired date. CUET should avoid open air burning of SW rather they may sale it to the villagers as fuel (Lakri) for cooking. Proper SWM needed to ensure better human health and safety. The SWM operation must be safe for workers and safeguard public health by preventing the spread of disease. Inefficient and dirty technology should be avoided and replaced by efficient and less Green House Gas emitting technologies. CUET may convert all the perishable or biodegradable SW to compost which is very natural and promotes less usage of harmful chemical fertilizers in the gardening or irrigation purposes. CUET may establish a central dumping plant/sanitary landfill as per the volume of generated waste. They may also initiate an incinerator by which they can burn hazardous medical wastes. In some instances, legislative actions are very successful for proper SWM and separate laws to specific products needed. For betterment of existing situation and maximize benefit, it is necessary to set recycling targets as well as roles, cost and profit sharing among stakeholders. For existing and upcoming demolished concrete, stakeholders may reuse it as a course aggregate after crushing within a definite sizes and shapes at a permissible combination with raw concrete for saving construction cost and proper SWM simultaneously.

CUET could promote both Polluters Pay Plan (PPP) and Take-Back Provision for its stakeholders to ensure sustainable environmental development and proactive SWM. It may be very effective in the limited income group. They usually try to generate less SW if they have to pay a handsome amount for it. But, high income group may doesn't bother it. CUET may setup a SW collection schedule - the SW worker collects 2 or more times in a day- at the morning and at the afternoon. There is a CUET medical centre. After vaccination or any surgical operation all the waste should be primarily sorted out and then put in the defined bin. Throwing medical waste here and there should be prohibited should be a punishable offense. CUET residents should Avoid Packaged item for unnecessary cases. Government should control the manufacturers to Minimize Extra Packaging. For Example: the washing ball soap does not required packaging at all. It increases the manufacturing cost also. It is very appreciated to create new utilities of broken pieces of bucket or plastic drum by using as a plant tub in garden. Target group could establish Synthetic Polymer Packaging in the places of paper made carton or polyethylene for use several times in future. For Example: the jute bag may be a successful replacement of polyethylene bag. Avoid One Time Product may be a core solution for the stakeholders. For Example: they can use razor with blade changing facilities instead of one time razor or use of Spouse Pac of Liquid Soap again and again.

Buy as much as needed, Resist Overuse and maintain Limited Inventory to avoid wastage. Homely huge inventory or storage may be simply a stupid decision for the perishable, non enduring goods. CUET may enroll or recruit a WM expert with required work forces and responsibilities. CUET should encourage e-waste recycling projects under public-private partnership mode. They could aware its stakeholders by arranging training to know how to dispose of e-waste effectively and efficiently. In study area, some street collectors are collecting the plastic borne SW and at the end of the day they sold it to the waste buyers at significant prices. CUET SWM policy should not overlook informal sector as they have a significant role in the SWM operation. Authority should integrate both the formal and informal operations towards achieving the objective of 3Rs. All the official documents should be print duel side so that ultimately use of paper and waste generation from printing paper may be decrease by 50%. Officials may use various sizes of paper for different uses and should try to print as less as possible.

CUET may initiate sorting at source, recycling at source and processing at source (i.e., Bio-gas Plant, Composting) for waste minimization. CUET is a residential cum institutional area from where a significant volume of SW may be collected every day. Therefore, a centralized sorting may be an effective option for the study area. CUET may establish a Measuring Scale based on weight - not on volume for promoting community based SWM. They may also use a standard bucket for it. In the study area, there are of paddy fields. From where, a lot of rice husk may available for power generation by biogas plant. This plant may support the scarcity of electricity demand for CUET at the emergency period. Recent research proves that, rice husk can be successfully used for bio-gas plant. There are some school/collage establishments in the study area and they could follow the roof top composting method and separate bin method for easily sorting out the recyclable for collectively selling [3]. CUET may also go for establish community based Compost Plant so that the generated SW may be converted to Compost Fertilizer or Biogas. CUET may arrange seminar, symposium, and workshop with its various departments to find comparatively better solution for SWM. CUET may also reward minimum waste generating community, family or person to motivate peoples to generate less SW. Awareness is an overarch issue. No doubt- if stakeholders become aware about the negative impact of SW, than social response will generate automatically. Continuous Research and Development (R&D) Program may reshape the traditional concept of SWM and recommends more adaptive methodology so that SWM at the different stages becomes easier, cost effective and environmentally susceptible. Both government and non government organization may support financially/logistically to enhance the R&D Program for proactive SWM at study area. CUET may initiate a research cell for sustainable SWM which may open an era to convert waste to wealth. The above mentioned concepts and presumptive ideologies are likely to turn the existing SWM into sustainable SWM apparently by demand of time in connection with attachment to further research.

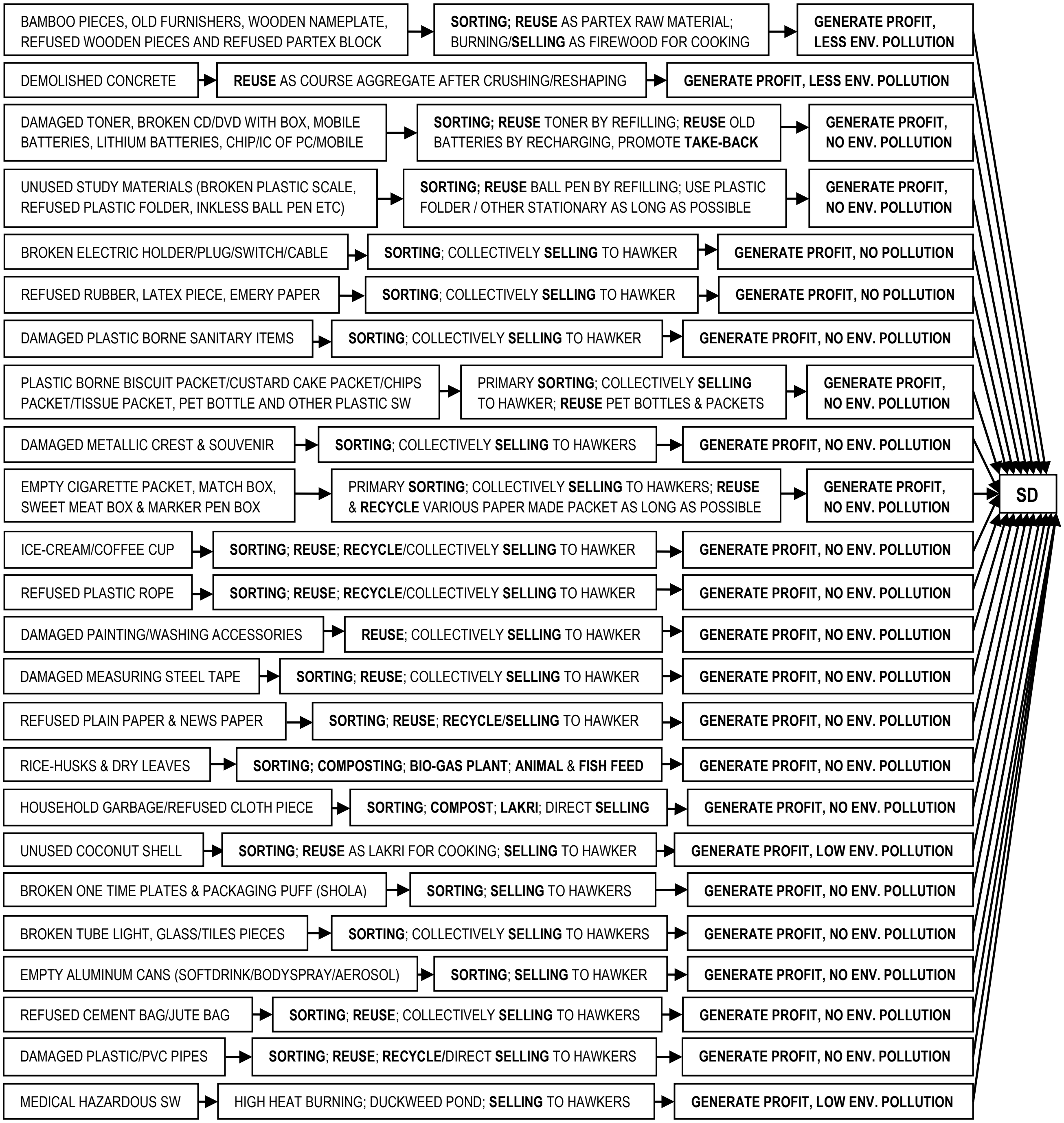

Figure-06: Proposed SWM Practices and its Future Consequences at the Study Area

CONCLUSION

It should not say- “don’t produce SW”, which is not desirable at all. Better to say- “please produce SW as less as possible to save the environment for the upcoming future generation”. To promote this slogan, the authority of the concern study area has to take strategic decision and set up a control chain for SWM from generation to disposal stages. Most of the wastes at the concern study area are money making. CUET should adopt the slogan “nothing is waste yet, everything is wealth”. Real scenario proves that, if the authority can establish an easy adaptive and suitable strategy for environment friendly SWM operation with effective and efficient management intervention from the generation stage to disposal stage, it may significantly improve their living surroundings with lifestyle and in the long run it may contribute to the sustainable environmental development.

ACKNOWLEDGEMENTS
The author is grateful for the logistic supports of the Dept. of Disaster and Environmental Engineering, Chittagong University of Engineering and Technology (CUET). Appreciation extended to Dr. Aysha Akter, Assistant Professor, Dept. of Civil Engineering, Chittagong University of Engineering and Technology (CUET) during field survey and providing relevant information.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M. I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7, PI.143 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Emergence 0f Comprehensive Policy Framework for Solid Waste Management of Megacity Region: The Case Of Dhaka

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ABSTRACT

Dhaka is a spontaneously developed megacity comprising an area of 590 sq. mile where sustainability of solid waste management is a challenge to city planning. Presently Rajdhani Unnayan Kartripakkha (RAJUK) has initiated two new projects namely Revision of Structure Plan and City Region Development project comprising large functional area of the megacity. RAJUK's master plans comprise many urban components including solid waste management. The implementation of the master plan of Dhaka is vested to different sectoral agencies as Local Government Institutions, utility agencies, public and private organizations. Almost all the organizations have some lacking and limitations. A comprehensive policy framework will definitely show the sustainable waste management system consisting action plan for the organizations in their respective jurisdiction through identification of landfill sites, waste dumping sites, location of Central Effluent Treatment Plants (CETPs) for industrial zones, a holistic mechanism for waste segregation, building plan permission imposing garbage dumping locations etc.

INTRODUCTION

Bangladesh being a poor country, the cities are also poor (Choudhury, 2008). Bangladesh is the ninth most populous country and twelfth most densely populated countries in the world. In particular, the projected urban population growth rate from 2010 - 2015 is 3% (UN, 2012). With this population growth, there is an increasing problem of waste management particularly in the larger cities. Currently, according to an UNFPA report, Dhaka is one of the most polluted cities in the world and one of the issues concerned is the management of municipal waste (Bhuiya, 2007). There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47, 064 tons per day by 2025. The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6 in 2025. A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement (Alamgir et al., 2007).

Khulna City Corporation of Bangladesh has no separate solid waste management Master Plan for Khulna City. KDA prepares the Solid Waste Management Master Plan for Khulna City. KDA can play significant role in implementing a number of good urban development projects by engaging all concerned sectoral agencies. KDA did not take initiative to undertake any project on solid waste management in Khulna city by the KCC. KDA could sit together with KCC for perusing KCC to design SWM projects for implementation of Solid Waste Management Improvement Proposals of KDA Structure Plan and Master Plan. The officials of KDA and KCC mainly the Engineers and Town Planners have lack of through knowledge and information on different urban development and planning problems and probable solutions due to non-availability of KDA Structure and Master Plan in the concerned offices and their departments. Copies of KDA Structure and Master Plans are also not found available in the libraries and Research and Development organizations of Khulna. This is also a reason of slow and non-implementation of SWM improvement proposals of the KDA Master Plan and Structure Plan. KDA and KCC have a very few Town Planners in their set up. If there were more Town Planners in KDA and KCC and they were assigned to analyze the City Master Plan and design urban development projects both KDA and KCC could develop and implement more projects including Solid Waste Management projects for Khulna City (Roy, 2011).

The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the Bangladeshis (Enayetullah et al., 2005). Bangladesh has minimal waste collection coverage which forces majority of the waste to be dumped in open lands. These wastes are not disposed of properly, where general wastes are often mixed with hazardous waste such as hospital waste (Enayetullah et al., 2006). In a report on solid waste management in Asia, the data showed that, in Dhaka, only about 42% of generated waste is collected and dumped at landfill sites, and the rest are left uncollected. As much as 400 tons are dumped on the roadside and in open space (Bhuiya and G. M. J. A., 2007). As such, these improperly disposed wastes pose serious health implications to the people where it may have the potential of transmitting diseases (Ahmed et al., 2009). Due to the lack of funding, there are also insufficient subsidies put in place for the issue of waste management in Bangladesh. Hence, there are essentially no proper disposal facilities to cater to the rapid creation of waste. At present there is no secured landfill site available in the country for disposal of hazardous industrial wastes (Kabir et al., 2012). This paper is intended to present a holistic policy proposal for sustainable Waste Management policy for Dhaka Megacity Region.

MEGACITY REGION IN WORLD AND ASIAN CONTEXT

A megacity is usually defined as a metropolitan area with a total population in excess of 10 million people. Some definitions also set a minimum level for population density (at least 2,000 persons/sq. km). A megacity can be a single metropolitan area or two or more metropolitan areas that converge. By 2025, according to the *Far Eastern Economic Review*, Asia alone will have at least 10 megacities, including Mumbai, India (33 million), Shanghai, China (27 million), Karachi, Pakistan (26.5 million), Dhaka, Bangladesh (26 million) and Jakarta, Indonesia (24.9 million people). The governance issues of all the megacity of the world are traced by integrative and functional regional planning. In the megacity context regional planning jurisdiction is termed as 'Extended Metropolitan Region'. Without considering EMR, the megacity's functions of infrastructure, investment, housing, environmental management can never be coordinated sustainably (Talukdar, 2006). Most of the Asian megacities like Tokyo, Bangkok, Jakarta, Metro Manila and Dhaka face the challenges of homogeneous characteristics accommodating more population, transportation, housing, formal and informal employment for the increased population.

MASTER PLAN POLICY IMPLICATION OF WASTE MANAGEMENT: A GLOBAL PERSPECTIVE

Guelph is considered to be one of the first planned towns in Canada. It prepared its Master Plan which sets path for waste management. The Solid Waste Management Master Plan (SWMMP) is now complete and sets a path to achieve new waste minimization, diversion and disposal targets, identifies both short and long-term programs designed to achieve the targets, and provides an estimate of the extent to which each component moves the City towards achieving the overall goals. Guelph residents participate in a three-stream curbside waste collection program - green for organics, blue for recyclables and clear for landfill (City of Guelph, 2013).

Green and blue bags and carts are collected weekly as per below mentioned categories of segregation on regular collection day, while clear bags or grey carts for garbage are collected every other week based on two collection schedules-Week A and Week B.

Table 1 Curbside collection of different category wastes in the City of Guelph, Canada

Green (Organic)	Blue (Recyclable)	Clear (Garbage for landfills)
• Food items (scraps, peels, bones, shells) • Tea bags, coffee grounds and filters • Paper towels and tissues • Household plants • Pet waste and litter (no plastic bags including those labeled "compostable" and "biodegradable") All plastics must be removed	• Aluminum • Boxboard and cardboard (flattened) • Glass (all colours) • Newsprint and paper • Plastic bottles and containers (all numbers) • Polycoat/Tetra Pak (milk cartons/juice boxes) • Shredded paper (in a separate blue bag) • Steel cans Containers must be empty	Items that are: • NOT compostable • NOT recyclable • NOT hazardous Now including: • Diapers and hygiene products • Styrofoam • Coffee cups

Source: http://guelph.ca/living.cfm?subCatID=902&smocid=1487.

EXISTING POLICY FRAMEWORK FOR WASTE MANAGEMENT FOR DHAKA MEGACITY REGION

Waste Management Policy Options in DAP Study

DAP study reveals that collection of solid wastes in important road sides is a common practice in Dhaka and in rural parts, solid wastes are thrown in adjacent low lying areas (**RAJUK, 2010**). Existence of Sanitary landfills is extremely deficient. DAP proposed industrial landuse planning categorizing in two landuse category of General and Heavy industrial zones respectively with specific policies for those two zones. It proposed relocation of hazardous industries from residential zones and provisions for approving building plans as per designated landuse category.

Waste Management Policy in Building Construction Rules, 2008

The root law of constructing building is ‘East Bengal Building Construction Act, 1952. As per provision of this Act ‘Dhaka Mohanagar Imarat (Nirman, Unnayan, Sangrakkhan o Oposaran) Bidhimala, 2008 was enacted which does not provide any fruitful and effective policy regarding waste management. Following are some provisions of waste management in this rules mentioned in clause 59 (Gha) (RAJUK, 2008):

- There should be specific location for domestic waste dumping bins in the courtyard of every building
- Institutions like hospitals, laboratories, factory buildings which produce solid, chemical etc. wastes should be provided with waste collection and disposal system
- Any types of wastes should not be fallen directly to the water bodies, canals, lakes and rivers
- Chemical or poisonous wastes should not be disposed in drains, dustbins, sewerage lines, water retention ponds, or disposed underground without treatment

Policy Options in the Study of JICA

A study on the Solid Waste Management in Dhaka City was conducted on December 2003 by the Technical Cooperation of JICA. Objectives of the study were to formulate a Master Plan for the Solid Waste Management in Dhaka City and developing human resources on Solid Waste Management in the course of the study.

PROPOSED SOLID WASTE MANAGEMENT POLICY FRAMEWORK FOR DHAKA MEGACITY REGION

According to World Health Organization (WHO) solid waste is defined as useless, unwanted or discarded materials and is not free flowing. Solid waste is the term now used internationally to describe non-liquid waste materials arising from domestic, trade, commercial, industrial and agricultural as well as public sector (WHO, 1971). Some specific proposals are proposed for the solid waste management policy framework for Dhaka megacity region. The proposals are presented in the following tables table 2 and table 3.

Table 2 Activity wise proposed policy framework for domestic wastes

Sl.	Activity	Master Plan Intervention	Strategy	Implementing Agency
1.	Providing spaces for Sanitary Landfill, dumpsites and dustbins	Provide site locations	Detailed Area Plan	RAJUK
2.	Waste Reduce, Reuse and Recycling	Provide space for Recycling	Impose 3R	Local Government and Civil Society/NGOs
3.	Controlling waste dumping into water bodies	Earmark of water bodies	Awareness generation	RAJUK/LGs
4.	Land reclamation using waste mass	Earmark of reclamation sites	Public-Private Partnership	RAJUK, LGs and Civil Society/NGOs
5.	Resources regeneration from wastes	Policy preparation for regeneration	Compost and organic fertilizer Promotion of SME	NGOs and Private Entrepreneurs
6.	Renewable Energy Re-production	Policy preparation	Facilitation, Funding, Incentives	City Corporations, Pourashavas
7.	Capacity Building of waste Management Departments	Policy preparation	Institutional Strengthening	City Corporations, Pourashavas
8.	Marketing of organic fertilizer	Policy preparation	Tax Rebate for Roof Top Gardening	LGs, Agriculture department, NGOs, Private Entrepreneurs
9.	Household Level Waste segregation	Incorporation in Building Construction Rules, BNBC	Separate dumpsites/bin locations in approved plans	RAJUK
10.	Waste Diversion target	Policy Incorporation	50% by 2015, 65% by 2020, 70% by 2025	City Corporations, Pourashavas

Table 3: Activity wise proposed policy framework for industrial wastes

Sl.	Activity	Master Plan Intervention	Strategy	Implementing Agency
1.	Relocation of Industries through zoning	Provide site locations	Land use Plan	RAJUK
2.	Designing and Implementation of industrial Estates	Provide space for Garments Polli, Knitting and dying, Textiles, Chemical and Polluting zones	Site Selection in Master plan	RAJUK, BSCIC, Ministry of Industries, Professional Institutes as BGMEA & BKMEA
3.	Prohibition of waste disposal in watershed	Earmark of water bodies	Awareness generation	RAJUK/LGs, NGOs
4.	Provision of Central Effluent Treatment Plant (CETP)	Earmark of CETP sites in master plan	Public Private Partnership, Incentives	RAJUK, LGs and Civil Society/NGOs, DONORs
5.	Provision of ETP in every industrial building	Incorporation in Building Construction Rules, BNBC	Imposition in building plan approval, DOE Clearance	RAJUK, DOE

RECOMMENDATIONS FOR TRIGGERING THE WASTE MANAGEMENT POLICY FRAMEWORK

Following recommendations are made for triggering the waste management policy framework for Dhaka megacity region:

- In context of megacity, a detailed and clearly defined waste management strategy should be incorporated in its solid waste management master plan.
- Secured landfill sites must be identified in the master plan for disposal of hazardous industrial wastes.
- There should be specific policy or guideline on efficient use of domestic and or agriculture waste for production of energy or fertilizer.
- RAJUK, DCC and pourashavas should take step for increasing number of Town Planners, Civil Engineers and Environmentalists in their regular setup for preparing, analyzing the City Master Plan and design urban development projects including Solid Waste Management projects for the mega city region.
- There should be strong partnership among city corporations, pourashavas, private sector and NGOs for functioning the waste management policies.
- Public awareness, participation and civic perception should be improved in adopting institutional mechanism to engage the residents, public organizations, NGOs and stakeholders in decision making and implementation of waste management schemes.
- Existing waste management infrastructures such as waste bins, sanitary landfills, waste treatment and recycling facilities should be improved.
- Private sector should be facilitated for landfill gas recovery and carbon trading based composting from organic wastes.
- As per recommendations of the Bangladesh Poverty Reduction Strategy Paper, the concept of 3R (Reduce, Reuse and Recycle) should be imposed for sustainable waste management practices.
- Awareness generation of all concerned stakeholders through campaigns should be made for controlling waste dumping into water bodies.
- Public Private Partnership should be enlightened for effective service delivery in urban solid waste management.
- Household level waste segregation should be done through separate dumpsites/bin locations as per directives of the Building Construction Rules, 2008.
- Capacity building of Waste Management Departments of City Corporations and Pourashavas should be strengthened.

CONCLUSION

Megacity Dhaka lacks a comprehensive waste management policy which is economically feasible, technologically suitable, socially acceptable and technically competent. Here rapid urbanization and population growth posed a great challenge of urban management threatening quality of life of its citizens. In Dhaka, inadequate policies, lack of institutional capacity and financial constraints are responsible for poor waste management. It is a demand of time to formulate megacity master plan incorporating comprehensive waste management policy for sustainable environmental governance.

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M. Alamgir, I.M. Rafizul, S.M.T. Islam, M.I. Nazir and S.R. Saha (Eds.)
ISBN: 978-984-33-7045-7 PI. 144 (1-6)

Proceedings of the WasteSafe 2013 – 3rd International Conference on Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Incineration and Selective Msw Collection in Tourist Areas in Southern Italy

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ABSTRACT

Municipal solid waste management is not only a contemporary problem but also an issue at world level. More in detail, the tourist areas are more difficult to be managed. The dynamics of municipal solid waste production in tourist areas is affected from the addition of a significant amount of population equivalent during few months. Consequences are seen in terms of amount of municipal solid waste to be managed, but also on the quality of selective collection. In this paper a case-study is analysed in order to point out some strategies useful for a correct management of the problem.

1. INTRODUCTION

The environmental regulations in Italy entrust the management of the municipal solid waste (MSW) selective collection (SC) to the municipalities. This fact causes a non-homogenous situation in neighbouring municipalities and can create difficulties among the citizens especially for the commuter ones but also to the tourists.

In some Italian regions SC is not yet optimized, thus the composition of the residual municipal solid waste (RMSW = the stream not collected separately for recycling purposes) is expected to change significantly in time. Tourism can affect quantity and quality of MSW and can affect the management of existing plants as incinerators. In particular, in tourist regions the significant presence of tourists and the consequent accommodation facilities (which often do not organize SC) are one of the main cause of the bad results in terms of SC performance. Other causes of inefficiency are lack of awareness of the citizens, lack of correct information by public administration, etc (Ranieri and Sirini, 2010; Castagna et al., 2012).

In the study an overview of the MSW produced in five tourist areas of Apulia (south of Italy) is reported. Separate collection in this area is operated by road container collection and door to door sytem (kerbside collection).

2. MSW COLLECTION CHARACTERISATION IN THE TWO CASE STUDIES

As explained above, in order to allow the critical analysis of the integration of RMSW incineration and SC in tourist areas, one Italian case-study has been selected. The main characteristics of the MSW in this case-study are reported below.

The region must face with the European Union target of 65% of selective collection (Consonni et al., 2011). The case-study the SC has not yet reached a high efficiency, MSW collection in tourist areas must be optimized and an incinerator is present (Ranieri et al. 2010a; Ranieri et a.l 2010b).

2.1 Case study

The ***case-study*** concerns a region in the South of Italy (Apulia) with around 4,000,000 inhabitants, where the tourist fluxes affect the local MSW generation with a noteworthy increase of inhabitant equivalent in summer. Some tourist area, Fasano and Monopoli municipalities particularly, increase their population up to 100 % during summer period (Regione Puglia, 2012).

The current systems for SC are:

- collection with street containers;
- kerbside collection.

The SC is 15% of the total collection as average currently. Kerbside system is operated by three domiciliary visit/week for the different waste fractions. In summer period the curbside collection increases to 4 times/week.

In Figure 1 the MSW composition is presented for the second case study. Compared to the first case-study, the dominance of RMSW is clear as a consequence of the low value of SC. However, a positive trend of SC is visible referred to the last three years.

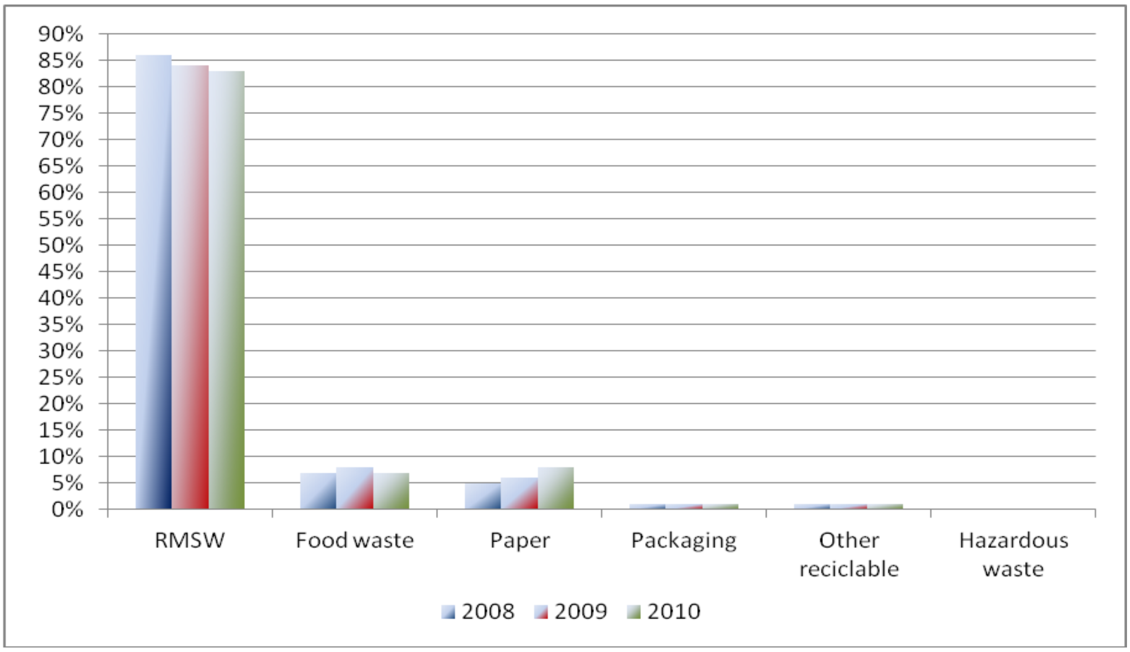

Figure 1. MSW composition for the case study (RMSW and SC fractions).

No different target are established by Apulian Region for the various fraction of the MSW as illustrated in Figure 2, where the same target of 65% is attributed to each fraction.

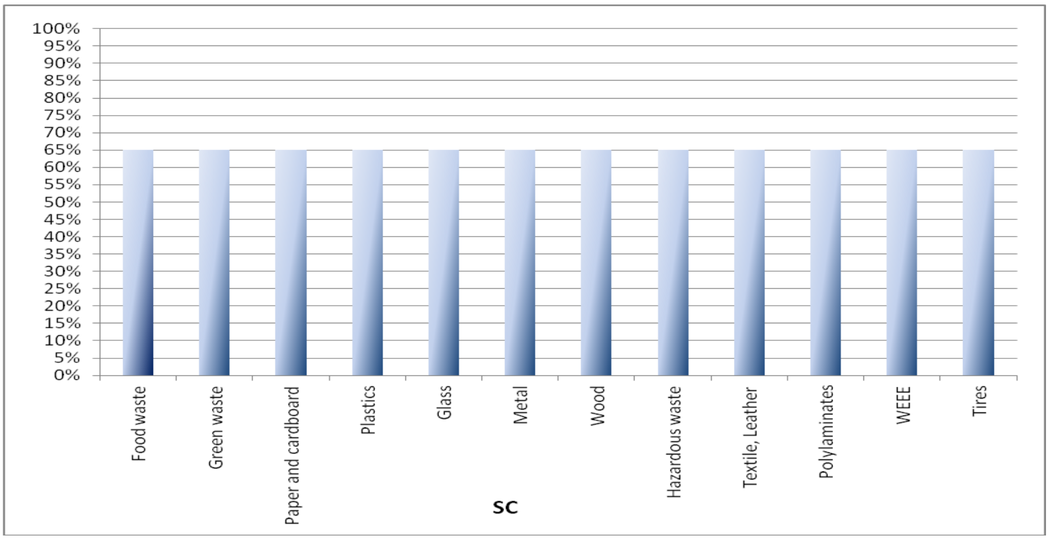

Figure 2. Target SC efficiencies for each fraction for the case study.

In Figures 3 and 4 the dynamics of the amount of per-capita MSW production and of the SC efficiencies for 5 Apulian tourist municipalities are reported (having 133,373 residents). It must be noticed that the summer period shows the lowest values of SC and the highest values of MSW generation. This can be explained by the unefficient behavior of the tourists in SC activities and on the increase of population equivalent in the summer period. Compared to the a non tourist case study, the peaks of August are more visible.

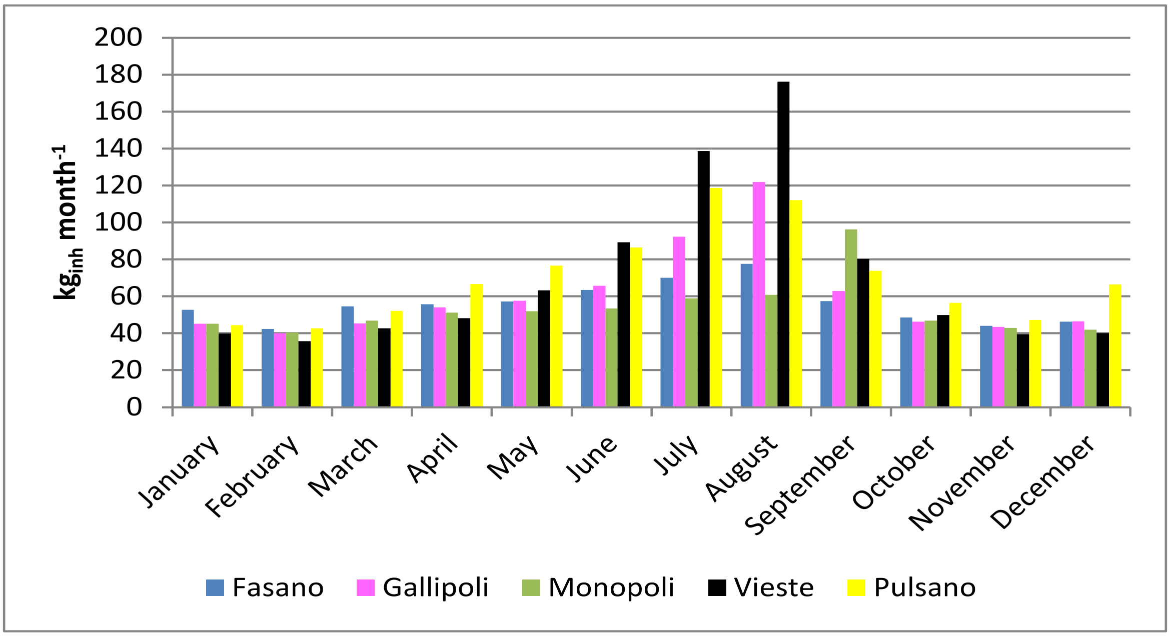

Figure 3. Monthly per-capita generation of MSW.

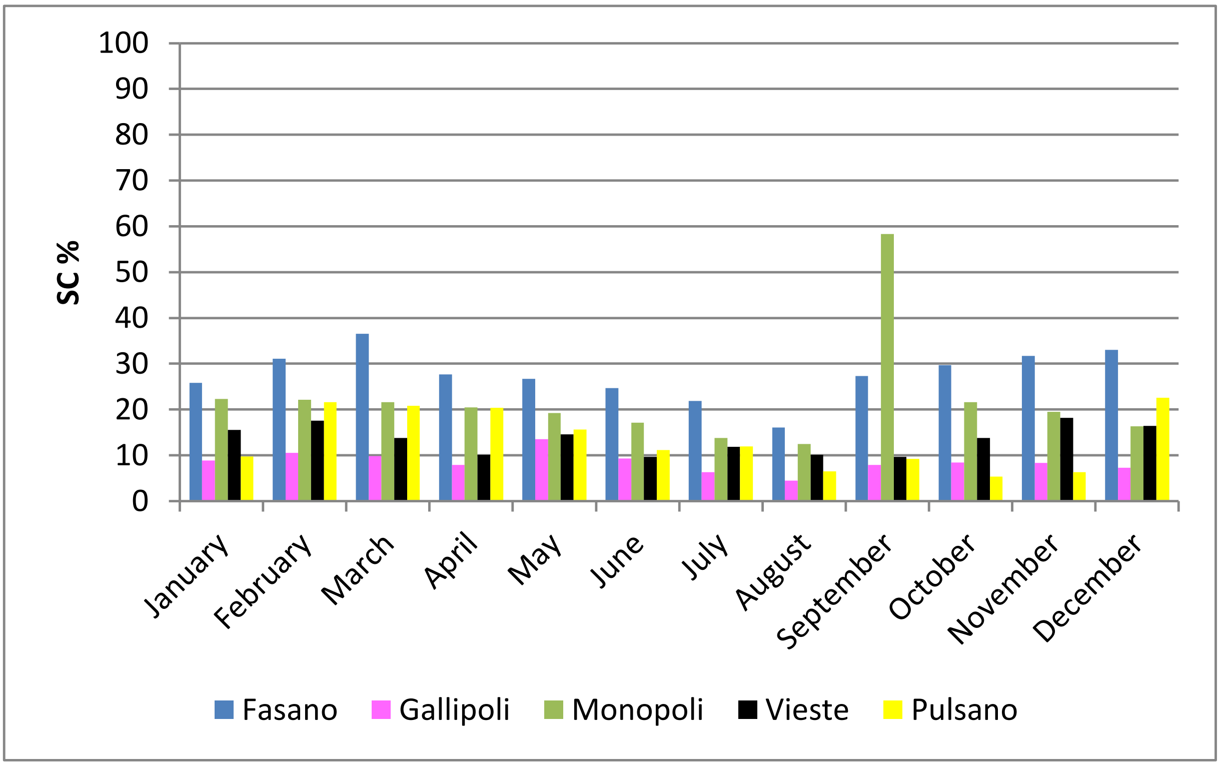

Figure 4. Percentage of SC during 2011.

3. RMSW TREATMENT CHARACTERISATION IN THE TWO CASE STUDIES

3.1 Case study

Figure 5 illustrates the Massafra incineration plant for the combustion of the pre-treated MSW in Apulia, as indicated in Figure 6. The plant that treats the MSW was constructed in order to produce a combustible material from MSW, that is RDF, that today has been modified into SRF (Rada and Andreottola, 2012). The scheme shows a typical one-stream option, exploiting the high percentage of food waste in RMSW (40%). In Table 1 some characteristics of the plant are reported. The amount of RDF treated yearly demonstrates that the capacity of the plant is not calibrated on the total amount of RMSW collected in the region. That means that the variability of RMSW during the tourist season can be faced with a different use of landfilling (that compensates the incineration capacity).

Figure 5. View of Massafra incinerator plant.

Table. 1 Technical details of the Massafra incinerator plant (Appia Energy, 2012)

Technical details of Massafra incinerator	
Power	10 MW
RDF consumption	12,5 t/h
Average LHV	3.365 kcal/kg
Hours of running plant	7.500 h/y
Production of energy	75.000.000 kWh/y

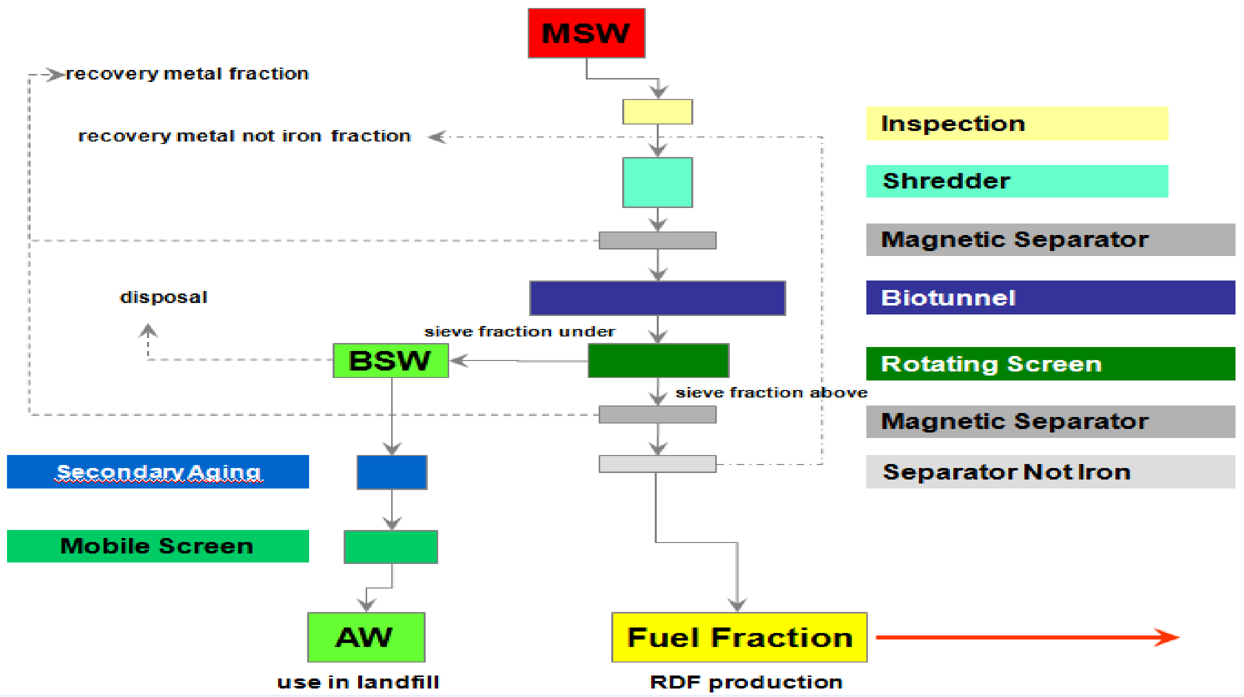

Figure 6. Block diagram of the RDF/SRF production.

3. DISCUSSION

A comparative analysis of the two case studies is presented in Table 2 taking into account economical aspects, environmental balances and social concerns. The role of incineration depends strongly on the presence and of the efficiency of SC (thus it depends also on the presence of tourism, indirectly).

Table 2. Comparative analysis

	Case study
Tourist awareness	Possibly low
Resident people behavior	Presently low efficient
Environmental balance	SC to be optimized
Role or RMSW incineration	Not fully integrated to SC
RMSW dynamics and tourism	Managed by landfilling
Incineration capacity aspects	Not calibrated on the region
Expected trend of SC	Strong effort expected
Detailed targets of SC	Absent
Energy from incineration	Co-generation
RDF/SRF role	Preferred
Economical considerations	SC unoptimised
Tourism and incineration	Not critical

5. CONCLUSIONS

The present paper analyses a case-study where tourism significantly affects MSW generation and SC efficiency. The role of incineration is analysed too, in order to verify if the presence of tourism affects design or management of the plant. The available data demonstrate that the fluctuations of RMSW can be significant, but on a wider area of collection the effect of "dilution" in more steady RMSW streams can reduce significantly the consequences on design and management of incineration.

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ISBN: 978-984-33-7045-7, PI. 145 (1-10)

Proceedings of the WasteSafe 2013 – 3rd International Conference on
Solid Waste Management in the Developing Countries
10-12 February 2013, Khulna, Bangladesh

Management of Park Solid Wastes in Khulna City

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ABSTRACT

Park is a designated land used by the public for recreation. Proper and efficient management of park solid wastes protect the health, safety and wellbeing of park users and operators. Problems of park solid waste management mainly include hazardous accumulations of dangerous debris and refuse; objectionable odors; and basic unsightliness. Food discards; paper, polythene and plastic packets; plastic and glass bottles; plastic and metal cans; tree leaves, branches, limbs and trimmings; etc. are the different categories of park solid wastes. There are ten parks in Khulna city. Shahid Hadis Park, Jatisangha Shishu Park, Khalishpur Wonderland Amusement Park, Muzgunni S S World Shishu Park, Prem Kanon etc. are the mostly used parks. Solid waste management of the privately operated parks is comparatively better. Waste bins are found only in these parks. On the other hand, solid waste management of the publicly operated park is merely good and poor in most cases.

BACKGROUND AND INTRODUCTION

Park is tract of land, designated land used by the public for active and passive recreation. It meets a multitude of human needs from physical to social and psychological (Urban Planning Guide, 1986:335). The parks are provided to meet with the needs of fresh air and peaceful enjoyment of the unspoiled nature. In congested city areas, it is not possible for the inhabitants to secure this type of recreation and therefore, the parks should invariably be provided for the benefit of much people (Rangawala and Rangawala, 1995:109). Better physical and social environment of parks attracts different sections of urban people. On the other hand, poor environment discourage them to use the parks. Often they make their children, family members and even relatives refrain from using the parks (Karim and Roy, 2010).

Proper and efficient collection, storage, and disposal of the solid waste generated in a park or recreation area are essential elements of the support services and facilities that must be considered in park planning. Because of the health and sanitary problems inherent in some solid waste left in parks, these problems must be carefully studied along with liquid waste treatment, drinking water, and safety/emergency provisions (Christiansen, 1977). Guelph is considered to be one of the first planned towns in Canada. It prepared its Master Plan which sets path for waste management. The Solid Waste Management Master Plan (SWMMP) is now complete and sets a path to achieve new waste minimization, diversion and disposal targets, identifies both short and long-term programs designed to achieve the targets, and provides an estimate of the extent to which each component moves the City towards achieving the overall goals. Guelph residents participate in a three-stream curbside waste collection program - green for organics, blue for recyclables and clear for landfill (City of Guelph, 2013). Khulna City generated 380 m. tons of solid wastes in 1998 and by the year 2020 it would be around 922 m. tons. Though statutorily Khulna City Corporation (KCC) is responsible for managing the solid wastes of Khulna City it has no separate Solid Waste Management Master Plan for improving the solid waste management system of Khulna City. Khulna Development Authority (KDA), a local city planning and development controlling authority prepared the City Master Plan and Structure Plan for the period of 2001-2010 and 2001-2020 in 2001. The Plans have population and solid waste generation forecasting for Khulna City and its adjacent urbanizing areas for different time periods of 2010, 2015 and 2020 with a number of solid waste management improvement proposals (Roy, 2011).

OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

- To find out the parks of Khulna City with their existing solid waste management system;
- To investigate the problems for management of park solid wastes; and
- To draw some recommendations for improving solid waste management system of the parks.

METHODOLOGY

The study is conducted in 2012 following mostly the social survey method. Both primary and secondary data is collected and used. Some primary data i.e. name, location, history, land area and solid waste management system of the parks etc. are collected from park authorities-Khulna City Corporation (KCC) and Khulna Development Authority (KDA), park operators, nearby people and park users through discussion and informal interview. Existing condition of the parks in terms of their solid waste management is investigated through field survey. Photographs of the parks are taken. Secondary data is collected from the documents and reports of KCC, KDA and offices of park operators. Book, dissertation, report, and national and local daily newspapers are reviewed and used as secondary sources. Collected data is analyzed and incorporated in texts, tables and maps. GIS software is used for preparation of maps.

KHULNA CITY AS THE STUDY AREA

Khulna is the third largest industrial and second largest port city of Bangladesh. It is a divisional city and acts as regional hub of administrative, institutional, commercial and academic affairs. It is located on the banks of the Rupsha and the Bhairab Rivers. It lies between $22^0$47´16´´ to $22^0$52´ north latitude and $89^0$31´36´´ to $89^0$34´35´´ east longitude. The city covers an area of 45.65 square kilometers with a population of near about 1.5 million. The city, for administrative purposes, is divided into 31 wards: each ward consists of different *mahalla*s, the total number of which is 143 (Population Census, 2001). Khulna Municipality was established in 1884. The area within which municipal limits was 12.02 square kilometers (KDA Master Plan, 2002). During late 1950s, and early 1960s Khulna became an important centre for industrial development. With the establishment of Mongla port, just about 40 km. south of Khulna, the city gained further momentum. Many new industries were setup at Khulna and commercial activities increased manifolds, and thus, the city became centre point of jute industries and jute trade in Bangladesh. After liberation, the population of Khulna continued to rise. Economy of the city is again strengthened with introduction of regional shrimp farming and shrimp processing activities (KDA Structure Plan, 2002). The average household size of Khulna City is 4.5 and literacy rate is around 94% (Population Census, 2001). Monthly income of about 66 percent employed people is within Tk. 5,000. About 30 percent of the total employs monthly income is within Tk. 2,500. They are the people who live below poverty level. Only 3.5 per cent of the employed people belong to monthly income group Tk. 15,000 and above (Khan, 2006).

STATUTORY PROVISION OF KCC IN MUNICIPAL SOLID WASTE MANAGEMENT

The Khulna City Corporation Ordinance, 1984 in its Chapter One titled “Public Health” under the Part II of “Functions in Detail” has the directive on “Removal, Collection and Disposal of the Refuse of the Municipal Area”. The section 75 and its sub-sections are as like as “75. (1) The Corporation shall make adequate arrangements for the removal of refuse from all public streets, public latrines, urinals, drains, and all buildings and land vested in the Corporation, and for the collection and proper disposal of such refuse. (2) The occupiers of all other buildings and lands within the Corporation shall be responsible for the removal of refuse from such buildings and lands subject to the general control and supervision of the Corporation. (3) The Corporation may cause public dust-bins or other suitable receptacles to be provided at suitable places and where such dust-bins or receptacles are provided, the Corporation may, by public notice, require that all refuse accumulating in any premises or land shall be deposited by the owner or occupier of such premises or land in such dust-bins or receptacles. (4) All refuse removed and collected by the staff of the Corporation or under their control and supervision and all refuse deposited in the dust-bins and other receptacles provided by the Corporation shall be the property of the Corporation (The Khulna City Corporation Ordinance, 1984).

SOLID WASTE MANAGEMENT SYSTEM IN KHULNA CITY

The responsibility of collection and disposal of solid waste generated from KCC area is lying under the management of KCC. Solid waste management system in KCC area is found improved mainly after 1998, the initiation of the intervention of PRODIPAN, an NGO. A number of NGOs and CBOs are now involved in door to door collection system with small-scale organic solid waste composting and organic fertilizer preparation. In the system of NGOs and CBOs, generally a garbage collector comes with a rickshaw van to collect waste from individual households. The collector then disposes off the waste to a transfer point from where KCC trucks pick it up and carries to the final waste disposal sites. The NGOs that work in the KCC are CLANSHIP ASSOCIATION, MUKTIR ALO, RUSTIC, BRIC, RUPAYAN, NABARUN SANGSAD, SEIAM, CHD, SPS and SAMADHAN. The Conservancy Department of KCC has lack of technical manpower i.e. Engineers, Town Planners and Environmentalist. This is why, performance of the department is not up to the mark.

Khulna City Corporation (KCC) and community based NGOs-CBOs are taking care of 60% of the total waste generated while the rest of them are unattended (KCC,2010). In fact, most of the wastes are collected from door-to-door without any sorting and either dumped in open space or improperly landfilled. Thus, the city is facing serious health risk due to uncollected domestic waste on the streets and other public places resulting into clogged drainage system and contamination of water bodies. According to the population census, the population of KCC area was 0.62 million in 1991. Considering the medium projection, it was estimated as 0.92 million for 2000 and it will be 2.05 million by 2020. Waste generation in the city area depends on its population. The Structure Plan estimated generation of solid wastes in the KCC area for the year 2000, 2010 and 2020 was 411 tons, 624 tons and 922 tons.

The solid waste management system in KCC area has been improved with increased collection and disposal efficiency. Manpower, transport and equipment facilities and solid waste collection and disposal efficiency of KCC are shown in the Table 1 and Table 2 below.

Table 1 Manpower, transport and equipment facilities of KCC in 2010

Manpower		Vehicle and equipments	
Designation	Nos.	Type/Name	Nos.
Conservancy Officer	1	Dumping Truck-7 ton (open 15 & covered 3)	18
Assistant Conservancy Officer	1	Normal Truck -5 ton (open)	8
Conservancy Supervising Inspector	1	Small Truck -3 ton (open)	8
Conservancy Supervisor	35	Rickshaw van (3 wheelers)	260
Labour/Conservancy Worker (Muster Roll-681 & Permanent-275)	956	Wheel burrow (for different Wards)	76
Total	994	Demountable Containers	20

Source: KCC, 2010.

Table 2 Solid waste collection and disposal efficiency of KCC in 2010

Population 2010	Volume of solid waste generation (ton/day)	Volume of solid waste collected and disposed by KCC (ton/day)	Collection and disposal efficiency (%)	Garbage Truck Trip per day
1.5	450	270	60	40

Source: KCC, 2010.

PARKS OF KHULNA CITY

There are ten parks in Khulna City-7 for children and 3 for all. Shahid Hadis Park, Jatisangha Shishu Park, Khalishpur Wonderland Amusement Park, Muzgunni S S World Shishu Park, Prem Kanon etc. are the mostly used parks. The parks are mostly established and maintained by Khulna City Corporation (KCC) and Khulna Development Authority (KDA). Seven parks are operated by KCC, two are operated privately by leaseholders and the remaining one is operated by a Religious Trustee Board. Table 3 shows the number of parks in Khulna City with their area and location. Map 1 shows location of parks in Khulna City.

Table 3 Parks of Khulna City

Sl.	Name of the Park	Estb. Year	Area (acre)	KCC Ward	Location/ Road	Managed & operated by
1.	Shahid Hadis Park	1884	1.35	21	Lower Jessore Road	KCC
2.	*Prem Kanon*	1928	1.67	16	*Prem Kanon* Road	*Satta Naryan Temple, Khulna*
3.	Golokmoni Shishu Park	1960	0.06	23	Sir Iqbal Road	KCC
4.	Jatisangha Shishu Park	1994	1.13	27	Khan Jahan Ali Road	KCC
5.	Solaiman Nagar Shishu Park	2003	0.57	25	Sher-E- Bangla Road	KCC
6.	Sonadanga Shishu Park	1981	0.46	17	Sonadanga R/A	KCC
7.	Nirala Shishu Park	1980	0.40	24	Nirala R/A (Rd.-17)	KCC
8.	Khalishpur Wonderland Amusement Park	1994	3.78	11	Khalishpur Housing Estate (Rd.-18)	KCC (Leaseholder)
9.	Muzgunni S S World Shishu Park	2006	9.00	9	Muzgunni Main Road	KDA (Leaseholder)
10.	KCC Solar Park	2007	4.33	17	SonadangaR/A	KCC

Source: Field survey, KCC and KDA, 2012.

Shahid Hadis Park

The park is situated at the northern side of Lower Jessore Road and in front of N*agar Bhaban* (City Corporation Building). It is in the Ward no. 21. It was established in 1884 at the time of formation of Khulna Municipality.

Prem Kanon (Garden of Love)

The park is situated at Prem Kanon Road near *Jora* gate (pair gates) in 16 no. KCC Ward. It was established in 1928 by the personal initiative of a renowned Maroary named Mongol Chand Chunilal Mehta. It is said that Chunilal loved his elder son Premshukh Mehta very much. He named the park as Prem Kanon after the name of his son Premshukh for long lasting his memory to people.

Golokmoni Shishu Park

The park is situated at the eastern side of Sir Iqbal Road in KCC Ward no. 23. It is near the *Dharmosava* temple. It is said that a local woman named Golokmoni excavated a pond as source of drinking water for the area general people on this land. In 1884, after introduction of the mechanical water supply system in the city, the pond was filled by municipality authority. 1n 1960, the then chairman of municipality Dost Mohammad established a park for the amusement of city children and women there.

Jatisangha Shishu Park

Jatisangha Park is situated at the western side of Khanjahan Ali Road near Shantidham mor. It is in the Ward no. 27. Once there was a big pond as source of drinking water for city people on that land. The pond was encircled for protection by *Tar Kata* (iron rope) and so, local people called it *Tarer Pukur*. Like other ponds, KCC filled it and established this amusement park for city dwellers. The park started its journey in 1994 with the name of Mohanagri Shishu Park. The park was renamed as Jatisangha Shishu Park on 21 November 1995 on the occasion of celebrating the United Nations Silver Jubilee.

Solaiman Nagar Shishu Park

The park is situated at the western side of Sher-E-Bangla Road near the south of Moilapota Mor. It is in 25 no. ward of KCC. In past, there was a slum on the land. As the slum was disgusting and ugly in such a public place, KCC cleared the slum for establishing this park on it.

Nirala Shishu Park

The park is situated in the southern part of Nirala Residential Area. It is developed by KDA as a community facility. It is in 24 no. ward of KCC.

Sonadanga Shishu Park

The park is situated in the Sonadanga residential area and developed by KDA. It is in the Ward no. 17. The park was planned for the amusement of children in the residential area.

Khalishpur Wonderland Amusement Park

The park was established in 1996. It is situated at the eastern side of 18. no. Road of Khalishpur Housing Estate under KCC Ward no. 11. KCC is the owner of the land.

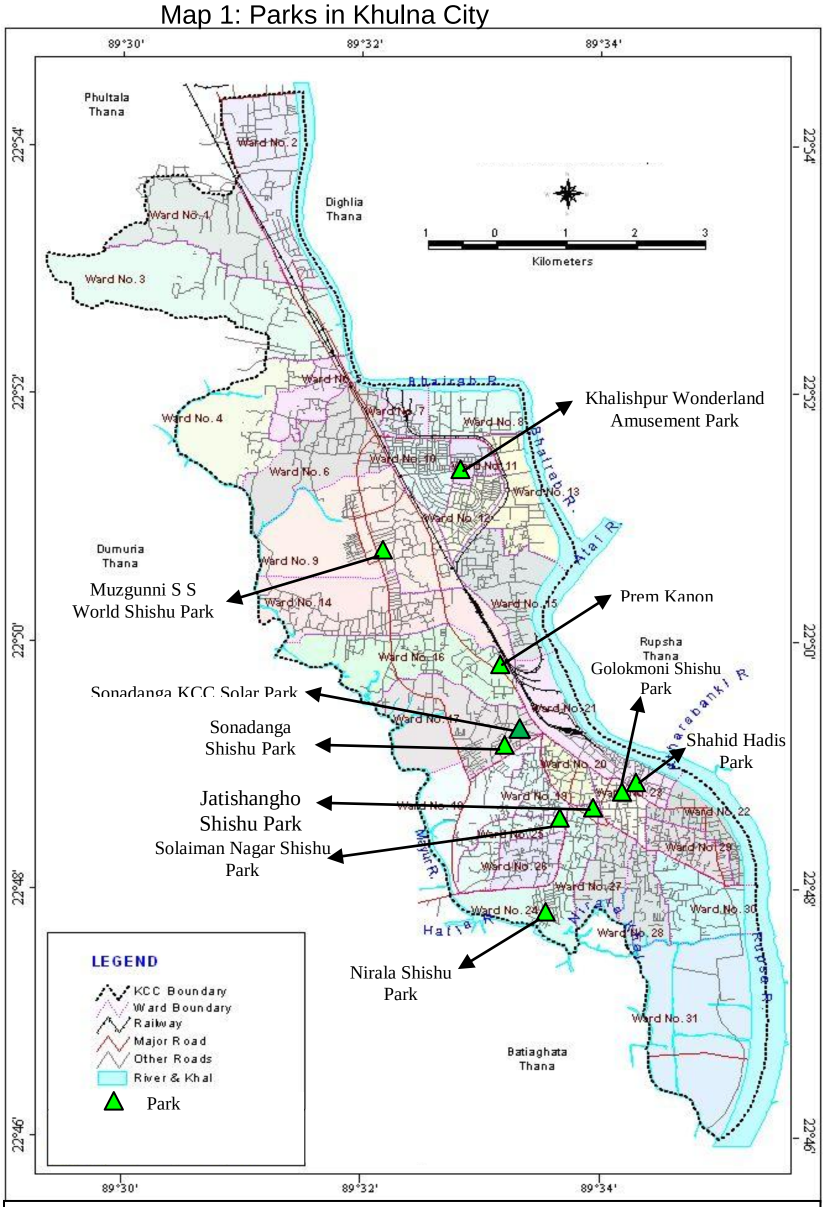
S S World Shishu Park

The park is situated at the eastern side of Muzgunni Main Road (KDA Outer Bypass). It is in KCC Ward no. 9. KDA has developed the park.

KCC Solar Park

KCC Solar Park is a newly established park. KCC has established it in 2007. It is in the Ward no. 17.

Map 1: Parks in Khulna City



Source: Reproduced from base map of BCAS, 2007 based on field survey in 2012

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ISBN: 978-984-33-7045-7, PI. 145 (1-10)

PARK SOLID WASTES

Food discards; paper, polythene and plastic packets; plastic and glass bottles; plastic and metal cans; tree leaves, branches, limbs and trimmings; etc. are the different categories of park solid wastes.

PARK SOLID WASTE MANAGEMENT IN KHULNA CITY

Collection, storage and disposal of park solid wastes protect the public health, safety and wellbeing of park users and operators. These also contribute significantly to the quality and aesthetics of the recreational setting of parks. Problems of park solid waste management include objectionable odors; presence of disease-transmitting vectors, insects and animals; hazardous accumulations of dangerous debris and refuse; and basic unsightliness. Park solid waste management can be categorized as publicly and privately (by leaseholders) operated.

Publicly Operated Park Solid Waste Management

Khulna City Corporation directly operates and maintains seven parks. The parks are Shahid Hadis Park, Golokmoni Shishu Park, Jatisangha Shishu Park, Solaiman Nagar Shishu Park, Nirala Shishu Park, Sonadanga Shishu Park and KCC Solar Park.

Shahid Hadis Park

Tree leaves, construction debris, unveiled polythene food packs, paper etc. are the generally produced solid wastes in Hadis park. There was a dustbin a few years ago on PC Roy Road at the outside western boundary close to the western gate of Shahid Hadis Park. Park wastes and street sweepings are left on this spot and KCC vans collect wastes from this point. There is a tea cum snacks stall at the northwestern corner inside the park. The wastes generated by this stall are not properly managed and makes also the park environment dirty. The park has lack of proper drainage facilities. Some unattended scattered solid wastes fall into the parkside drains and clog, which create water stagnation in the park during heavy rainfall. Re-design, reconstruction and redevelopment works of Shahid Hadis Park are going on.

Golokmoni Shishu Park

At times nearby households, grocery shops and tea-snacks stalls dispose of their wastes inside different corners of Golokmoni Shishu Park. Fruit and wood trees such as mango, coconut and rain trees are planted along inside boundaries of the park. These trees produce more leaves. The fallen leaves unattended for long period become waste. The park is not swept regularly. A heap of park, drain and street sweepings is found at the southwestern inside corner of the park.

Jatisangha Shishu Park

Waste management of Jatisangha Shishu Park is poor. The park is not swept regularly. Wastes are scatterd all over the park. The park is mainly swept before and after holding some festivals and functions like *Boishakhi Mela* (Fair of Bengali New Year), *Eid* Mela (Eid Fair), *Pujar* Mela (Puja Fair) etc. There are number of haphazardly planted local leafy tress inside the park, which creates the park dirty. Some kitchen shops, tea and bakery stalls are scatteredly found along its outside eastern and western boundary. The shops, stalls and some nearby households dispose of their wastes on roadside close to its second (No.2) gate.

Nirala Shishu Park

The park is maintained by KCC and its management system is poor. Although the residential area has two well organized Welfare Associations/Community Based Organizations (CBOs) named *Nirala Abasik Alaka Janokallyan Samity* (Nirala Residential Area Welfare Organization) and *Nirala Abasik Alaka Adarsha Janokallyan Samity* (Nirala Residential Area Ideal Welfare Organization), the organizations do not take care of the park. Plenty of local trees such as coconut, betel nut, rain tree, *Korai*, *Khai* etc. are there in the park. Trimmings and unattended leaves of the trees are mostly the wastes of this park. Outside drains and inside are of the park is not regularly swept.

Sonadanga Shishu Park

There is big banyan tree at the center of Sonadanga Shishu Park. Arum cultivation is found inside its western-southern boundary. There is a dustbin at the western side of Sonadanga Shishu Park. Nearby households dispose of their kitchen wastes in this dustbin, which is not cleaned regularly. Some local people are using the park as storage of their building construction materials making the park dirty. The park is also not swept regularly. The residential area has a welfare association but it does not look after the park.

Sonadanga KCC Solar Park

Solid waste management of this park is average. Goats are found to graze in this park. There is a ditch full with water hyacinth in its southern part. Paper and polythene packs as wastes are found scattered in the park. The park is not swept regularly.

Solaiman Nagar Shishu Park

The park is situated at the western side of Sher-E-Bangla Road near the south of Moilapota Mor. It is in 25 no. ward of KCC. Total area of the park is 0.5744 acre. In past, there was a slum on the land. At present there is no ride in the park. Now local children play cricket inside the park. There are number of haphazardly planted local tress inside the park. There is a big and unique *chula* market (mud made furnace) along the outside eastern boundary of the park on Sher-e-Bangla Road. Solid waste management of this park is average.

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Privately Operated Park Solid Waste Management

There are two privately operated parks with fees on entry and rides in Khulna city. The parks are Khalishpur Wonderland Amusement Park and Muzgunni S S World Shishu Park. Khalishpur Wonderland Amusement Park is established on KCC land. Solid waste management system of the two parks is better than the publicly operated parks without fees on entry and rides in them.

Khalishpur Wonderland Amusement Park

Khalishpur Wonderland Amusement Park is established on 3.78 acre KCC land in Ward no. 11. A private leaseholder has taken the land lease from KCC for a period of 20 years since 1994 for establishing this park. Entry fee of this park is Tk.30 and fees for enjoying per ride of all the 22 rides is Tk.20. There are 9 (nine) waste bins in the Khalishpur Wonderland Amusement Park. Park users dispose of their wastes in the waste bins and sometimes outside the bins. These wastes are collected by 4 (four) cleaners appointed by the Park operator. Then they hands over the wastes to KCC waste collecting vans from the park. Sometimes, wastes are disposed to nearby secondary disposal sites. Finally KCC picks up the wastes to landfill site. At times, some wastes are used to fill up the small dug holes made inside different parts of the park. Park wastes are not burnt. Wastes are not segregated in different categories for reuse and recycling. Waste management of this park is good.

Muzgunni S S World Shishu Park

There are 14 (fourteen) waste bins in the Muzgunni S S World Shishu Park. Park users dispose of their wastes in the waste bins and sometimes outside the bins. The wastes are collected by cleaners appointed by the Park operator. Park wastes are generally burnt inside the park. At times, some wastes are disposed into nearby secondary disposal sites of KCC. Finally KCC picks up the wastes to landfill site. Wastes are not segregated in different categories for reuse and recycling. Adequate numbers of rain trees produce huge leafy wastes in the park. Waste management of the park is good.

Prem Kanon Park

The park is situated at Prem Kanon Road near *Jora* gate (pair gates) in 16 no. KCC Ward. Total area of the park is 5.00 acre. It was established in 1928 by the personal initiative of a renowned Maroary named Mongol Chand Chunilal Mehta. In the park, *Kamini* trees are given shapes of different animals namely tiger, elephant, horse, deer etc. Waste of this park is mainly the leaves of trees and shrubs. Other wastes include papers, polythene packs etc. merely dropped by visitors. There is no trash bin in this park.

As the poorly maintained parks are not swept and cleaned regularly, there inhabits mosquitoes, flies, rats etc. insects and pests along with dogs and cats detrimental to human health.

Table 4 Parks of Khulna city with trash bins and level of solid waste management

Sl.	Name of parks	No. of Trash Bin	Level of service	Sl.	Name of parks	No. of Trash Bin	Level of service
1.	Shahid Hadis Park	-	Average	6.	Sonadanga Shishu Park	-	Poor
2.	Prem Kanon	-	Average	7.	Nirala Shishu Park	-	Poor
3.	Golokmoni Shishu Park	-	Poor	8.	Khalishpur Wonderland Amusement Park	09	Good
4.	Jatisangha Shishu Park	-	Poor	9.	Muzgunni S S World Shishu Park	14	Good
5.	Solaiman Nagar Shishu Park	-	Average	10.	KCC Solar Park	-	Average

Source: Field Survey, 2012.

RECOMMENDATIONS FOR IMPROVING WASTE MANAGEMENT SYSTEM OF PARKS

The recommendations made for improving the solid waste management system of parks of Khulna city are:

- The park operators should regularly sweep and clean the parks
- Parks having local leafy plants and trees can be brought under re-plantation with ornamental shrubs and trees that produce less leaves as park waste
- Concerned Ward Councilor, nearby shop owners, household owners need to be made aware to make the park waste free
- The park operators can keep specially designed attractive waste bins in the parks
- Separate provisions of waste bins for different category of wastes can be made
- Waste bins in parks should be located at appropriate locations and these should be shown in layout plans
- Awareness on park solid waste management issues of the staffs of waste collecting organizations i.e. GOs, NGOs and CBOs and school-college students can be raised through training, orientation and campaign etc.
- The parks to be declared as “No Plastic Zone” to make refrain the users to enter the parks with plastic packs
- Parks to be regularly inspected by the City Mayor, Ward Councilors, Officers of Conservancy Department and NGO-CBO representatives
- Park Solid Waste Management Committees can be formed by concerned stakeholders
- More Research and Development projects on aspects of park solid waste management can be undertaken by different organizations like KCC, Universities, NGOs and CBOs
- Care to be taken to manage the park vectors, pests and insects like dogs, cats, rats, mosquitoes, flies etc. detrimental to health and nuisance to park users
- Instruction boards on park cleanliness and waste management for park users can be established in the parks
- A separate guideline on management of park solid waste can be prepared by the Conservancy Department of KCC through in-depth research, dialogues, consultation meetings, workshops etc. with concerned stakeholders
- KDA and KCC can jointly design projects on solid waste management for Khulna city including components of park waste management
- More technical manpower i.e. Engineers, Town Planners and Environmentalists can be recruited in the Conservancy Department of KCC following the proposed organogram of KCC and its Conservancy Department. It will help to get momentum of the Conservancy Department with better performance and sincerity.

CONCLUSION

Solid waste management of the privately operated parks is better than the publicly operated parks in Khulna City. Management system of park wastes can be improved by the coordinated efforts of GOs, NGOs, CBOs and all concerned stakeholders. Public Private Partnership (PPP) can be an effective initiative in this regard.

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