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APPLICATION OF GIS FOR MONITORING IMPACT OF ARSENIC ON HUMAN HEALTH IN DHAKA DIVISION

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ABSTRACT:

This study examines the overall arsenic pollution scenario in groundwater in the districts of Dhaka Division. In this study, a widespread analysis of the available data has been done and maps were plotted using 'ArcGIS 9.1' Software. Analysis of this data is the main concern of study. During mapping, percent area contaminated up to mouza level, population exposed to contamination, population awareness of ground water pollution, number of patients in the region have been analyzed. And on the basis of the analysis some outcomes are focused in this study. The objectives of the study are to depict the contamination scenario in Dhaka division, to analysis of the data to find out the vulnerable areas and to find out the overall health condition and awareness of the population.An important aspect of mapping was the use of sophisticated GPS coordinated tube wells' water quality data.

KEYWORDS: *Arsenic (As), Ground Water, ArcGIS, Percent Contamination,ppm, Dhaka Division*

1. LITERATURE REVIEW:

There is clearly a very serious problem of arsenic in groundwater in much of southern and eastern Bangladesh In terms of the population exposed to it is the most serious groundwater arsenic problem in the world[1-6] The groundwater arsenic problem in Bangladesh arises because of an unfortunate combination of three factors: a source of arsenic (arsenic is present in the aquifer sediments), mobilisation (arsenic is released from the sediments to the groundwater) and transport (arsenic is flushed away in the natural groundwater circulation) [2-3].Groundwater contamination by arsenic was first discovered in the west of Bangladesh in late 1993 following reports of extensive contamination of water supplies in the adjoining areas of India. Further testing in 1995 and 1996 showed that contamination extended across large parts of southern and western Bangladesh The discovery of arsenic however (in 1993) put a dent into this success story[2-3]. Close to one-third of all shallow tubewells in Bangladesh exceed the national standard for permissible arsenic concentration of 50 µg/l [4]. In response to the discovery of arsenic, the Government of Bangladesh (GOB) and a variety of national and international organizations started arsenic measurement and mitigation programmes[5]So, arsenic contamination in drinking water is a great concern of this study.

2. ANALYSIS OF THE ARSENIC CONTENT IN GRUNDWATER OF DHAKA DIVISION

2.1 Data Collection: The data considered here was collected from the different agencies involved in the work of underground water. Mainly this secondary data was collected from Department of Public health Engineering (DPHE) and The United Nations Children's Fund (UNICEF).From collected data it is seen that Faridpur, Gopalganj,Madaripur and Munshigonj are mostly vulnerable for arsenic in drinking water. In this project study,a thorough analysis of the available data have been made. These data includes number of people surveyed, number of tubewells, percentage contamination of the tubewells, tubewell ID ,tubewell colours, number of people affected etc. GPS locations of tubewells and arsenic concentration of two Thanas named Bhanga in Faridpur district and Serajdikhan in Munshiganj district were also collected. These data were converted to database format using GIS software. Awareness was assessed with the help of a carefully designed questionnaire. Hundred percent accuracy is not possible in this method. Because here whole area is not counted. So there is some error. But it is compensated near to 100% by calculation of error. The two thanas Bhanga and serajdikhan have 13 unions both which are divided into 13 domains each. Then 8 domains were considered for questionnaire survey. This domain selection is based on the fact that which area is more effective for this assessment. Then survey is done. And finally on the basis of results of questions awareness of people has been assessed. The numbers of patients, their identity were enlisted in the civil Surgeon office for the whole districts. Civil Surgeon himself or advise a person to give the lists of affected patients(fig.4) in his area. From this lists the required data were sorted for the unions. This was done in this study for patient detection.

2.2 Results and Discussion:

Ground water quality data of about 5000 tubewells sample which covers most of the arsenic concerned areas in these districts was analyzed and shown in the study area map (Fig.1). Allowable limit of Arsenic in water for drinking in Bangladesh is 10 ppb (WHO drinking limit) and 50 ppb (Bangladesh drinking limit). GIS database was used to detect and classify the sample data based on the concentration above 10 ppb.. Dhaka division is divided into 17 administrative districts, some are contaminated by arsenic in ground water and some are free from it (Fig.3). It is observed that Gopalgonj ,Madaripur, Faridpur, Rajbari,Manikganj,Shariatpur,Munshiganj, some parts of Narayanganj Netrakona are vulnerable areas of arsenic contamination in ground water.These areas are in fact the actual study concern. Data available regarding arsenic are number of thana, number of union,number of mouza,Average red and green tube well percentage,Average arsenic concentration, Percentage of population use red tube wells,arsenic concentration(ppm) distributions of this tube wells,Public economic status,Average public awareness,Health condition of the population.number of usable ponds .On the basis of the results of analysis some valuable steps are taken about what to do for the people in the vulnerable areas. From the Table-1,it is found that there are about 3000 population(Fig.2) in this area among whist male is 52% and female are 48% in which 70% of the population use the red marked tube wells(Table-1). In this the number of red tube wells is 89% and green is 11% which indicate this area is a danger zone for the users of ground water as drinking water. The health condition of the local people is shown that the bad condition of health is 5%, normal condition is 73%and the rest 22% is in good condition. It seems may be very good health condition . But logic shows the opposite. Because arsenic accumulation occurs without showing external response for years this is very dangerous. It is known that after years of accumulation of arsenic from drinking water, it shows its external symptoms. People do not know that they are receiving this poison in their body for years.So People who are in normal health condition must acquiring the arsenic although they are in normal health condition and as they are drinking water from these red tubewells. .If they don't stop drinking water from these contaminated tubewells, their health condition will be bad after some years later. On the other hand people who are in good health condition cannot assure that they remain in good health for years because of frequent contamination of drinking water due to arsenic. This is also true for the people for serajdikhan listed in Table-2.But this area is less critical than Bhanga.This condition of ground water due to arsenic contamination is alarming for the population for any area of Bangladesh.

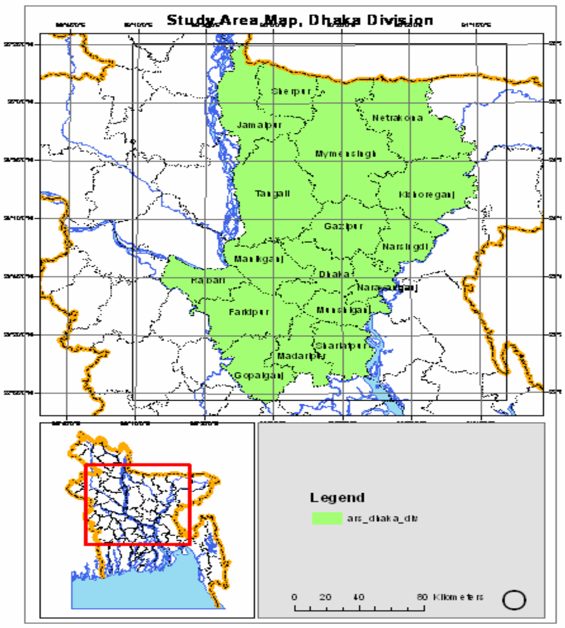

Fig.1 Map showing the Study Area

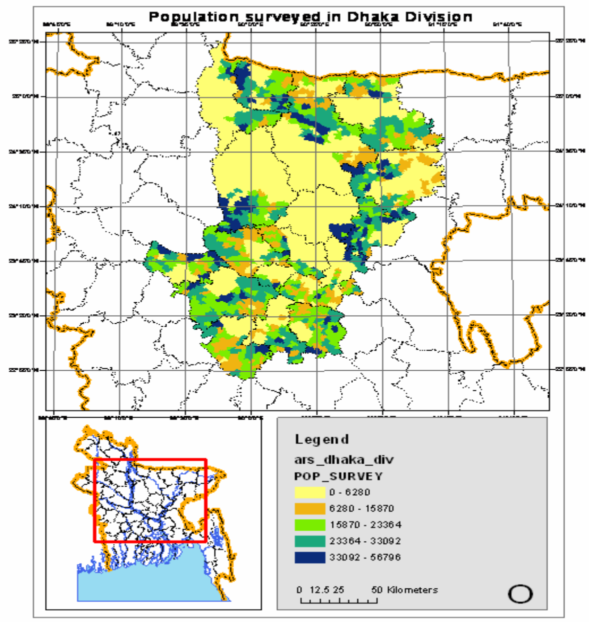

Fig.2 Number of population surveyed

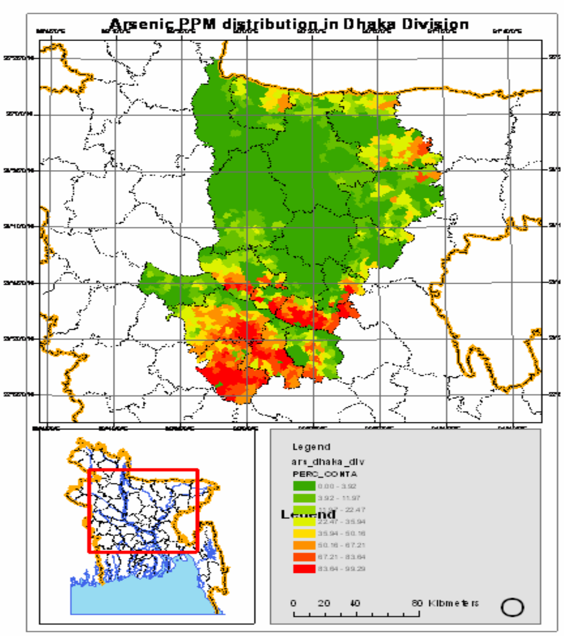

Fig.3 Affected Areas in Dhaka Division

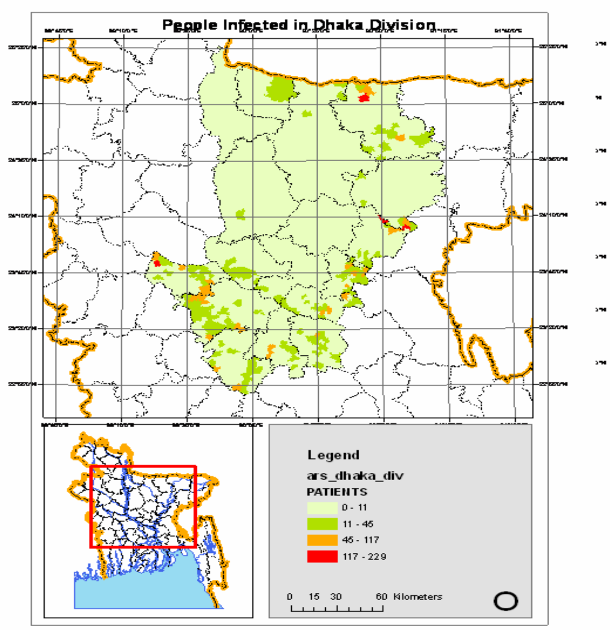

Fig.4 Affected People in the concerned areas

Table-1: Analysis of Bhanga thana database

Gr-1	Users	Gr-2	Health condition ratio	Gr-3	TW category	Gr-4	Male-Female user ratio
Total	22500	Total	2659	Total	3000	Total	2686
Red TW user	15693	Bad	127	Red	2569	Male	1410
Green TW user	6807	Normal	1947	Green	341	Female	1276
%RU	70%	Good	585	%Red	89%	% Male	52%
% GU	30%	%Good	22%	%Green	11%	%Female	48%
		%Bad	5%				
		%Normal	73%				

Table-2: Analysis of Serajdikhan thana database

Gr-1	Users	Gr-2	Health condition ratio	Gr-3	TW category	Gr-4	Male-Female user ratio
Total	24500	Total	2299	Total	2289	Total	2240
Red TW user	12887	Bad	23	Red	1314	Male	1470
Green TW user	11613	Normal	2162	Green	975	Female	770
%RU	53%	Good	114	%Red	57%	% Male	66%
% GU	47%	%Good	5%	%Green	43%	%Female	34%
		%Bad	1%				
		%Normal	94%				

Code: Gr=Group,TW=Tube well, RU=Red tube well users, GU=Green tube well users.Gr-1: User of tube wellsGr-2: Public health condition ratioGr-3: Tube well category
Gr-4: Male female user ratio

2.3 Union-basis analysis of arsenic contamination:

Table-3: Union basis data analysis of Bhanga Thana

Thana	Union	Mouza #	% of red TW	Aerage As Concentration(ppm)	% of population aware	% of patient
Bhanga	Algi	17	70.1	.47	75	.13
Bhanga	Azimnagar	11	32.5	.25	50.44	.02
Bhanga	Bhanga	9	80.4	.41	46.1	.29
Bhanga	Chandra	10	73.3	.41	27.3	.021
Bhanga	Chumordi	2	54.3	.45	33	.24
Bhanga	Ghorua	19	62.3	.44	63.8	.082
Bhanga	Hamirdi	6	51.6	.45	61.10	.86
Bhanga	Kalamridha	10	55.4	.29	46.63	.042
Bhanga	Kaolibera	17	65.4	.32	47.53	.06
Bhanga	Manikdaha	12	60.9	.39	49.41	.86
Bhanga	Nasirabad	7	45.9	.3	35.37	.05
Bhanga	Nurullagonj	11	65.6	.52	50.64	.23
Bhanga	Tuzarpur	7	64.8	.36	54	.104

Table-4: Union basis data analysis of Serajdikhan Thana

Thana	Union	Mouza #	% of red TW	Aerage As Concentration(ppm)	% of population aware	% of patient
Sirajdikhan	Balurchar	8	26	.14	96.4	0
Sirajdikhan	Basail	11	27.8	.06	96.2	0
Sirajdikhan	Bavaragadi	7	28.4	.33	90.4	0
Sirajdikhan	Chitracot	9	67.6	.27	88.15	0
Sirajdikhan	Icchapur	5	24.8	.19	100	.07
Sirajdikhan	Jainsar	10	24.5	.19	96.6	.1
Sirajdikhan	Kavain	11	45.42	.1	100	0
Sirajdikhan	Kola	9	38.9	.18	98.5	.45
Sirajdikhan	Latabdi	9	25.02	.21	89.27	0
Sirajdikhan	Madivapur	16	41.1	.18	96.7	0
Sirajdikhan	Rajanagar	10	41.03	.06	95	0
Sirajdikhan	Rasunia	7	38.5	.18	99.6	025
Sirajdikhan	Shekharnagar	7	40.1	.13	98.13	.003

The red tube well users are more than 50% in these Unions of Bhanga,WHO limit range for contamination (10 ppb)is already exceeded and very close to 50 ppb.Public awareness is less than 50%and percentage of patients is more. But within the Unions of serajdikhan red tubewell users are less than 50%, arsenic contamination exceeds who range but not very close to 50 ppb, public awareness is more than 90%, no of patients are zero in some Unions.There are some Unions where the number of patients decreased with the increase of awareness (Figure:5 and Figure-6).Although the lack of awareness and concentration are the most important and primary criteria for the health problems,other factors are also involved in arsenic contamination.For example the unavailability of Technological help i.e. implementation of technologies at the root level, long distance of household from healthcare centre, lack of safe water options available, safer but less convenient alternatives, low income status etc. But if the total condition is considerd it can be seen that where awareness is more, percentage of patients is low and vice-versa for the two thanas. And the percentage of people awareness in Bhanga is about half of serajdikhan and the patients in Bhanga is 3.29 times of serajdikhan. So, it can be said on the basis of the analysis that awareness is the most important parameters which plays a vital role in reduction of the no of patients. On the other hand, the concentration percentage increase the number of patients increased if assess grossly for these two thanas from Figure 7 and 8. So grossly it can be conclude the concentration of arsenic in drinking is also a great factor for the increase of patients. But the awareness is the most important factor. Because if the usage or extraction of ground water for both drinking and irrigation purposes is decreased and the surface water usage is increased the health contamination can be avoided to a large scale.

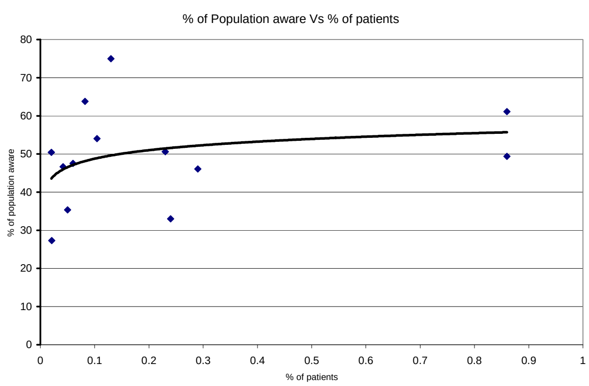

Fig.5 Relationship of public awareness and number of patients,Bhanga Thana,Faridpur

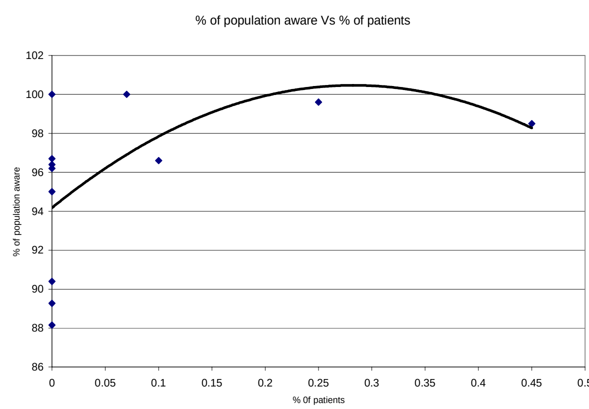

Fig.6 Relationship of public awareness and number of patients,Serajdikhan Thana,Munshiganj

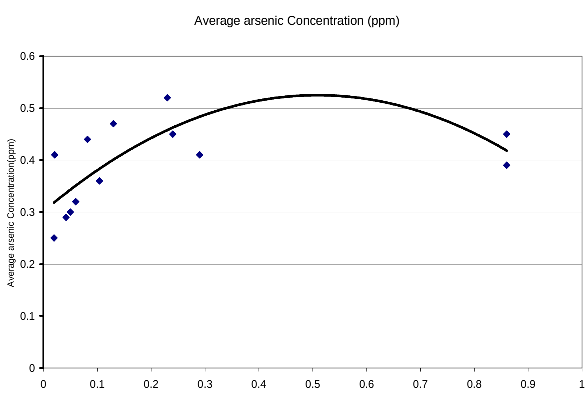

Fig.7 Average arsenic concentration and patients Bhanga,Faridpur

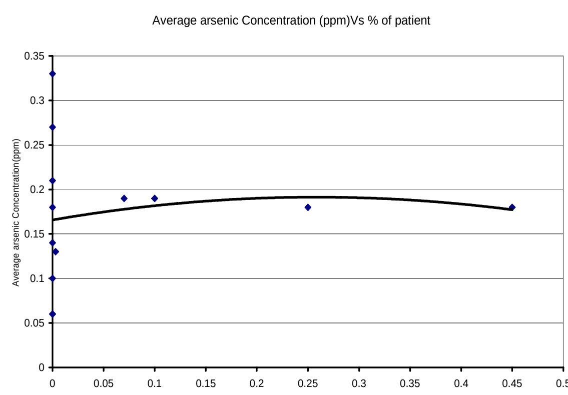

Fig.8 Average arsenic concentration and patients in Serajdikhan,Munshigonj

3. CONCLUSIONS AND RECOMMENDATIONS

Here only the two thanas Bhanga and Serajdikhan are our study concern because of the lack of appropriate data for the whole Dhaka Division.For this reason the most only these two thanas are taken into the study.It is clear from the monitoring that percentage of red tubewll users in Bhanga and Serajdikhan is about 90 & 60 .And 94% of the people in Serajdikhan are in normal Health condition and in Bhanga it is 73%.It is also seen from the analysis that people in Serajdikhan is more aware than Bhanga thana which is about 4%.About 5 % people in Bhanga are in bad health condition by arsenic where in Serajdikhan it is only 1%.If this monitoring is done on the basis of union level, it is this result is also alarming in Bhanga thana. It is clear that mass awareness regarding arsenic contamination is the most vital thing. When people will be aware of the problem automatically they will try to find their alternative safe water source. But Future data collection should include GPS coordinating, which would be beneficial for further analysis There is the lack of data collection of the organizations GPS data value which should be done immediately for further research.Arsenic removal technologies should be introduced to the people in the concerned area of groundwater contamination.Continuous monitoring of the existing arsenic condition in the affected areas is important. Building of mass awareness should be prioritized.

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A COMPARATIVE STUDY ON THE FIXED BED PYROLYSIS OF DIFFERENT BIOMASS SOLID WASTES

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ABSTRACT

The increasing use of fossil fuels for energy production is a matter of great concern. In this context the use of biomass as an energy source is of great importance, as it constitutes a part of an alternative solution for the replacement of fossil fuels. Biomass can be converted into useful forms of energy using a number of different processes. Of these, biomass pyrolysis is drawing increased attention as it is perceived to offer significant logistical and hence, economic advantages over other thermal conversion processes. The whole world is generating a significant amount of linseed, hay of catkin, wheat straw and nutshell as solid wastes. In many places it is creating environmental and disposal problems as well. An attempt has been taken to convert these wastes into value-added materials and energy by fixed bed pyrolysis system. In the present work, studies have been conducted using different solid wastes as feed material to determine particularly the effect of pyrolysis temperature, and particle size on the pyrolysis product yields. A maximum oil yield was obtained at a pyrolysis temperature of 400^0C – 500^0C for the lower and medium size particles. The pyrolysis products were characterized and compared for some fuel properties like higher heating value, viscosity, pH value and density.

Key words: *Pyrolysis oil, Fixed bed, Biomass solid waste.*

1. INTRODUCTION

Energy plays a crucial role in modern life. It is needed for heating, lighting and cooking in households and for virtually every industrial, commercial and transport activity. At the global level, consumption of energy is growing steadily – by around 2% a year in the decade 1990-2000 and probably more in 2000-2020. Biomass energy is of growing importance in satisfying environmental concerns over fossil fuel usage. Wood and other forms of biomass including energy crops and agricultural and forestry wastes are some of the main renewable energy resources available. Using Biomass energy sources in place of fossil fuels reduces emission of greenhouse gases and other pollutants, improves security of supply by boosting diversification of energy production, and encourages the creation of new jobs and businesses. Biomass solid waste is also attractive from the point of view of ease of availability, high carbon content, low moisture and ash content, low or even no cost, no conflict arising from alternative usage, solving solid waste disposal problems and keeping the environment clean. In some cases, it may have some existing usage; however, there may be better utilization and application from the point of view of energy recovery and environment that need to be emphasized. There are various biomass solid wastes in Bangladesh. A few examples are: nutshell, wheat straw, linseed residue, hay of catkin, rice straw, sugarcane bagasse, jute stick, sawdust, rice husk, empty fruit bunches, livestock, scrap tire, refused plastic, wastepaper etc. These carbonaceous solid wastes are renewable energy sources and therefore, the potential of converting them into useful energy such as liquid fuel, should be seriously considered. In this way, the wastes would be more readily useable and environmentally more acceptable. It is found from the characterization of these biomass solid wastes that these solid wastes contain higher percentage of volatile matter. This high volatile content biomass has high potential for pyrolysis liquid production. Among various thermo-chemical conversion technologies, pyrolysis is considered as an emerging technology for liquid oil production [1, 2]. Pyrolysis is the thermal degradation of organic matter either in total absence of air or with a lack of a stochiometrically needed amount of oxygen to the extent where gasification does not occur. Pyrolysis can be carried out in fixed bed or in fluidized bed. Fixed bed system is considered in this study. The fluidized bed system is more complex and more coke is formed [2]. Pyrolysis processes are usually conducted in a reactor where heat is applied to the feed stock either externally or by the partial combustion of feedstock. Three products are usually obtained in a pyrolysis process: gas, liquid and char. When organic matter organic matter is heated in a noncreative atmosphere, the devolatillisation results in vapors and gas being separated from char product. The vapor products are cooled below heir their dew point and the condensed liquids are obtained. This oil obtained from pyrolysis process is easily transportable, it can be burnt directly in the thermal power station, can be injected into a conventional petroleum refinery, burnt in the turbine or upgraded to obtain a light hydrocarbon fuel [3, 4]. The solid char can be used to make activated carbon [5]. Besides the char has its potential to be used as fuel. The gas has a high calorific value, sufficient to be used for the total energy requirements of the pyrolysis plant. Thus, there is a great possibility of producing large amount of bio-crude from these biomass solid wastes by pyrolysis system. Bangladesh is an agriculture-based country. The major agricultural residues or by-product of this country are nutshell, wheat straw, linseed residue, sugarcane bagasse. The conventional uses of these biomass solid wastes are as fuel as for cooking, cattle feed, raw material for paper and pulp industries and huge amounts are unused and wasted, and also creat disposal problem. The technologies for producing oil are evolving rapidly with improved process performance, larger yields and quality products. According to Soltes [6], both the product yield and chemical composition of pyrolysis oil can be varied according to the process conditions. Thus, the pyrolysis conversion will be a new development in the alternative renewable sources of energy by this highly expected technology. In Bangladesh there is no project work or commercial production plant for liquid production from solid waste that can be used as engine fuel, industrial usage, power generation etc. Recently Malaysia and India have given their attention toward the pyrolysis technology. A number of research works in the field of pyrolysis has been carried out in the Department of Mechanical Engineering of Rajshahi University of Engineering & Technology (RUET). The feasibility of this technology has been proved from the results of the experimental research study on pyrolysis [7, 8]. Nutshell, wheat straw, linseed residue and hay of catkin are considered in this study to obtain liquid fuel using fixed bed pyrolysis technology.

2. MATERIALS AND METHODS

2.1 Biomass

The biomass solid wastes were collected locally in Rajshahi (Bangladesh). The feedstock was ground and sieved to different sizes and was finally oven dried at 110 ^{o}C prior to pyrolysis. The size of feedstock for nutshell and wheat straw was 300-600μm and 600-1200μm, for hay of catkin 300-600μm and 600-1180μm, and for linseed residue ≤1.75mm, 1.75-2.36mm and 2.36-4.75mm. The proximate and ultimate analyses of linseed residue are presented in Table 1.

Table.1 Proximate and ultimate analyses of linseed residue

Proximate Analysis (wt. %)				Ultimate Analysis (wt. %)			
Contents	Linseed	Nutshell	Wheat straw	Elements	Linseed	Nutshell	Wheat straw
Moisture	6.7	4.06	5.17	Carbon	61	49.98	43.2
Volatiles	77.7	74.22	71.32	Hydrogen	8.5	5.71	5.00
Fixed Carbon	10.7	21.16	16.69	Nitrogen	2.3	0.21	0.61
Ash	5.6	0.56	6.82	Oxygen	28.2	43.35	39.4

2.2 Pyrolysis Reactor

The experimental system was a fixed bed pyrolysis unit. Liquefied Petroleum (LP) gas was supplied in order to dispose of the pyrolyzed vapor products to the condenser. The schematic diagram of the Conversion system is shown in Fig. 1. The reactor was 6 cm in diameter and 29 cm in height, constructed of stainless steel. The reactor was heated externally by a biomass heater at different temperatures. A blower was used to supply the air for burning biomass in the heater. The temperature of the reactor was controlled by varying the air supply that was directly related to the blower speed. Pyrolysis vapor condensed into liquid in the condenser and was collected in the liquid collectors. The noncondensible vapor was flared to the atmosphere. The char was collected from the reactor after completing a run. The gas was measured by difference.

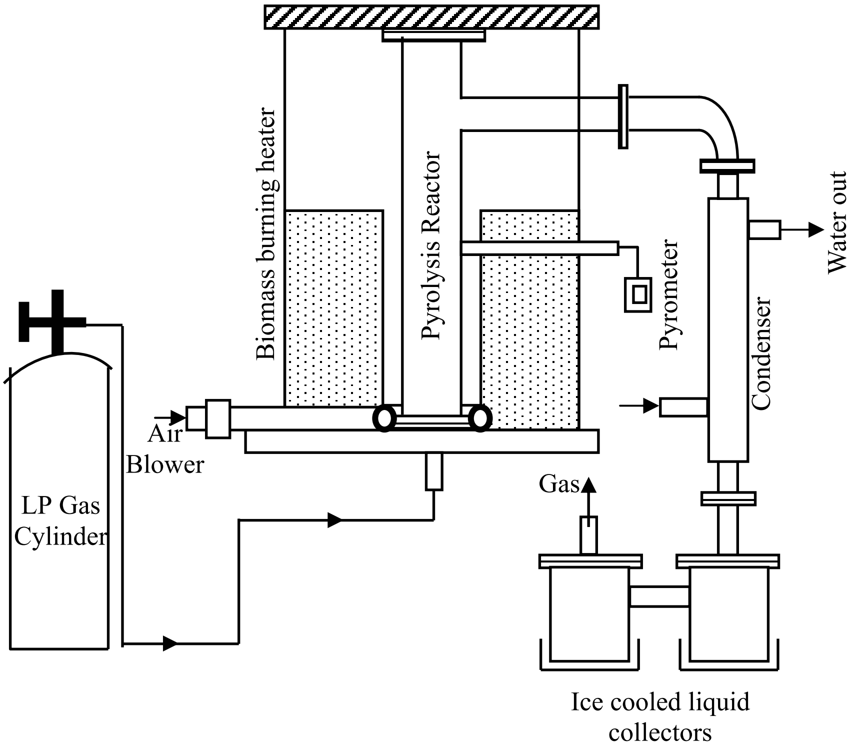

Fig.1 Schematic diagram of fixed bed pyrolysis system.

2.3 Fuel Properties of the Pyrolysis Liquid

The pyrolysis liquid obtained was characterized for their physical properties. These properties were determined by standard testing procedures. The properties determined were kinematic viscosity, higher heating value and density.

Table.2 Comparison of Linseed oil with biomass derived pyrolysis oil and conventional fuels

Properties	Linseed	The hay of catkin	Nutshell	Wheat-straw	Pyrolysis Oil of wood	Palm Shell liquid [9]	Diesel
Kinematic Viscosity (cSt)	8.72	10.95	9.72	9.852	35 to 53	14.63	2.6
H.C.V (MJ/kg)	33.35	23.43	19.34	17.23	18.10	22.10	45.80
Density (kg/m^3)	1095.0	900	1098.6	1096.8	900 to 800	830	803
Specific gravity	1.095	1.078	1.009	1.0968	0.90 to 0.80	0.830 (40^0C)	0.832

Kinematic viscosity is a measure of resistance to gravity force of a fluid. Viscosity of a liquid is an important property since it affects the flow of the liquid through pipelines. The average kinematic viscosity of linseed residue, hay of catkin, nutshell and wheat straw was found to be higher than conventional diesel fuel but lower than other biomass derived pyrolysis oil.

The higher heating value is a measure of the quantity of heat released in total combustion and therefore, measures the energy content of the fuel. In this work higher heating value was determined by oxygen bomb calorimeter. The heating value of the pyrolysis oil from linseed residue, hay of catkin, nutshell was found to be higher than that of other biomass derived pyrolysis oil.

Density of a substance refers to mass per unit volume. The average density of linseed residue, hay of catkin, nutshell, wheat straw was higher than that of conventional fuels, such as 803 kg/m^3, 664 $kg/m^3$and 755 kg/m^3 respectively for diesel, petrol, and kerosene.

3. RESULTS AND DISCUSSION

3.1 Product Yields

In general, three products were recovered after each run. From the two liquid collectors, a fairly fluid, oily organic liquid was obtained. The liquid yield was high showing the potential of recovering of liquid hydrocarbon from the pyrolysis of solid waste. The liquid appeared brownish dark with a strong acrid smell. The char was collected from the reactor. This char was expected to be very reactive, and precautions were required to ensure that it would not be exposed to air when still hot. The gas was diluted by the large flow rate of LP gas and flared into atmosphere. Through the experimental investigation it was found that the optimum reaction condition for linseed residue was at reactor bed temperature of 400 ^{0}C for feedstock size of 2.36mm, for hay of catkin, nutshell and wheat straw 500 ^{0}C for feedstock size of 300-600µm.

3.2 Effect of Pyrolysis Reactor Bed Temperature on Product Yields

The yields obtained from different experimental run with linseed residue, hay of catkin, nutshell and wheat straw as the feed materials at different reactor bed temperature have been presented in Figures 2, 3 and 4 respectively. At lower and higher reactor bed temperatures the liquid yields were less in comparison to that at an intermediate temperature. However, the char yield was higher at lower temperature and this was found to be decreasing with increasing temperature. The maximum liquid product yields were obtained at an intermediate temperature of 400 ^{0}C for linseed residue and 500 ^{0}C for hay of catkin, nutshell and wheat straw. The reason behind this is the lower temperature was not sufficiently high enough for the pyrolysis devolatillization reaction to take place completely rendering reduce amount of liquid and gaseous products. Again the higher temperature was causing secondary cracking reaction of the vapors yielding more gas at the cost of liquid product yield. However, the intermediate temperature was sufficient enough for complete pyrolysis reaction to take place and at the same time this temperature was not much high for secondary reaction to take place rendering maximum quantity of liquid product with less amount of char residues and gaseous products. The liquid product is maximum at smaller particle size. This may be due to the fact that the larger size particles were not adequately heated up so rapidly causing incomplete pyrolysis.

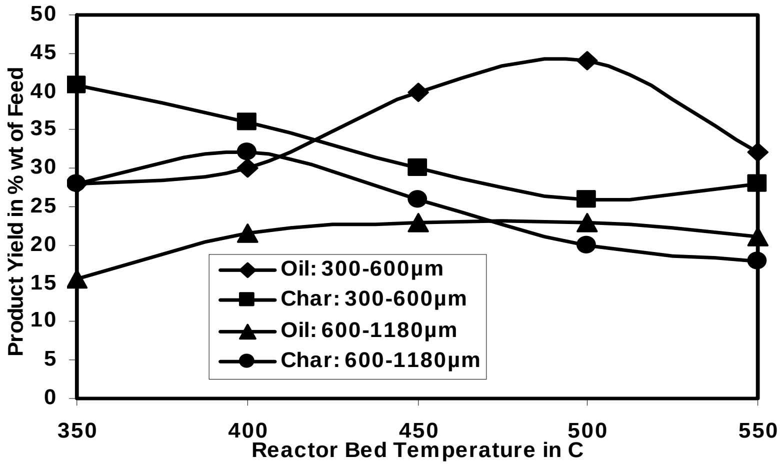

Fig.2 Effect of pyrolysis reactor bed temperature on product yields from hay of catkin

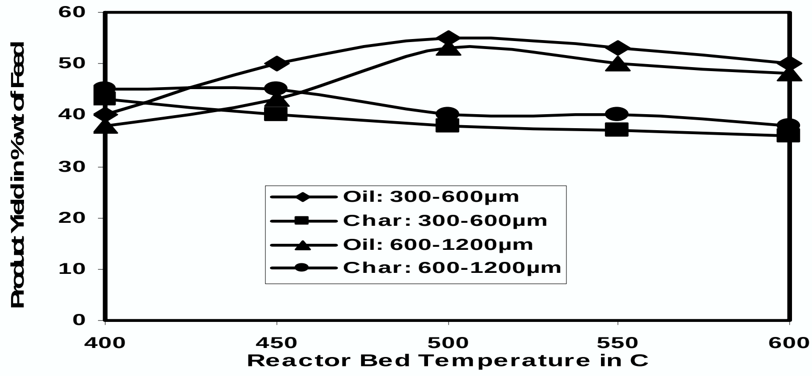

Fig.3 Effect of pyrolysis reactor bed temperature on product yields from nutshell

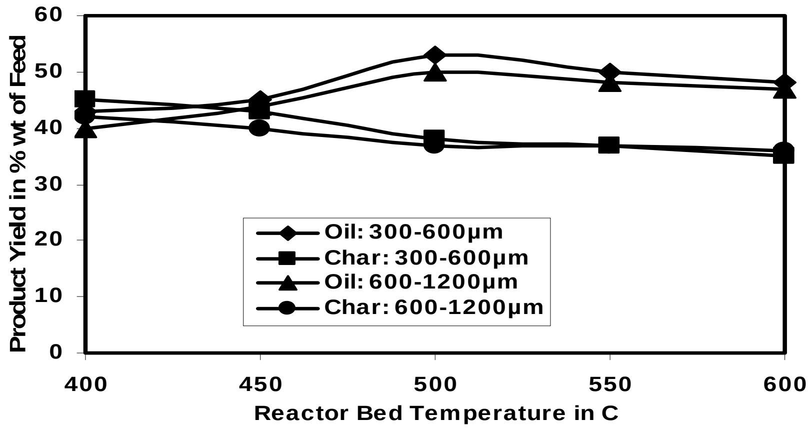

Fig.4 Effect of pyrolysis reactor bed temperature on product yields from wheat-straw

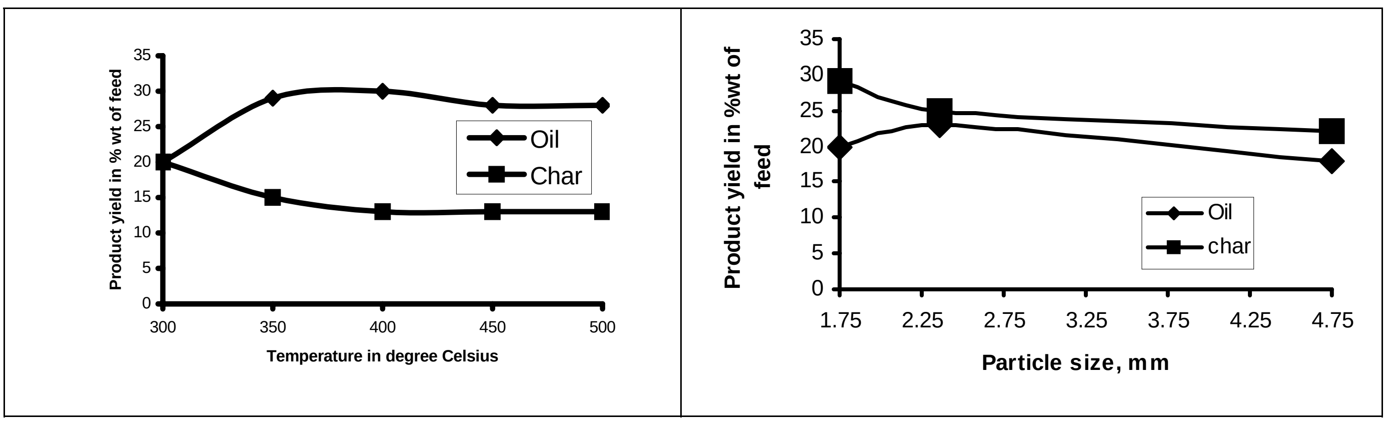

Fig.5 Effect of pyrolysis reactor bed temperature on product yields from linseed residue

4. CONCLUSION

- The maximum liquid yield was found to be 44, 55 and 53 wt% of hay of catkin, nutshell and wheat straw feed respectively at a reactor bed temperature of 500 ^{0}C and 30 wt% of linseed residue feed at a reactor bed temperature of 400 ^{0}C. The liquid product yield is found to be increasing with pyrolysis reactor bed temperature up to a certain temperature after which it is decreasing with temperature. The char yield is found to be decreasing with the rise of pyrolysis reactor bed temperature.
- The liquid product was maximum at smaller particle size. This may be due to the fact that the larger size particles were not adequately heated up so rapidly causing incomplete pyrolysis.
- The pyrolysis oils were single-phase liquid products of brownish dark color with acrid smell.
- The heating value of the pyrolysis oil was found to be higher than that of other biomass derived pyrolysis oil. On the other hand, kinematic viscosity was found much lower than that of other biomass derived pyrolysis oil. Thus, linseed residue may be considered as an important candidate of potential sources of alternative fuels for which further investigation is required.

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NO_X REDUCTION IN A HYBRID PLANT: BOILER SIMULATION FOR REBURNING

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ABSTRACT

Hybrid plants are a possibility to combine a highly efficient diesel engine with a steam boiler connected to a steam turbine and produce electricity with low total NO_x emission level. The combustion in the diesel engine with local regions of high temperature produces a large amount of thermal NO_x). The exhaust gases from the diesel engine are delivered to the steam boiler. The steam boiler is adapted to the conditions necessary for a reduction of NO_x to N_2. This gives a combined process with significant reduction of NO_x. The architecture and circumstances of NO_x reduction in a boiler in a hybrid plant are different from a pure boiler. The objective is not to reduce the amount of nitrogen oxides produced in the boiler but reduce NO_x already existing due to the combustion process in a diesel engine. This gives the possibility to implement reburning in the primary zone, i.e. the grate. To determine the NO_x level and estimate the overall potential a computer simulation of the boiler was developed. Using low quality biomass a NO_x reduction up to 75 percent and an overall efficiency of 45 percent was predicted by the simulation tool.

KEYWORDS: *Hybrid plants; NOx; Diesel engine; Boiler*

1. INTRODUCTION

NO_x is one of the major concerns besides CO_2 emissions when it comes to reduction of impacts on our environment and human health. Nitrogen oxides contribute to acid rain, water quality deterioration (eutrophication) and particulate matter (PM). Furthermore it is responsible for ground-level ozone (smog) and N_2O is a greenhouse gas, which affects the climate change [1][2]. Moreover there is a strong economical incentive for NO_x reduction.

NO_x is a major problem concerning diesel engines, which is on the other hand economical and ecological reasonable because of their high energy efficiency up to 45 percent [3]. A widespread solution for NO_x reduction is secondary treatment with selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) by the application of ammonia. The main disadvantage of SCR is the weight, the size and the costs of the catalyst. For instance on ships, space requirement and stability are a big issue and makes the implementation of SCR difficult and expensive [4]. SNCR is more compact but requires complex running conditions as high temperatures and long residence time [5][6]. A well designed gas flow in a steam boiler allows a low NO_x level without secondary treatment (Folsom 2001). But combustion of biomass in a steam boiler with a steam turbine gives an electric efficiency of only around 30 percent and this is – compared to the diesel engine – quite low [7].

The simulation has been performed to combine both ways in a hybrid plant and get the total efficiency up to the range of a diesel engine and the overall NO_x emissions as low as in a boiler. The hybrid plant consists of a diesel engine, which runs on liquid bio fuel and a boiler that is fed with low quality biomass. The application of biomass and liquid bio fuel gives a CO_2 neutral solution. The exhaust gases from the diesel engine with a high NO_x level are delivered to the boiler. The combustion in the boiler is adjusted to produce a certain amount of NO_x reducing agent in a defined stage. NO_x is reduced to ordinary N_2. A typical basic layout of the plant is shown in Figure 1.

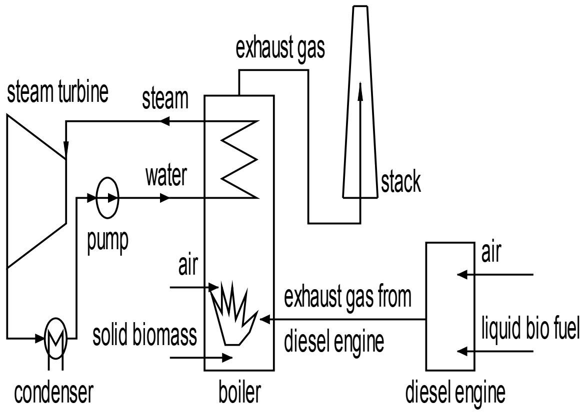

Figure 1: Hybrid plant design.

2. REBURNING IN HYBRID PLANT

The architecture and circumstances of NO_x reduction in a boiler in a hybrid plant are different from a pure boiler. The objective is not to reduce the amount of nitrogen oxides produced in the boiler but reduce NO_x already existing due to the combustion process in a diesel engine. Thus nitrogen oxides already exist before entering the boiler while in a conventional setup they are only produced during combustion in the boiler. This gives the possibility to implement reburning in the primary zone, i.e. the grate (Figure 2). The idea is not to use natural gas for reburning, but methane and hydrogen released during combustion, to achieve a CO_2 neutral solution. A significant amount of both types of volatiles exist in solid bio-mass.

In conventional boilers this kind of reburning doesn't occur as NO_x is only created due to high temperatures by burning the CH_4 and H_2. There is almost no coexistence of nitrogen oxides and methane and hydrogen. A sketch of the new layout is shown in Figure 3. Compared to Figure 2 there is no injection of reburning fuel and no separate reburning zone. Primary and reburn zone are integrated on the grate.

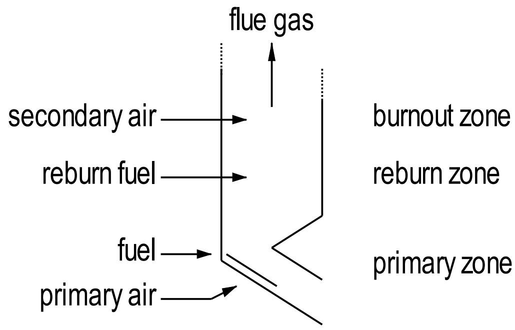

Figure 2: Boiler with reburn zone

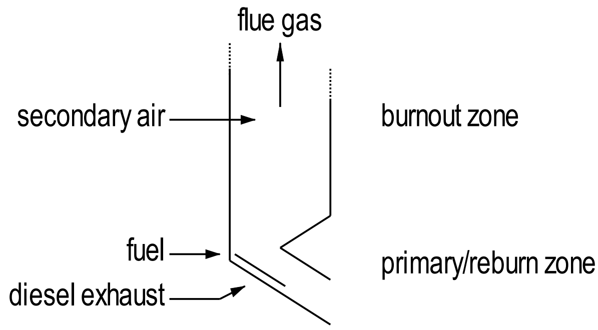

Figure 3: Reburning in hybrid plants

3. BOILER SIMULATION

The main focus lies on the chemistry going on in the boiler and trying to understand the chemical reactions taking place during the process of reburning. Doing a simulation the reaction kinetics can be exported.

3.1 Basic layout and system modeling

The model of the boiler consists of six reactors. The network is visualized in Figure 4. The inputs are enlisted on the left side: air, biomass and diesel exhaust. Biomass and exhaust gases from the diesel engine are fed to the grate for drying, release/combustion of volatiles and char combustion. In the model those stages are separated. However heat transfer is possible. The calculation focuses most on the reaction of the volatiles with the exhaust gases as reburning of NO_x occurs in this step. The secondary combustion is then processed with air. There is no more potential for NO_x reduction by feeding exhaust gases as the methane contained in the volatiles is mostly used in the bed (grate). Both heat exchangers are applied to cool down the gases and deliver heat for steam production.

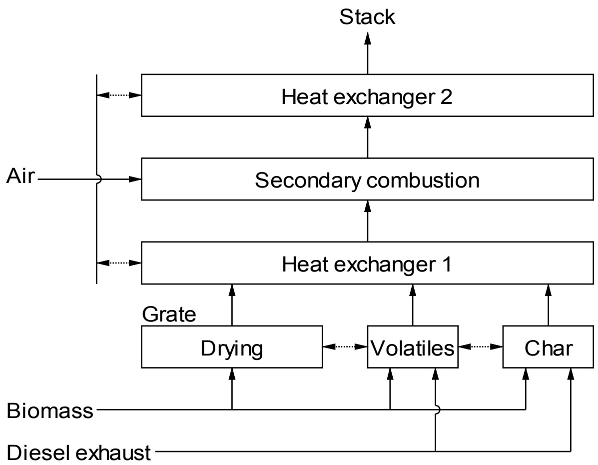

Figure 4: Flow scheme of boiler system model

The individual reactors are modeled as stirred. This doesn't represent reality in detail as it is assumed that concentration of molecules and temperature are the same all over one reaction room. However this gives a first idea about what happens in which zone especially since the main six zones in a boiler are represented.

The calculation itself is transient. This is necessary as the chemical equilibrium will not be obtained and residence time in the different reactors plays a major role for NO_x reduction as well as production. History of the reaction, e.g. whether it's ignited or not, is of importance.

3.2 Computational Background

The simulation is setup as a Matlab program based on the Cantera toolbox for chemical reactions. The program consists of a main routine ("boiler_main"). Before starting the calculation the system is initializes ("boiler_initialize"), the last saved state is loaded, the reservoirs containing information about biomass, diesel exhaust gases, air, etc. are defined ("boiler_define_reservoirs"), the flow rates are adjusted and the reactor network is built up ("boiler_define_network").

During the calculation loop intermediate states are saved for backup and temperature, pressure and molar fractions of the molecules are stored for visualization. Post processing consists of saving the final state ("boiler_save_state") and generating output ("boiler_create_output"). The output shows temperature, pressure and molar fractions as a function of time in each reactor (Figure 5, Figure 6) and produces a summary containing information about residence times in the reactors and NO_x emissions (ppm).

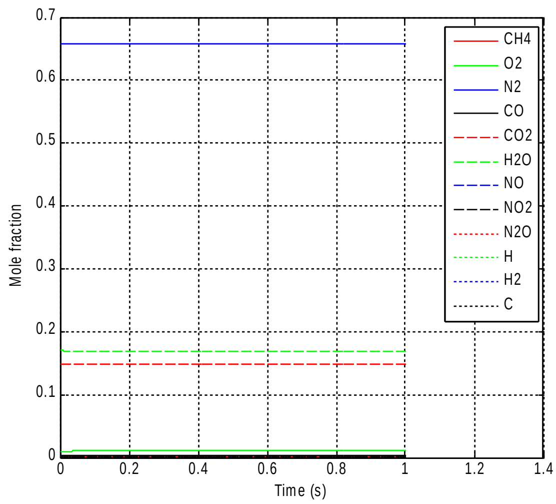

Figure 5: Mole fractions in the secondary combustion reactor

For showing the overall nitrogen oxides reduction the NO_x input (kg per second) due to the introduced diesel exhaust gases is compared to the NO_x output (kg per second) after the second heat exchanger. This data is contained in the summary file.

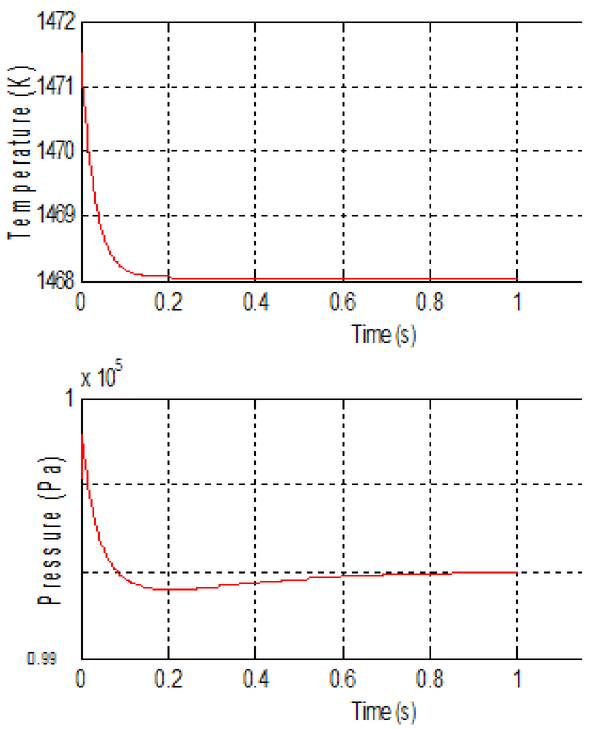

Figure 6: Temperature and pressure in the secondary combustion reactor

4. RESULTS

The results presented here are outcomes of the simulation. Thus one has to accept, that they do not represent reality. The figures are a result of the model. They cannot be more exact than the assumptions and simplifications made. Nevertheless it should be possible to read tendencies and get a rough overview.

4.1 NO_x Reduction

A comparison of different types of biomass is presented in Table 1. Biomass feeding is set to 1 kg/s, stoichiometric ratio (lambda) for combustion of volatiles is 0.9 (rich combustion), char combustion is done with an amount of exhaust gas satisfying production of pure CO and secondary combustion runs with a lambda of 1.2 (lean combustion).

In the following wood as a biomass fuel is studied in detail. A variation of the lambda value in the volatiles reactor leads to the following results (Table 2). The other parameters remain unchanged.

Table 1: NOx reduction for different types of biomass

	NO_x input	NO_x output	NO_x reduction
	[kg/s]	[kg/s]	[%]
Wood	0.0119	0.0047	60.5
Bagasses	0.0069	0.0023	65.6
Rice straw	0.0098	0.0042	57.0
Wheat straw	0.0107	0.0040	62.3
RDF	0.0066	0.0031	52.2

Table 2: NO_x reduction for different stoichiometric ratios for combustion of volatiles

Lambda	NO_x input	NO_x output	NO_x reduction
	[kg/s]	[kg/s]	[%]
0.5	0.007132	0.005512	22.7
0.6	0.008338	0.004282	48.6
0.7	0.009545	0.002173	77.2
0.8	0.010752	0.002963	72.4
0.9	0.011958	0.004719	60.5

Using a stoichiometric ratio of 0.8 for the volatiles, a variation of lambda in the secondary combustion zone is investigated. The outcome is presented in Table 3. Not shown here is that with low lambda values the amount of CO in the exhaust increases.

Table 3: NO_x reduction for different stoichiometric ratios in the secondary zone

Lambda	NO_x input	NO_x output	NO_x reduction
	[kg/s]	[kg/s]	[%]
1.0	0.010752	0.002648	75.4
1.1	0.010752	0.002821	73.8
1.2	0.010752	0.002963	72.4
1.3	0.010752	0.003085	71.3
1.4	0.010752	0.003191	70.3
1.5	0.010752	0.003285	69.4

One can conclude that the type of biomass plays a role for the potential of nitrogen oxides reduction. The total amount reduced (kg/s) depends on the amount of released hydrogen and methane. As lambda was kept constant the percental reduction was around 60 percent for all types. The stoichiometric ratio for combustion of volatiles is the parameter with the most significant influence. The optimum is around 0.7 for this case.

4.2 Reaction kinetics

As reburning takes place in the part of the grate where volatiles are released from the biomass, the chemical reactions there – between volatiles and diesel exhaust gas – were investigated. The rates of creation and destruction of species containing nitrogen are summarized in Figure 7. Notice that the y axis is logarithmic. NO and NO_2 are reduced. In the grate the destruction rate of nitrogen containing species is a bit higher than the creation rate.

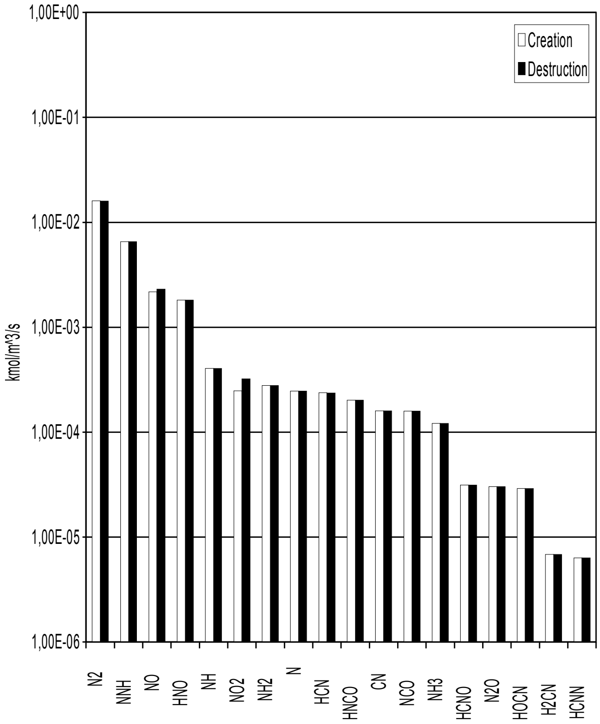

Figure 7: Creation and destruction of species containing nitrogen

The reactions with the 20 highest reaction rates involving a species containing nitrogen are shown in Figure 8. The mechanism for reduction of NO_x is complex. As there are more than 90 reactions involved in processing nitrogen it is hard to get an overview of the mechanism. E.g. reaction 2 converts NO into HNO. But this HNO reacts back to NO on different paths (Reaction 3 and 7). The reaction of nitrogen oxide with CH_2 and CH to HNCO and HCN seem to be the initial reactions for reburning (Reaction 11 and 17).

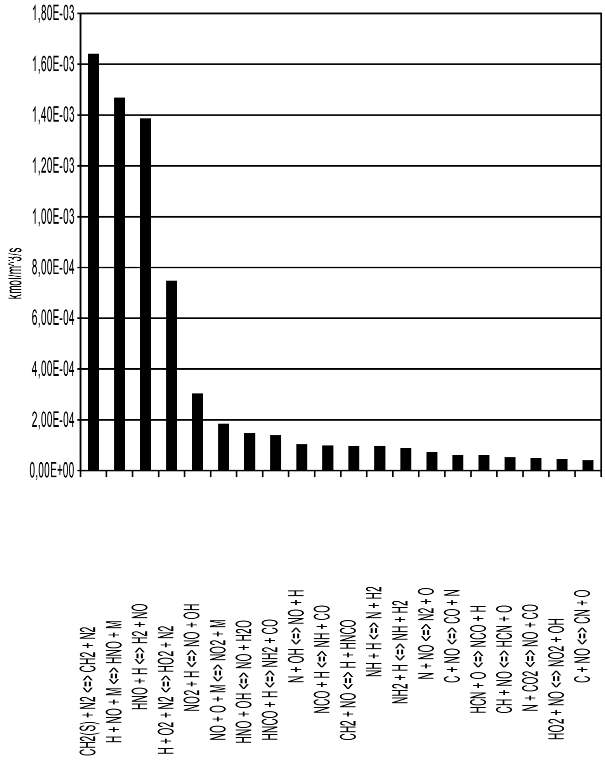

Figure 8: Net reaction rates of reactions containing nitrogen

An important role plays reaction 14. It creates N_2 from elementary nitrogen and NO. Elementary nitrogen is primarily produced from NH (Reaction 12).

4.3 Efficiency, Power Output and Emissions

To calculate the overall efficiency the following settings were applied: The stoichiometric ratio (lambda) for combustion of volatiles is 0.8 (rich combustion), char combustion is done with an amount of exhaust gas satisfying production of pure CO and secondary combustion runs with a lambda of 1.2 (lean combustion). The exhaust gas is taken out at 400 K.

Comparing different kinds of low quality biomass the results presented in Table 4 were obtained. The average value of the total efficiency is in the range of 40 to 45 percent. RDF, having a low heating value and high moisture content, has the lowest performance compared to the other types.

Table 4: Total efficiencies and total power input and output values

	Total eff.	Total power output [MW]	Power output steam turbine/total
Wood	0.43	44	0.61
Bagasse	0.46	43	0.61
Rice straw	0.44	45	0.62
Wheat straw	0.45	45	0.62
RDF	0.40	36	0.52

Besides efficiency emissions of NO_x in g per MJ of useful energy are important. In order to obtain this value, the mass flow rate of NO_x – measured in kg per second – as well as energy output and total exhaust mass flow is calculated by the simulation tool. Table 5 contains the results both for the pure diesel engine and the boiler exhaust in a hybrid plant.

Table 5: NO_x emissions for diesel engine and boiler exhaust gas.

	Diesel exhaust gas		Boiler exhaust gas	
	[kg NO_x/s]	[g NO_x/ MJ]	[kg NO_x/s]	[g NO_x/MJ]
Wood	0.0454	2.660	0.0127	0.2889
Bagasse	0.0454	2.660	0.0102	0.2350
Rice straw	0.0454	2.660	0.0137	0.3064
Wheat straw	0.0454	2.660	0.0124	0.2759
RDF	0.0454	2.660	0.0149	0.4153

Comparing these values to the mean value in Sweden (0.06 g NO_x per MJ of useful energy), one can notice that the NO_x emissions are still high but the overall reduction is good.

5. CONCLUSIONS

The aim was to find a cheap way to reduce NO_x as effective as possible in a hybrid plant. The simulation indicates a reduction of up to 70 percent. Due to practical issues like imperfect mixing a more conservative estimate is 60 percent. The emissions are still high. Thus an additional SNCR could be applied. The costs for the reductant are less than half compared to a configuration without reburning due to reduced amount of NO_x in the exhaust of the boiler. A SCR is no alternative. The amount of flue gas remains the same meaning that the size and the costs of the catalyst wouldn't change. Applying an additional SNCR unit, reducing the nitrogen oxides by another 75 percent, gives a total reduction of 90 percent.

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IMPACT OF TRACE METAL ON ENVIRONMENT FROM LANDFILL MSW: A CASE STUDY IN DHAKA CITY

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ABSTRACT

An investigation was carried out to find the possible trace metal impact on the water and underground environment from improper dumping of MSW in Dhaka City. This study includes four dumping sites: Matuail, Gabtoli, Berri-band and Uttara. Besides, an old dumping spot, Jatrabari was also selected to find out a long-term trace metal impact on the underground environment as well as to observe the leaching of trace metals by water through the soils of dumping spot. Analytical method X-ray Fluorescence (XRF) and Total Refection X-ray Fluorescence (TXRF) were used for traces metal analysis solid wastes samples, and water samples. In our analysis we have found a higher concentration of metals which is really harmful for our environment and underground water source. Some recommendations have been made to gat rid of environmental damage from improper dumping of MSW.

KEY WORDS: *Solid waste, Trace metal, Landfill MSW, Environmental impact.*

1. INTRODUCTION

Urban areas are the focal point of environmental problems and these may include house holds, the place of work, the neighborhood, the city, the wider region and the world. Solid waste is a generic term used to describe the things that we throw away. According to US EPA, solid waste may be defined as “Any discarded items; things destined for reuse, recycle, or reclamation of sludge and hazardous waste”. But in general, the definition excludes the radioactive and in-situ mining waste. Therefore the solid waste can be defined as the useless, unwanted, and discarded materials that are generated form the consumption and production [4].The main sources of Municipal Solid wastes are Residential Waste, Commercial Waste, Industrial Waste, Demolition and Construction Waste, Agricultural Waste, Farm house waste: Motor Garages, Sewage Waste, and Hospital Waste [4]. Trace metals are metals in extremely small quantities, almost at the molecular level, that reside in or are present in animal and plant cells and tissue. Trace metals includes iron, magnesium, zinc, copper, chromium, nickel, cobalt, vanadium, arsenic, molybdenum, selenium, etc. In high doses, they may be toxic to the body or produce deficiencies in other trace metals; for example, high levels of zinc can result in a deficiency of copper. In rapidly growing cities of the developing world, the urban solid waste management (SWM) is currently regarded as one of the most immediate and serious problems faced by the urban government. Dhaka, the capital of Bangladesh, is one of the fast growing metropolitans of the world with an annual average growth rate 6.6%. The population of this mega city with an area of 1353 sq. km. is estimated to be 10.41 million while that of Dhaka City Corporation with an area of 344 sq. km is 6 million. These 6 million residents generate about 3000 metric tons of municipal solid waste per day [1]. Only 82% of these wastes are removed by the Dhaka City Corporation and the rest lies on the road side and low lying land [2]. Solid wastes are one of the important sources of toxic metals. They also cause physical and biological pollution of the environment. These elements tend to be persistent pollutants and can accumulate in ecosystems and food chains [3].

2. METHOD OF STUDY

2.1 Sample Collection

Solid Waste: Four decomposed solid waste samples were collected from the dumping spots situated in different locations- Matuail, Gabtoli, Beriband and Uttara under the Dhaka City Corporation. The samples were collected from 2-3 feet depth from the surface using a stainless steel knife and taken in polyethylene bags.

Underground Soil: Five underground soil samples were collected by a hydraulic agar machine from the old Jatrabari dumping spot from different depths in order to check any trace metals leaching effects on the soils. This place was once used as the dumping spot around 10-15 years ago. The sample was collected from two points of the site: Dhaka–Demra road side Dhaka-Chittagong road side. From Dhaka –Demra road side two samples from the depths of 25 and 30 ft and from Dhaka–Chittagong road side three samples from depths of 20, 25 and 30 ft were collected, respectively.

2.2 Preliminary Sample Preparation

Both solid waste and soil samples were dried in porcelain dishes at 105° C for 4 hours in an oven. The dried samples were cooled and grounded in an agate mortar with a pestle. The powdered samples were kept in polyethylene bags and preserved in desiccators

2.3 Trace Metal Analysis

Considering the matrices of the samples the analytical method namely X-ray Fluorescence (XRF) was found to be suitable for carrying out elemental analysis in the samples.

2.4 Preparation of Pellet from Powdered Sample

In XRF method the sample in the form of a pellet is excited with X-ray beam. 0.3 g of each of powdered samples was pressed into a pellet of 1-cm diameter and 1 mm thickness with a hydraulic press pellet maker (Specac) using a pressure of 3 tons. Triplicate pellets of each sample were made. The pellets from the standard sample were also prepared similarly for the construction of a calibration curve. All pellets were preserved in desiccators until irradiation.

2.5 Sample Irradiation and Data Accumulation

The sample pellet on a string backed plastic holder was irradiated with 10 mCi Cd-109 radioisotope annular source for about 4000 seconds to excite the characteristic X-rays of the elements present in the sample. The X-rays were detected with the Si (Li) detector of 170 eV resolutions. The X-ray spectrum of each sample was collected by a multi channel analyzer and transferred to a computer for storage, processing and evaluation of the net X-ray intensities [10].

2.6 Concentration Calibration

In X-ray fluorescence analysis, for estimation of concentration, the calibration of the spectrometer was carried out by determining the sensitivity of the system for each of the elements to be determined [11]. The sensitivity of a spectrometer is expressed as the rate of change of analyte-line intensity with a change in the analyte concentration.
The sensitivity, Si for an element is defined as:

$$I = Si\ Ci$$

I = the intensity, counts/sec, of an analyte X-ray line from a sample
Si = the sensitivity in counts/sec per jig/g
Ci = concentration of the analyte in the standard sample (Ag/g)

As the sensitivity of an element varies as a smooth function of its atomic number the concentration calibration factor is expressed as the number of X-ray photons per sec per unit concentration of the element versus it atomic number. As the analytical method used for the present work is based on direct comparison, a waste sample and a soil standard [11] having similar type of matrices were used for concentration calibration in order to compensate the matrix effects. The sensitivity of each element was calculated based on its average peak areas. The calibration curve was constructed by plotting the sensitivities of the elements (counts per second per ppm) as a function of atomic numbers. The concentrations of all unknown elements in waste and soil samples were determined by using the respective calibration factors. All calculations and construction of curves were done using the QXAS [12].

3. ANALYSIS OF A REFERENCE STANDARD

The quality of the analytical work was assured through analysis of a reference standard material IAEA the established calibration curve. The elemental concentrations were found to be comparable with their certified values.

3.1 Solid Waste

The analysis of trace metals in solid waste samples from different locations of Dhaka City Corporation has been carried out. The samples collected from Matuail, Gabtoli, Berri-band and Uttara are briefly designated as MSWS, GSWS, BSWS and USWS as shown in the Table 1. The elements- K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Zr, Pb were investigated in samples. All these elements could not be measured. The elements measured in all samples includes K, Ca, Ti, Mn, Fe, Cu, Zn, As, Rb, Sr and Zr and Cr, Ni, Se, Pb were detected below their detection limits.

The concentrations of these elements in the individual samples were found almost similar. The average concentrations of trace metals in solid waste samples seem to be very high compared to those of an agricultural soil investigated in a recent study (Table 1) [13]. The solid waste is a composite substance consisting of various organic and inorganic substances containing various trace metals. In addition, after dumping, it decomposes and mixes with soil which also may contribute trace metals to the waste. Water of different origin such as rain water, flood water may also contribute trace metals to solid waste. A comparison between the concentration of trace elements in agricultural soil and solid waste are given in figure 1.

Table1. Concentration of Heavy metals in Solid Waste Samples Collected from Different solid Wastes Dumping Spots in Dhaka City and Unpolluted Agricultural Soil.

Elements	Concentrations of Elements in Solid Waste Samples Collected from Different Dumping Areas (mg kg^{-1})				Elemental Concentrations (mg /kg) Of Agricultural Soil	
	GSWS	MSWS	BSWS	USWS	Sample-I	Sample-2
K	17500±8000	16400±9600	26600±12000	16400±8100	<5491	<5491
Ca	61100±24200	52300±20800	87400±34400	55600±22000	<3300	<3300
Ti	5830±2351	5726±2306	5529±2235	5249±2105	5137±1366	4930±1296
Mn	1486±599	1569±628	1554±621	2127±846	497±161	531±150
Fe	35000±17300	31700±12400	37000±14500	32800±12900	35910±8860	33410±7530
Cu	88.38±35.37	63.71±26.03	99.09±40	80.17±32.36	56.4±27.2	60.4±27.3
Zn	234±92	222±87	345±135	234±92	64.3±12.2	65.3±14
As	32±13	28.62±12.95	112±44	25.48±12.02	<1 1.5	<1 1.5
Br	6.693±3.37		<13.30	14.76±6.37	<8.9	<8.9
Rb	294±115	320±125	312±122	296±116	137±34	140±33
Sr	772±302	765±300	773±303	777±304	37±9	40±8

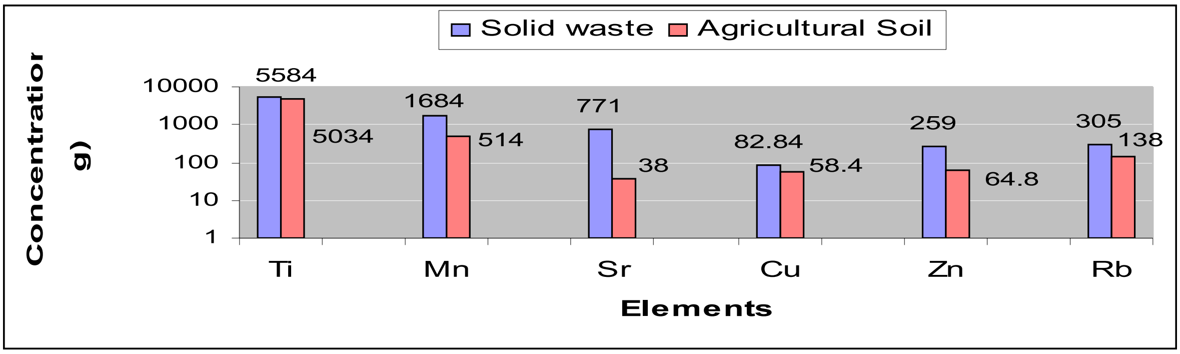

Figure1. Comparison of Trace Concentration between Agricultural Soil and Solid Wastes

3.2 Soil

Five underground soils samples collected from two sides of an old dumping spot (Jatrabari) were analyzed for trace metals. Two samples collected from Dhaka-Demra road side and three samples from Dhaka-Chittagong road side were investigated for a number of elements- K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Zr, Pb. The results are described in the Table 2. All these elements could not be measured in the samples collected from two sides.

Table2. Heavy Metal Analysis in Soil Samples Collected at Different Depths of Jatrabari` Old Dumping Spot

Elem-ents	Elemental Concentrations (mg/kg)				
	DDRS (25 ft) Sand	DDRS (30 ft) Silt	DCRS (20 ft) Silty Clay	DCRS (25 ft) Clay	DCRS (30 ft) Sandy Clay
K	17900±5300	11900±370	15700±400	21000±5700	19900±6900
Ca	10000±2600	6465±2465	8318±2934	10800±2800	7751±2920
Ti	7546±2852	6817±2530	8677±3102	8384±2978	8840±3162
Mn	759±102	633±92	2835±1354	Nil	Nil
V	<1782	1129±479	Nil	<1048	1137±481
Cr	<618	488±87	Nil	Nil	Nil
Ar	<2.075	<1.909	Nil	<1.75	2.17±0.80
Fe	32600±6800	34900±7200	41300±1260	34300±720	33200±6900
Cu	<465.166	494±168	396±151	608±203	565±182
Zn	242±73	170±58	187±55	265±70	206±62
Ga	67.07±23.63	<50.463	<46.156	80.13± 23.49	55.52±19.44
As	24.93±8.78	<19.875	42.2± 11	28.80±10.14	27.79±8.91
Rb	171±36	169±35	146±30	177± 37	172±36
Sr	126±26	121± 25	63.19± 3.23	139±29	135±28
Y	52.33±11.27	54.31±11.92	34.35±7.38	46.37±10.35	37.95±8.59
Zr	354±731	380±78	335± 69	416±86	400±82

The average concentrations obtained for elements in DDRS and DCRS samples were found to be of almost similar profile. However, DCRS samples have shown little higher concentrations for most of the elements investigated.

However, the concentrations of trace metals analyzed in the present underground samples were found to be significantly high in comparison with the elemental concentrations in a recently investigated agricultural soil.

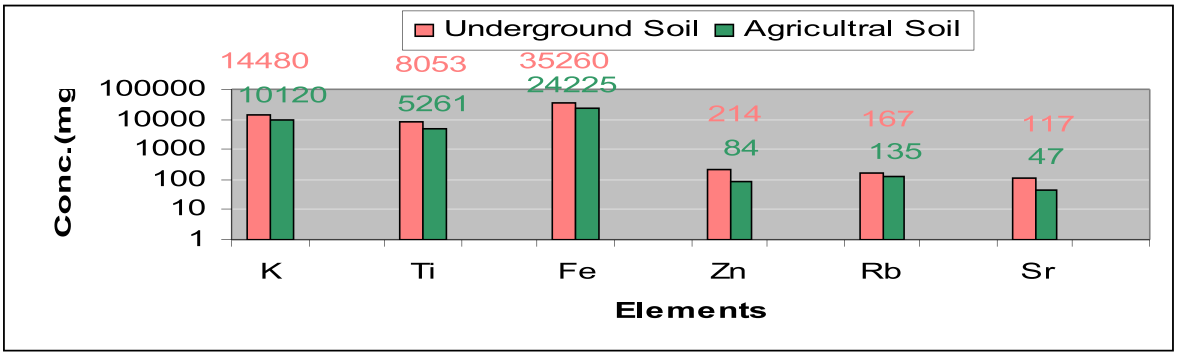

Figure 2: The Concentration Variation in Underground Soil and Agricultural Soil

4. CONCLUSION

The heavy metal concentrations in wastes sample were much higher than those found in an unpolluted soil. So it can be assumed that the solid wastes may play a significant role to the contamination of trace metals to the soil by the process of leaching and runoff. The solid wastes dumped in an unplanned way in the Dhaka City Corporation are a great threat to the environment and the national health. The following steps should be taken for the proper management of MSW.

The open dumping of the solid wastes causes water pollution, bad odors, flowing paper, fires, flies, rats etc. These problems may be overcome by establishing sanitary dumping system. The government should take urgent steps to establish sanitary dumping system. Wastes dumping site should be selected with considering surrounding environmental and socio-economic conditions. This includes the avoidance of locality and wet lands i.e. lakes, rivers etc. The major part of municipal solid waste from domestic and commercial areas is combustible and biodegradable. These wastes should be used for making bio-gas and compost fertilizer as far as possible.

The solid wastes should be dumped in a high place where flood water cannot reach during rainy season. Effective barrier should be made around the dumping spot to prevent the spreading of the wastes. Govt. of Bangladesh should make a legal framework for the safe disposal of wastes in the environment by local government of by either with NGO'S participation.

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STUDIES OF AIRFLOW AND POLLUTION LEVEL IN LONGITUDINAL ROAD TUNNEL DURING TRAFFIC JAM CONDITIONS

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ABSTRACT

This paper presents the detailed airflow pattern and pollution level for the westbound Melbourne City Link tunnel under severely congested traffic conditions. The time averaged equations for velocity, pressure, temperature and mass fraction of emissions were solved using the CFD software FLUENT 6.0. Under severely traffic jam conditions, the mass fractions of O_2, CO_2 and CO were found to be in the ranges of 0.1-0.16, 0.05-0.14 and 0.0005-0.002, respectively. These high levels of pollutants were detected despite the fact that roof-mounted fans pushed exhaust fumes out the exit and sucked fresh air in from the inlet of the tunnel. The emissions from the vehicles posed a threat to human health.

KEYWORDS: *Traffic jam, tunnel, emission, airflow, fan.*

1. INTRODUCTION

The objectives of ventilation in road tunnels are to provide drivers and passengers with an adequate supply of oxygen for respiration and to dilute toxic gases emitted from vehicles to safe concentrations. The airflow inducted by the moving vehicles (piston effect) is usually sufficient to drive fresh air in and discharge polluted air out in short tunnels of up to 300 m long [1-5]. However, in long tunnels, mechanical ventilation systems such as jet fans and exhaust shafts are needed in addition to the piston effect of the moving vehicles to keep the amount of toxic gases within safety limits [1, 3, 6, 7]. Numerical prediction of detailed exhaust emissions and airflow patterns in a relatively longer road tunnel is restricted by computer power and CPU time. Therefore, numerical developments used for the simulation of tunnel ventilation systems and pollution levels are restricted to short tunnels or shorter versions of long tunnels [5-8]. However, reduced scale models may not always be adopted for long and complex systems integrating many ducts and nodes [7, 9]. Nevertheless, the results show that under normal operating conditions of moving traffic the pollution level in the tunnel is low, where the exhaust emissions are pushed out and fresh air is sucked into the tunnel by the piston effect created by the moving vehicles. However, during traffic jam conditions, the airflow inside the tunnel is induced by the buoyancy effect and the pollution level is found to be unsafe for human beings. A proper ventilation system can bring this pollution down to a safe level.

A number of studies have been carried out to model the ventilation systems of road tunnels for efficient design, appropriate location of fans and to estimate losses in ducts [10, 11]. When two or more fans in series are needed for very long ducts, the distance between fans should be such that the pressures at the points of entry of the second and subsequent fans are balanced between the inside and outside of the ducts. This is to avoid negative pressures inside the ducts inducing air from the tunnel, which contaminates the fresh air inside the ducts.

Mathematical models using computational fluid dynamics (CFD) are used for the assessment of airflow patterns and fires in tunnels, on railway platforms and within other complex structures [12-14]. The main validation of these studies is obtained from experiments done on room fires, by comparing the predicted and measured velocities and temperatures [15, 16]. The effect of heat release rate of the fire on the ventilation of tunnels was studied by several authors [17, 18]. It was found that forced ventilation has a greater enhancing effect on the heat release rate of heavy goods vehicle fires, but has little effect on that of car fires.

CFD techniques were used in the present study for the assessment of the level of pollution inside the tunnel under severe traffic jam conditions. The tunnel used in this study closely resembles the 1600 m westbound Melbourne City Link one-way tunnel. Numerical prediction of detailed airflow patterns inside the tunnel is also presented. The pollution levels at normal breathing height for mammals are shown for the case of all-fans-running. The results are compared with the data available in the literature. The detailed predictions obtained with CFD models will thus assist in demonstrating system capability in worst-case scenarios of fire and major accidents in road tunnels.

2. MELBOURNE CITY LINK TUNNEL

The Melbourne City Link tunnel comprises the westbound (Domain) tunnel, which is about 1600 m long, and the eastbound (Burnley) tunnel, which is about 3500 m long. Each tunnel has three lanes. This study was conducted on the westbound tunnel which contains 12 reversible jet fans mounted in a staggered formation on the ceiling. These jet fans are 1.8 m in diameter and have a capacity of handling 80 m^3/s of air. At the western end of the tunnel is a ventilation station, at which polluted air is extracted from the tunnel. The main inlet to this ventilation station is about 200 m west of the tunnel exit portal. Air enters the ventilation station and exits through a chimneystack located at the top of the tunnel. There are four axial flow fans in the ventilation station with a capacity of 140 m^3/s.

3. SOLUTION DOMAIN AND BOUNDARY CONDITIONS

This study was performed on the westbound tunnel only and was modelled for one-way traffic condition. The cross-section of the road tunnel investigated has a profile identical to that of the actual City Link tunnel, which has a height of 7 m and a width of 12 m. Under severe traffic jam conditions, it was assumed that all the cars, buses and trucks were at an average distance of 1 m from each other. In addition, in each lane there were three cars followed by a truck or a bus. An appropriate amount of exhaust was released from the rear of each vehicle [19]. Atmospheric boundary conditions were applied at both ends of the tunnel. Temperature of the air induced into the tunnel was taken to be 20°C. Detailed description of the model can be found in Ref. 20.

4. RESULTS AND DISCUSSIONS

Due to severity, the results are shown on the right side of the tunnel, which are between the middle and right lanes. For the passengers inside the vehicles, the normal breathing height inside the tunnel would be between 1 and 3 m. Therefore, the results are presented at different heights of 1, 2 and 3 m. Along the tunnel, points are selected at an interval of 100 m with more points at entry and exit portals. Graphs are plotted along the tunnel showing 0 m at the exit portal and 1600 m at the intake portal.

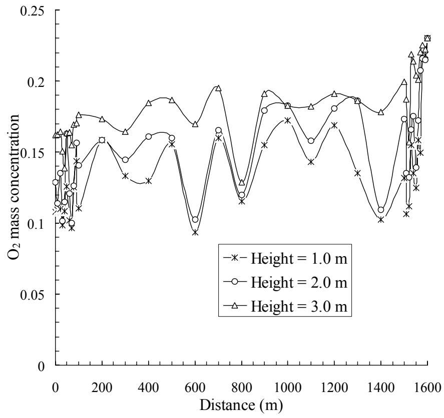

Fig.1 O_2 concentrations.

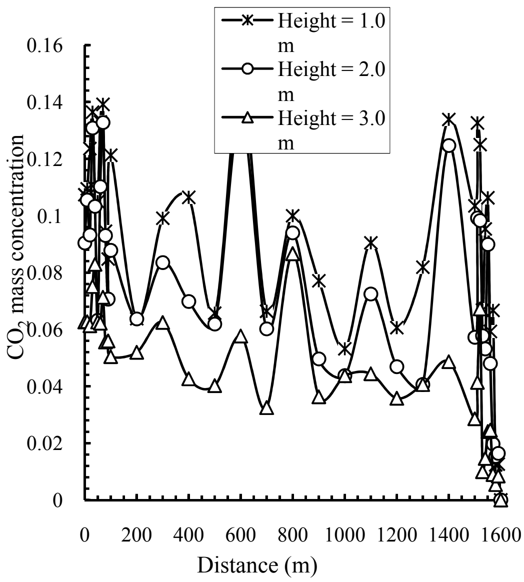

Fig. 2 CO_2 concentration

Analyses of traffic jam conditions were done assuming both the reversible jet and axial flow fans were running. The jet fans were mounted in a staggered formation on the ceiling of the tunnel at approximately 60 m spacing. The purpose of the jet fans was to assist in pushing the exhaust fumes along the tunnel.

The emission levels, static temperatures and velocity magnitudes at various points along the tunnel are shown in Fig. 1-5. This is the case one would expect when all the reversible jet and axial fans are running. The exhaust coming out of the vehicles was at high temperature (measurements showed an average of 50°C for cars and 80°C for buses and trucks) and hence lighter than the ambient air, which was relatively cooler (initially at 20°C). The velocity vectors, not included in this paper for brevity, show that the emissions released in the horizontal direction from the rear of each vehicle immediately changed their direction and travelled upward due to buoyancy and the suction effect of the jet fans. The exhaust gases were then pushed by the jet fans towards the exit portal.

The emission levels are shown in terms of concentrations of O_2, CO_2 and CO. In general, the emission levels were higher at a height of 1.0 m and then, gradually decreased upwards. Also, the levels were higher in between the middle and right lanes than in between the right lane and the tunnel wall. The O_2, CO_2 and CO levels were in the ranges of 0.1-0.16, 0.05-0.14 and 0.0005-0.002, respectively. This could be detrimental to human health especially for the event of long time exposure [21].

The temperatures at a height of 1-2 m varied between 30-32° C with the higher temperatures of up to 62° C occurring near the exhaust of the vehicles. Similarly, numerical predictions to simulate fires in a tunnel in Taiwan showed an average temperature of 30°C far away from the fire owing to traffic jam with 300°C occurring near the fire [16, 22]. For this study, the velocity magnitudes show that higher velocities occurred at a height of 3 m as compared to those at 1 and 2 m, which was due to the action of the jet fans. The velocity was in the range of 4-7 m/s, which agrees well with the limiting longitudinal air velocity in tunnels to be not more than 10 m/s to ensure safe evacuation [22].

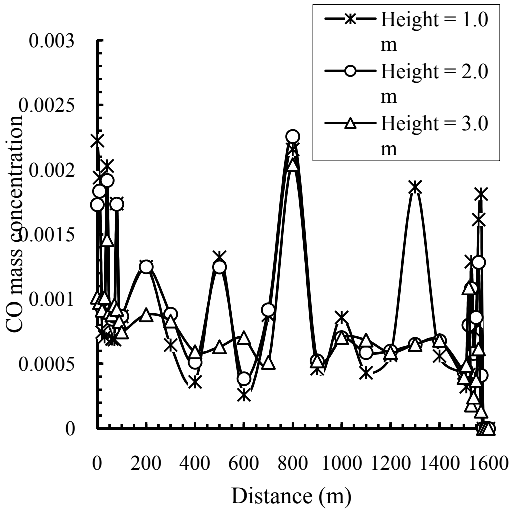

Fig. 3 CO concentrations.

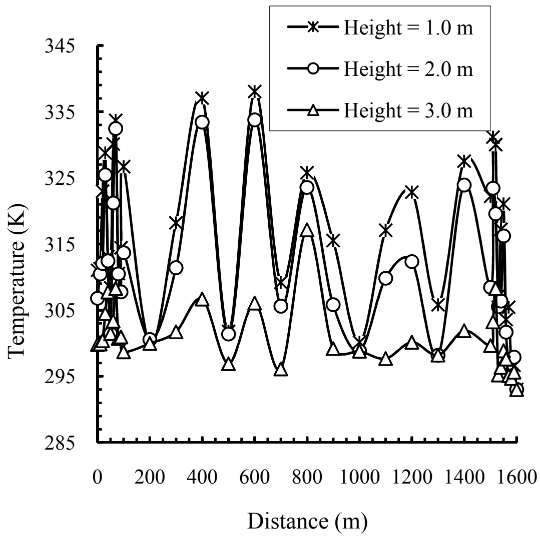

Fig. 4 Temperature distribution.

The case studied here was an example of extreme traffic jam conditions, where the whole tunnel was nearly full of vehicles. There were 387 gasoline cars and 129 diesel trucks/buses inside the tunnel. Under this extreme condition, it is evident from the results that the O_2, CO_2 and CO levels were unsafe for humans. It is worthwhile to mention here that the situations examined in this study were for steady state conditions, which would arise after a prolonged traffic jam. However, in reality, this situation may arise within 10 minutes, when the tunnel is full of vehicles due to an accident at the exit portal [21]. Nevertheless, it is expected that within a short period of time, necessary measures would be taken to clear the jam and the normal traffic flow would resume.

6. CONCLUSIONS

The 1600 m Burnley road tunnel is constructed to reduce traffic congestion in and around the city of Melbourne. Jet fans are located on the roof of the tunnel to assist in bringing fresh air in and pushing exhaust fumes out of the tunnel in conjunction with the piston effect of the moving vehicles. There were cases where traffic was blocked for several hours due to an accident [21]. Therefore, using FLUENT 6.0, computational fluid dynamics analyses were carried out to examine the pollution levels and airflow patterns inside the Burnley tunnel under severe traffic jam situations.

The velocity patterns show that the toxic fumes emitted from the vehicles were pushed towards the tunnel exit while fresh air was drawn in from the tunnel inlet by the jet fans. Under steady state conditions, at particular locations within the breathing height range in the tunnel, mass concentrations of O_2, CO_2 and CO were in the ranges of 0.1-0.16, 0.05-0.14 and 0.0005-0.02, respectively. This is of great concern as this could be detrimental to human health.

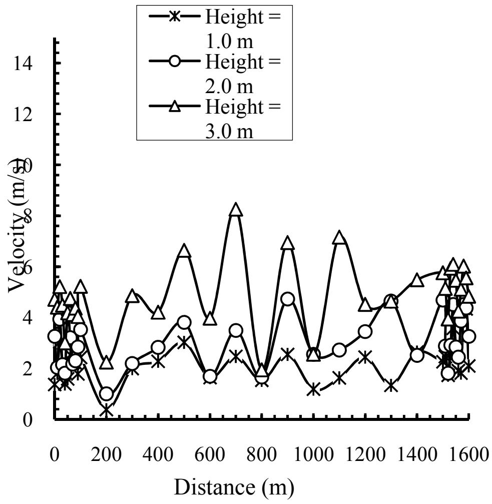

Fig. 5 Velocity distribution.

The pollution levels inside the tunnel disclose the fact that switching off vehicle engines and quick evacuation are vital steps in the case of an accident inside the tunnel. The emissions released from the stationary vehicles when the engines are running pose serious health hazards inside the tunnel. Therefore, effective measures should be taken as soon as an accident happens and passengers must be able to reach a point of safety within 6 minutes [21].

7. ACKNOWLEDGEMENT

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ENERGY UTILIZATION AND ENVIRONMENTAL ASPECTS OF RICE PROCESSING INDUSTRIES IN BANGLADESH

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ABSTRACT

A study was conducted to analyze the energy utilization as well as the environmental aspects of the rice processing industries in Bangladesh. Presently, Bangladesh produces about 40 million ton of paddy (rough rice) each year. Paddy processing needs huge amount of thermal and electrical energy. The thermal energy comes from sun and biomass. For the drying of paddy about 10.7 million GJ of net solar energy was used for drying of paddy in 2000 and this value will increase to 20.5 million GJ in 2030. The share of thermal energy from rice husk is calculated to be 44.8 million GJ in 2000 and this will increase to 86.0 million GJ in 2030. Therefore, it is clearly noted that a huge amount of renewable energy is being used in rice postharvest processing in Bangladesh and hence it is helping the environment from global warming. Both the biogenic and non-biogenic carbon dioxide emissions were calculated as 5.3 and 0.4 million ton, respectively in 2000 and these values will increase to 10.2 and 0.8 million ton, respectively in 2030. The amount of biogenic carbon dioxide is renewed by the rice plant every year. The non-biogenic carbon dioxide emission occurred due to generation of electrical energy by using fossil fuel. The demand of rice increases every year due high pressure of population causing the increasing demand of energy for rice processing. Therefore, a proper policy should be undertaken for future need of energy in rice processing industries.

KEYWORDS: *Rice parboiling, Drying, Rice milling, Energy, Emission*

1. INTRODUCTION

Rice is the staple food of Bangladeshi people. In agriculture sector, rice dominates total agricultural production. The contribution of rice to GDP accounting for 58.3 percent of value added in agriculture (9.1 percent of total GDP). Rice is the main source of calorie accounting about 72.8 percent of calories consumed in 1998 [1]. Bangladesh producing a bulk amount of rice every year to mitigate the calorie needed for the people. International Rice Research Institute (IRRI) reported [2] that the total rough rice production in world was more than 600 million ton in 2004. The rough rice production of Bangladesh is about 6% of total world rice production and this is the 4th rank position according to individual country production in the world. This is an indication of abundant biomass production in Bangladesh. In the year 2006, about 39.59 million ton of paddy was produced [3]. There are different types of rice processing in Bangladesh. About 30% of total paddy produced nationally is processed by households and do not enter the market. Another 20% is processed in large rice mills where mechanical drying is done. The rest 50% of the total paddy production is thus processed in small and medium rice mills [4]. Rice husk is a by-product of rice which is very good biomass fuel. This mass is amounting 20% of total rough rice production. Rice husk is mainly used for parboiling and drying of rough rice before milling. Drying process is mainly done under direct radiation of sun light on a floor. There are some mechanical drying processes which are done by using the rice husk as source of thermal energy. The milling process is completely done by using electrical energy. The parboiling and drying operation of rice processing is consuming huge amount of energy from renewable sources. Therefore, the study was conducted to investigate the energy consumption pattern and the global warming potential of rice processing in Bangladesh.

2. METHODOLOGY

This study was conducted in rice mills of Bangladesh. The different unit operations of rice food grain processing were critically analyzed to determine the energy consumption from different sources. Mainly there are three different unit operation of rice food processing viz. i) parboiling, ii) drying and iii) milling. Out of these three unit-processes parboiling and drying need thermal energy. Parboiling process is the partial boiling of rough rice (paddy) with steam. The parboiling process requires energy to produce steam. Rice husk is used for producing steam. The energy required for parboiling of paddy is calculated using Equ (i).

$$E_{parboil} = \frac{W_{husk} \times C_{husk}}{W_{paddy}} ------(i)$$

Where,

$E_{parboil}$ = energy required for parboiling of paddy, kJ/ton
W_{husk} = weight of husk required for parboiling, kg
W_{paddy} = weight of paddy parboiled, ton
C_{husk} = calorific value of rice husk, kJ/kg

After parboiling the paddy is left for drying. Drying is the removal of moisture from parboiled paddy. The drying operation is mainly done on a floor under direct radiation of sunlight. The drying process requires a huge amount of thermal energy for removing the moisture from paddy. To calculate the water removed from rough rice during drying process, the following Equ. (ii) is used. The thermal energy requirement for the sun drying of paddy is calculated using Equ. (iii).

$$W_w = \frac{M_w}{1 - M_w} \times W_d --------(ii)$$

Where,

W_w = water removed from paddy, kg
M_w = moisture content in paddy, decimal
W_d = weight of dry mass of paddy, kg

$$E_{sun\_drying} = W_w \times L ----------(iii)$$

Where,

E_{sun_drying} = energy required for sun drying, kJ
W_w = water removed from paddy, kg
L = latent heat of evaporation of water, kJ/kg

Energy required for mechanical drying comes from two sources viz. heat energy from rice husk combustion and electrical energy from grid for blowing hot air. The quantity of energy required for mechanical drying are calculated as follows Equ. (iv) & (v).

$$E_{heat\_drying} = \frac{W_{husk} \times C_{husk}}{W_{paddy}} - - - - - (iv)$$

Where,

$E_{heat\_parboil}$ = heat energy required for mechanical drying of paddy, kJ/ton
W_{husk} = weight of husk required for mechanical drying, kg
W_{paddy} = weight of paddy dried, ton
C_{husk} = calorific value of rice husk, kJ/kg

$$E_{elec\_drying} = \frac{E_{kWh}}{W_{paddy}} - - - - - - - - - - (v)$$

Where,

E_{elec_drying} = energy required for mechanical drying, kWh/ton
E_{kWh} = electricity consumed during mechanical drying operation, kWh
W_{paddy} = weight of paddy dried, ton

After drying the paddy is milled to get rice food grain. Rice husk is obtained as by-product of milling that is ready for using as energy for parboiling. The Electrical energy from national grid is used for milling of paddy. The electricity needed for milling of paddy is measured as follows:

$$E_{milling} = \frac{E_{kWh}}{W_{paddy}} - - - - - - - - (vi)$$

Where,

$E_{milling}$ = energy required for milling, kWh/ton
E_{kWh} = electricity consumed during milling operation, kWh
W_{paddy} = weight of paddy milled, ton

A scenario was analyzed using LEAP (Long-range Energy Alternatives Planning system) program to see the energy consumption pattern and to determine the global warming potential from rice processing in Bangladesh. Energy demand is calculated as follows:

$$E_{demand} = \sum A \times EI - - - - - - - - (vii)$$

Where,

E_{demand} = energy demand, GJ
A = activity level, ton paddy processed
EI = energy intensity for the activity, GJ/ton

To address the emissions, LEAP includes a Technology and Environmental Database (TED) that provides extensive information describing the technical characteristics and environmental impacts of a wide range of energy technologies including existing technologies, current best practices and next generation devices. The mathematical expression of emission that references the chemical composition of the fuel as follows:

$$Loading_{CO_2} = C_{content} * FO * \frac{CO_2}{C} - - - - - - (viii)$$

Where,

$Loading_{CO2}$ = carbon dioxide emission, kg
$C_{content}$ = carbon content in specified fuel, kg
FO = fraction oxidized
CO_2, C = constant

The emission is calculated by the LEAP program based on the following principles:

$$Emission = E_{consumption} * E_f --------(ix)$$

Where,

$E_{consumption}$ = energy consumption

E_f = emission factor

3. RESULTS AND DISCUSSION

3.1 Energy Consumption in Different Operations of Rice Processing

Bangladesh produces staple food grain for the country people with 2.2% growth since decades. About 70% of rice is processed in local rice mills and the rest amount is processed by the local people and some grain is kept as seed. There are three different stages of paddy processing viz. i) parboiling process, ii) drying of the parboiled paddy and finally iii) milling operation. The energy intensities of different unit-operations of rice processing are shown in Table 1. The load of electrical energy varies according to the capacity of rice mill. According to the Directorate of Food, about 25000 of small rice mill and 500 large rice mill are in operation throughout the country. The total peak load of the rice mill is estimated as 835.3 MW (Table 2).

Table 1. Energy intensity of different unit-operation of rice processing

Activity level	Rice husk (kg/ton)	Solar (MJ/ton)	Electricity (kWh/ton)
Parboiling	120	-	-
Sun Drying	-	556	
Sun + Mechanical drying	70	340	8.7
Mechanical drying	110	-	17.4
Steel huller milling	-	-	19.0
Modern milling	-	-	29.26

Source: Field survey 2008

Table 2. Electrical load of rice mill

Activity	Average load, kW*	N0. of rice mill**	Total peak load, MW
Steel Huller Mill (Engleberg)	30.4	25000	760.0
Modern rubber roll mill	150.6	500	75.3
Total peak load			**835.3**

*Field survey 2008, **Directorate of Food 2005

In parboiling operation, the paddy is boiled partially with steam. The steam is produced in a boiler by combusting rice husk. The consumption of rice husk energy for parboiling of paddy is estimated as 37.1 million GJ in 2000 and this value will increase to 71.3 million GJ in 2030 (Table 3).

In drying operation, the moisture in the paddy grain is removed by applying heat energy. The drying operation is done in three different ways viz. i) direct radiation of sunlight, ii) mechanical drying, and iii) the combination of sun drying and mechanical drying. In the mechanical drying method, rice husk energy is used as a source of thermal energy and electrical energy is used to blow the thermal energy through the wet grain. The consumption of rice husk, electrical and solar energy for drying are 7.7 million GJ, 0.3 million GJ and 10.7

million GJ, respectively in the year 2000 and these values will increase to 14.7, 0.6 and 20.5 million GJ in 2030 (Table 3).

The final stage of rice processing is milling operation. In this operation, the dried paddy is processed to separate the food grain. In this stage only the electrical energy is used to run the milling machinery. The consumption of electrical energy in milling operation is estimated as 1.9 million GJ_e in the year 2000 and 3.6 million GJ in 2030 (Table 3).

The above discussion clearly indicates that major energy for rice processing come from renewable energy source such as biomass and solar. The energy use pattern in different unit operation is shown in Figure 1. The large thermal energy is consumed in parboiling process of paddy. The second highest amount of energy is consumed in drying operation. The electrical energy is required in mechanical drying and milling operation. The consumption of different type of energy for rice processing system is shown in Figure 1. A large quantity of rice husk is consumed for rice processing.

Table 3. Final energy demand for rice food grain process

Unit operation \\ Year	2000	2010	2030
Parboiling operation			
Rice Husk (Million GJ)	37.1	46.1	71.3
Drying operation			
Rice Husk (Million GJ)	7.7	9.5	14.7
Electricity (Million GJ)	0.3	0.4	0.6
Solar (Million GJ)	10.7	13.3	20.5
Milling operation			
Electricity (Million GJ)	1.9	2.4	3.6

Calorific value of rice husk = 14 MJ/kg [5], 1 kWh = 3.6 MJ

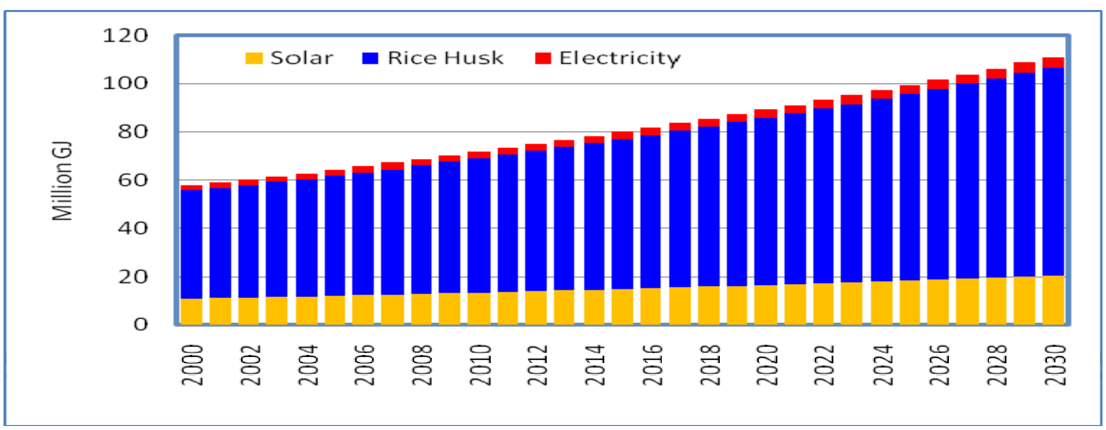

Figure 1. Final energy demand for rice food grain processing in Bangladesh

3.2 Global Warming Potential

Environmental impact of rice processing in Bangladesh is analyzed with LEAP program. The global warming potential CO_2 equivalent is shown in Figure 3. Since the most energy required for rice processing comes from renewable sources, the global warming potential is very less. The biogenic CO_2 emission was estimated as 5.3 million ton in 2000 and 10.2 million ton in 2030. The biogenic carbon dioxide is renewed by rice plant every year.

However, the non-biogenic carbon dioxide was estimated as 0. 4 million ton in 2000 and 0.8 in 2030 (Figure 2). The non-biogenic carbon dioxide emission occurred due to the electrical energy use. Therefore, the least developed country like Bangladesh where the huge amount of renewable energy is being used, there should be given special care to compensate the adverse effect of global warming like sea water level rise.

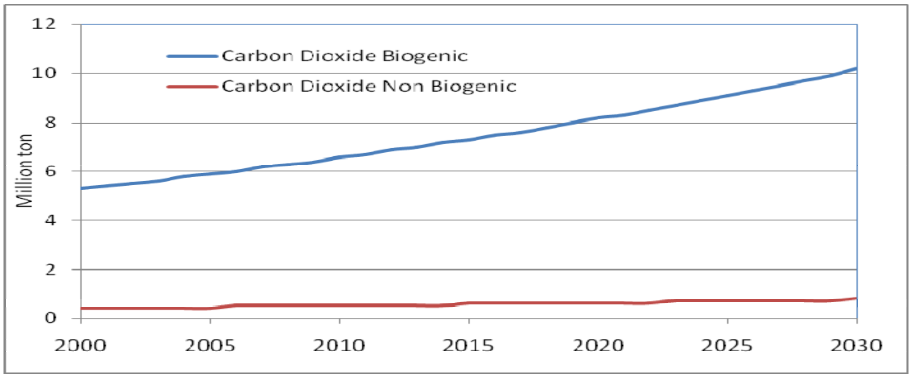

Figure 2. Global warming potential due to rice processing in Bangladesh

4. CONCLUSIONS

Bangladesh is using huge amount of renewable energy for the processing of stable food rice for 150 million of people each year. Bangladesh contributes a lot to save earth from global warming by using the renewable energy instead of fossil fuel. The demand of rice increases every year due high pressure of population causing the increasing demand of energy for rice processing. Therefore, a proper policy should be undertaken for future need of energy in rice processing industries.

5. REFERENCES

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