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Prospect of Electric Energy from Solid Wastes of Rajshahi City Corporation: A Metropolitan City in Bangladesh.

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Abstract. Municipal solid waste is a serious environmental hazard and social problem in Bangladesh. Currently a massive volume of solid waste is generated every day in the Municipal areas and unfortunately solid waste management is being deteriorated day by day. Consequently the country has had serious crisis of electricity, load shedding is now impractical as living standards and become a great barrier in socio-economical growth. Now, interest in renewable energy resources from organic solid wastes has increased, as there is a huge amount of energy locked in these wastes. By meeting the both, power generation from MSW can play a vital role in socio-economical development of the country. A study on the potential of such energy resources is presented in this paper. The study conducted through personal in depth interview; data collection from primary and secondary sources; MSW sample collection with performing laboratory test; data processing and analysis; and drawing recommendation and conclusion. It is found that electricity production from MSW could be an alternative way of power generation as well as waste management.

Keywords: Municipal solid waste, alternative source of electricity, composition of MSW, waste and energy.

1. Introduction

Bangladesh is a densely populated country, country's population will be about 17 crore by 2020 (BBS, 2001; Population Council, 2010). In countries like Bangladesh Municipal solid wastes creates an incredible environmental hazard and social problem in city lives (Hasan & Chowdhury, 2006). A massive volume of solid waste is generated every day in the city areas and unfortunately solid waste management is being deteriorated day by day due to the limited resources in handling the increasing rate of generated waste (Enayetullah & Hashmi, 2006). Here in Bangladesh, in most cases wastes are disposed of only by land filling, a few resource recovery plants available in the country (Bhuiyan, 2010). While, there is a great opportunity of producing energy like gas as well as electricity. Most of developed countries generate electricity from their solid wastes. In many parts of the world, solid waste is used to produce electric power via incineration or gasification of the fuel, or through landfill methane capture, and much research has focused on waste-to-energy solutions (Parizeau, Maclaren & Chanthy, 2006). Thermal treatment may reduce the waste volume up to 90%, this simultaneously could address two problems: disposal of solid waste and generation of electricity (Smith, Whitty, Quintero & Ojeda, 2007). In addition, the prudent use of natural resources is one of the broadest objectives of sustainable development (Philips, Pratt & Pike, 2001).

Electricity, gases are the most important form of energy which can lead the country for several steps to the developed one. Bangladesh's installed electric generation capacity was 4.7 GW in 2009; only three-fourth of which is considered to be 'available' (Energy Bangla, 2010; The New Nation, 2010). Only 30 percent people of the population of Bangladesh has access to electricity and frequent load shedding disrupts the whole economy of the country (Meah, Sadrul Ula, Kearns, & 2010). There are some mega-cities in

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Bangladesh namely Dhaka, Chittagong, Rajshahi, Khulna, Barisal, Rangpur, Sylhet etc. produce a huge amount of solid waste every day which are only disposed by land filling (Alam & Sohel, 2008). The enormous increase in the quantum and diversity of waste materials generated by human activity and their effects on the environment, have led to an increasing awareness to adopt scientific methods for safe disposal of wastes. The technologies for recovery of energy from wastes can play a vital role in mitigating the problems. At present there are 522 urban centers in the country including 254 pourashavas and 6 City Corporations, generate about 13,332 tonnes of solid wastes per day and it will be about 47000 tons/day by 2025 (Chowdhury, 2008: Suryanarayanan, 2010). Rajshahi City Corporation is one of the second biggest densely populated cities in Bangladesh.

1.1. A Brief on Rajshahi City Corporation (RCC)

Rajshahi City is located in the north west of Bangladesh bordering India to the south. Rajshahi City Corporation (RCC), which was formed in 1987, covers an area of approximately of 92.93 square km being (BBS, 2001; Hossain, Halder, Mondal & Haque, 2010). There are a number of schools, colleges, universities etc. having a population of 0.75 million (BBS, 2001; RCC, 2010). The city generates approximately 300 tones of solid waste/day. Of the total, only 210 tones are collected and dumped into the open dumping ground, the remaining 90-140 tones of waste are dumped straight into drains, water bodies and open spaces (Ali, 2011). There are 30 wards in RCC, only 13 wards are covered by 'door to door waste collection' facilities. RCC has only one dumping site (3.5 feet deep in 15.98 acre area) and 35 secondary collection points (Akter, Rahman & Sharmin, 2010). The waste is only used as a land filling material which is now being a burden for RCC and will create a great problem for the next generation.

Still, there is no electricity generation unit has been set up in Rajshahi as a result the city dwellers are often facing acute load-shedding and erratic power supply (NFB, 2004). Due to frequent load shedding, mills and factories are experiencing setback (The Daily Independent, 2010). Power Development Board can supply only 25 megawatts of electricity against the demand of 65MW and the sales of instant power supply appliances have sharply increased on its outskirts against the backdrop of severe load-shedding (Hindustan Times, 2010). Now, the alternative source of power generation has become a crucial demand..

2. Objective of the Study

1. To identify how much waste is produced per capita per day and determining how suitable it is for energy production.
2. To determine the amount of energy produced by the incineration process.
3. To find out the possibility whether it can be established as a power generation as well as waste management arrangement in the region.

3. Scope of the Study

It has been found by many surveys and analysis that the quality, quantity and nature of solid waste changing over time and with development. Populated cities of developed countries have more consume of waste and their quality, i.e. calorific value is much higher.

In this situation 'waste to energy' generating process will help to get rid of the problem of electricity scarcity and waste management. This study will serve:

a) It represents the calorific values of all the components of waste in different moisture content.
b) How much energy can be produced to convert it into electricity and the total possible electric energy is calculated here.
c) It is justified here whether the generation of electric power from the municipal solid waste if Rajshahi City, would be feasible or not, with respect to production and waste management.

4. Methods and Materials

Both primary and secondary data have been used in conducting the study. Primary data have been collected by personal MSW sample collection and in depth interview of respondents group like city corporation employees and garbage collectors. Their opinion is collected to get an insight into existing waste management system. Secondary data have been collected through pursuing different reports of City

Corporation, web materials, various articles, journals and books. In collecting the MSW sample to conduct a study at local conditions, a variety of waste characterization methods can be used (USEPA, 1996). A simple method is the sampling for the characterization of Municipal Solid Waste (MSW) is sampling directly from waste generation sources, which is applied for this study. The first level is stratification by waste generation sources such as residential, commercial, institutional and open areas (as street sweeping). The Second is seasonal stratification as Bangladesh has three main seasons: summer, monsoon and winter thus sampling was designed to collect during these seasons. A total of fifty samples were collected from city area of Rajshahi.

4.1. Sample weight

The smaller sample weight is the greater variance of the waste sample composition and if the sample weight is decreased from approximately 91 kg, the sample variance will be increased rapidly (Klee, 1980). In Bangladesh, about 80% waste components passing through the 100 mm sieve opening (Alamgir & Ahsan, 2007). Considering the size target sample weight for this research was set at 100 kg.

4.2. Field protocol

The preliminary survey was conducted to 5 representative wards of RCC which has different waste generation sources such as domestic, commercial, street sweeping, industrial, clinical etc. The commercial establishments were categorized as wet market, shopping complex, hotel, restaurant, educational institutions and others. In industrial and clinical areas husking mill, saw mill, garments factory, pharmaceuticals, hospitals, diagnostic centre were selected. The daily average generation rate per capita in each source was evaluated. A total 150 MSW sample from different source were collected to determine the waste composition in RCC.

4.3. Laboratory protocol

The weight of the collected waste samples were measured in the laboratory of Local Government Engineering Department (LGED), Bangladesh and then transported to the designated shed for sorting. Firstly the waste generated per capita per day in RCC is calculated (Table 1). Secondly the MSW was categorized in to six typical categories (Table 2). Then the composition was categorized into ten major categories as Organic material; Food / vegetable waste, Paper product, Garden waste, Polyethylene, Plastic / Rubber, Wood, Textiles, Leather, Glass and Inorganic material; Ferrous & non ferrous material (Table 3). Subsequently, calorific values of different components of wastes were found out (Table 4). Standard personnel safety procedures were followed during the sorting process such as wearing gloves, apron, safety glasses and boots, etc.

5. Waste generation in RCC

Waste generation per day in a specific area and percent composition of various waste components are the two most important types of data for decision makers (Cheng & Hu 2010). This information is necessary in order to identify waste components to target for finding resource of energy and recycling programs (Staley & Barlaz, 2009). To meet this demandnwaste generation per day is estimated (Table 1).

Table 1: Waste generation in RCC

Sources	MSW generation (kg/day/capita)	MSW from different sources/day (%)
Domestic waste	0.309	77.2
Street sweeping	0.005	1.2
Commercial including market waste	0.074	18.6
Industrial waste	0.004	1.00
Clinical waste	0.003	0.74
Others	0.006	1.49
Total	**Waste generated 0.401 kg per day**	

Source: Author(2010).

5.1. Composition of the Waste

The nature and quantity of solid waste is changing over time and with development (EEA, 2002). In urban Bangladesh, solid wastes are originated from residential houses, street sweeping, commercial, industrial and other sources includes dust, ash, vegetable and animal bones, paper and packing of all kinds, rags and other torn fabrics, garment materials and many other trash (Alam & Sohel, 2008). From the field survey it is found that there are a number of organic compounds in the solid waste of RCC. The average percent fraction of total generated solid waste of Rajshahi City collected from different sources at different location of the city is given in Table 2.

Table 2: Present typical constituents of solid wastes in Rajshahi City Corporation

Item	% by dry weight
Domestic waste	61.5
Street sweeping	20.0
Commercial including market waste	10.0
Industrial waste	5.0
Clinical waste	1.0
Others	2.5

Source: RCC (2010); Field Survey (2010).

From the laboratory test and analyses, the composition of the solid waste of Rajshahi City was found is shown in Table 3.

Table 3: Average composition for solid waste for different areas of Rajshahi City Corporation

Waste component	Percentage of the total	Moisture content%
Organic material		
Food / vegetable waste	88.68	64
Paper product	3.27	07
Garden waste	1.83	48
Polyethylene	1.95	04
Plastic / Rubber	0.85	02
Wood	0.02	12
Textiles	1.11	14
Leather	0.04	07
Inorganic material		
Glass	0.14	01
Ferrous & non ferrous material	0.06	02
Other	2.05	40

Source: Author (2010).

6. The Problem

Population of the entire city corporation in Bangladesh is very high and RCC is the second most populous city and its population is estimated to be double in the next 5 years (Clemett, Amin, Ara, & Akan, 2006). The RCC having population of 0.75 million generating a huge amount of solid waste (0.4kg /capita/day) 300000 kg/day sets a serious environmental problem .The main concern this problem has generated is where the final disposal of the MSW will be done since the spaces in sanitary landfills are almost over and the areas for these scarce. There are about 1.0 % of hospital and clinical waste among the total municipal solid waste which is a mixture of toxic chemicals, radioactive elements and other pathological substances highly dangerous for human lives. The indiscriminate disposal and uncontrolled with open dumping also clogs the urban drainage system, causes water stagnation and threatens contamination of the water supply. Thus the growing problems of solid waste in Bangladesh are posing increasing threats to the health of its residents. On the other hand, as the population increases, demand for electricity also increases and now the country facing a tremendous power crisis which obstructing the socio-economic development of the whole nation. This is why other alternatives for the disposal of MSW are very much needed to be studied.

6.1 Problem Management

Annual power consumption grew at a higher rate than the population of the city and this trend is expected to continue in the future. Generation of solid waste has been increasing, especially in urban areas, in conjunction with accelerated population growth with changing habit and quality of life. It is difficult to get new dumping yards and if at all available, they are far from the city and this adds to the exorbitant cost of transportation. It is high time the municipal corporations, state governments, and policy makers take up the matter seriously. The best option is to reduce the volume by effective treatment of the waste. In recent years, the waste-to-energy project has gained attention due to its double benefit of resource generation and pollution abatement. Moreover, it may also present an opportunity, because much of the waste comprises energy-rich materials that can be used in advanced power production systems for generation of electricity.

7. Calorific values of MSW

More than 80% of the waste is food or vegetable waste. These huge amounts of food or vegetable wastes contain about more than 65% moisture and their calorific value per/Kg is not too high. But the important matter is that the calorific value of the waste generated in Rajshahi City is 7.94 MJ/kg, as found in this study which is enough for producing electricity. Therefore, municipal solid waste can be use as alternative sources of electricity. The calorific values are shown in Table 4.

Table 4: Calorific value of the solid waste component

Name of the sample	Calorific value (MJ/kg)
Newspaper	16.80
Normal paper	14.24
Textile	15.70
Leather	10.70
Garden waste	7.90
Vegetable waste	19.70
Polytechnic	40
Plastic	40
Other wastes	18

Source: Author (2010).

8. Analysis of Electricity Generation

For the analysis of electricity generation Dulong`s formula is used. The principal products of anaerobic decomposition are methane and carbon dioxide; ammonia, hydrogen sulfide and mercaptans (sulfonated hydrocarbons) are also generated (Themelis & Kim, 2002). The percentages of carbon hydrogen oxygen and nitrogen or sulfur in different constituents of the waste are shown in Table 5.

Table 5: Ultimate analysis of "Dry Stream" components of MSW

Component of waste stream	% weight				
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur
Food/Vegetable waste	46.5	4.3	42.8	2.4	0.1
Paper product	43.5	6.0	44.0	0.3	0.2
Garden waste	44.2	5.4	45.6	2.6	0.2
Polyethylene	80.5	14.3	3.2	2.0	
Plastic/Rubber	60.0	7.2	22.8	-	-
Wood	49.0	6.0	42.7	0.2	0.1
Textile	55.0	6.6	31.2	4.6	0.2
Leather	69.0	9.0	5.8	6.0	0.2
Others	26.3	3.0	2.0	0.5	0.2

Source: Adapted from Themelis & Kim, 2002.

The above values may not be so accurate for RCC except vegetable and garden waste these values will not change a large. Therefore the components of MSW from the analysis of Themelis and Kim could be used in case of analyzing the MSW of RCC.

Table 6: Weight of organic components of MSW per day with respect to moisture content

Organic waste component	% of total	Moisture content (%)	Moist mass (ton)	Dry mass (ton)
Food/vegetable waste	88.68	64	266.04	95.77
Paper product	3.27	07	9.81	9.123
Garden waste	1.83	48	5.49	2.86
Polyethylene	1.95	04	5.85	5.65
Plastic/rubber	0.85	02	2.55	2.50
Wood	0.02	12	0.06	0.053
Textiles	1.11	14	3.33	2.86
Leather	0.04	07	0.12	0.11

Source: Author, 2010.

Again, for determining the approximate chemical formula for dry combustibles and percentage composition of carbon, hydrogen, nitrogen and sulfur, table 5 is reviewed.

Table 7: Chemical composition of waste fractions in RCC

Organic waste component	Dry mass (ton)	% weight				
		Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur
Food/vegetable waste	95.77	46.5	7.3	39.8	2.4	0.1
Paper product	9.123	43.5	6.0	44.0	0.3	0.2
Garden waste	2.86	44.2	5.4	45.6	2.6	0.2
Polyethylene	5.65	80.5	14.3	3.2	2.0	
Plastic/rubber	2.50	60.0	7.2	22.8	-	-
Wood	0.053	49.0	6.0	42.7	0.2	0.1
Textiles	2.86	55.0	6.6	31.2	4.6	0.2
Leather	0.11	69.0	9.0	5.8	6.0	0.2
Others	3.69	26.3	3.0	2.0	0.5	0.2
Tons per day	113.49	58.45	8.99	46.046	2.67	0.1329
% composition		51.50	7.92	40.57	2.35	0.1171
Atomic Weight (kg/kmol):		12.01	1.01	16.00	14.01	32.07
No. of Mmol/day:		4.86	8.90	2.87	0.19	~0.0
Number of atoms		6	10.98	3.54	0.23	~0.0

Source: Author, 2010

***Approximate chemical formula of "dry" combustibles**: $C_6H_{10.98}O_{3.54}$*

The heat released from combustion of solid wastes is partly stored in the combustion products (gases and ash) and partly transferred by convection, conduction, and radiation to the incinerator walls and to incoming waste. The energy content of the waste can be estimated using the modified Dulong Equation or the heating value of individual waste components.

Modified Dulong's Equation:

Heat (KJ/kg) = 337C + 1428 (H – O/8) + 9S

Where,

C = Carbon (%)

H = Hydrogen (%)

O = Oxygen (%)

S = Sulfur (%)

$\therefore$ Heat (KJ/kg) = 337 × 0.515 + 1428 (0.0792 – 0.4057/8) + 9 × 0.0

= **214.24 KJ/kg**

$\therefore$ Steam energy available = 70 % of heat energy

= (0.70 × 214.24) KJ/kg

= 150 KJ/kg

$\therefore$ Electric power generation = Steam energy ÷ 11395 kj/kWh

= (150/11395) kWh/kg

= 0.01316 kWh/kg

(Waste generation of RCC=0.75x0.4x1000000=300000kg/day)

$\therefore$ **Total electric power generation = (**0.01316 × 300000) kWh/day

= 3949.1 kWh/day

= **3.949 MWh/day**

Now,

Station service allowance = 6% of electric power generation

= 0.237 MWh/day

Unaccounted heat loss = 5% of electric power generation

= 0.197 MWh/day

Net electric power generation = Electric power generation – (Station service allowance +Unaccounted heat loss)

= 3.949 – (0.237 + 0.197)

= 3.515 MWh/day

From the analysis of different studies it is found that the price for producing per unit electricity from municipal solid waste by incineration would be between Taka 9.5—10.5 (USD 0.136—0.15/unit) (PREGA, 2005; GKNS Energy Pvt Ltd., 2008). Where in Bangladesh, it is found that the electricity production cost for each unit of electricity from wind-based power plant could be around Taka 10 to Taka 12 (USD 0.142—0.171/ unit), from diesel fired power plants is Taka 8 to Taka 14 (USD0.114—0.200/ unit) and Taka 8 (USD0.114) from furnace fired power units (BEN, 2009; Ahsan, 2011).

Municipal Solid Waste (MSW) contains organic as well as inorganic matter. The latent energy present in its organic fraction can be recovered for gainful utilization through adoption of suitable Waste Processing and Treatment Technologies. The recovery of energy from wastes also offers other benefits as follows:

- The total quantity of waste gets reduced by nearly 60% to over 90% depending upon the waste composition and the adopted technology;
- Demand for land, which is already scarce in cities for land filling is reduced;
- The cost of transportation of waste to far-away landfill sites also gets reduced proportionately; and
- Net reduction in environmental pollution.

It is, therefore, only logical that, while every effort should be made in the first place to minimize generation of waste materials and to recycle and reuse them to the extent feasible, the option of Energy Recovery from Wastes be also duly considered.

9. Technology preferred

Mass Burn Incinerator is one of the earliest wastes to energy technologies and the Mass Burn plants incinerate wastes as received without pre-processing (PREGA, 2005; Cheng& Hu, 2010). Majority of Waste to Energy (WTE) plants in operation in the Asia are based on incineration, a mature and simpler technology compared to others (Xu & Liu, 2007; Yuan, Xiao, & Li, 2008). Incineration transforms heterogeneous wastes into more homogeneous residues with the primary benefit of substantial reduction of the waste's weight (up to 75%) and volume (up to 90%). During incineration, MSW is combusted at high temperature; air is continuously supplied to ensure the complete combustion of the components to stable and natural molecular forms. The solid residues can be sent to landfills or cleaned up and used off-site for certain construction purposes (Cheng& Hu, 2010). In addition, WTE can reduce the transport of MSW to distant landfills and the associated emissions and fuel consumption (Kaplan, DeCarolis & Thorneloe, 2009). The Electricity generation by this process is much higher than any other although extra fuel is needed to run the process. Only the problem that will arise in this method is the drying of wastes in rainy season which may be solved by providing a large area by shed and heating by additional fuel. Other technologies of producing electric power requires dry land and low moisture containing waste which are not be available in this region. Therefore, considering volume reduction of MSW, electricity generation capacity, requirement of less area and as the Bangladesh has gas reserve the incineration technology could be chosen.

10.Recommendations

The study formulates recommendations the following recommendation:

- Solid wastes produced in Municipalities may be used as a renewable clean energy source.
- An immediate decision is needed to be taken by the RCC authority as well as the Government of Bangladesh to implement waste-energy production project as an alternative option of power generation to meet the electricity scarcity of the country.
- A consultative meeting should be held with environmentalist, healthcare service providers, waste handlers, and municipal authorities to select appropriate place and technology of producing energy from MSW.
- Solid waste-energy production technology should also be considered as pollution diminution as well as greenhouse gases reduction tools in making decision on implementing of waste-energy production project.

- Consideration of the limitation of imported fossil fuels should also be taken into account in making the viability of the project.

11.Conclusion

Waste to energy solves the problem of MSW disposal while recovering the energy from the waste materials with the significant benefits of environmental quality, increasingly accepted as a clean source of energy. Research and technology development focusing on corrosion phenomena, flue gas control, fly ash management and beneficial reuse of residues will further drive the growth of WTE industry. WTE incineration needs to be implemented to make greater contribution in supplying renewable energy in Bangladesh, while helping solving the country's MSW management problem in the coming decade. The challenge of MSW disposal and the demand for alternative energy resources are common in many developing countries. Experimentally a 5-10 MW power plant may be installed based on the quality and current generation of solid wastes in RCC. It can also be considered as a Waste Management Plan rather than as an Electricity Generation Project as the technology can lead to a substantial reduction in the overall waste quantities requiring final disposal, which can be better managed for safe disposal in a controlled manner while meeting the pollution control standards. In addition, power produced from the WTE activity can reduce the costly natural resources "fossil fuel" utilization in power generation. It is expected that the experience on the development of WTE in Bangladesh can offer some helpful lessons to other developing counties.

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