Municipal Solid Waste and its Management in Rajshahi City, Bangladesh: A Source of Energy

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Abstract- This study focuses on existing and an improved solid waste management system of Rajshahi City Corporation (RCC) area for improving its inhabitants' environmental health. The improved management system shows that energy can be recovered from solid waste. The paper also focuses on the characterisation and composition of municipal solid waste including moisture content and calorific value. The data shows that the moisture content in city waste is significantly higher with the calorific value of 15.51 MJ/kg and recoverable electrical energy is 4.482MWh/day approximately. Furthermore, the paper recommends the appropriate technology for solid waste disposal in the area of RCC to attain its goals.

Keywords- Solid waste; solid waste management; energy recovery; solid waste characterization.

1. Introduction

Municipal Solid Waste (MSW) is nothing but useful material at wrong place increasing at a very high rate in the urban areas of Bangladesh, one of the densely populated Least Developed Asian Countries (LDACs) due to rapid urbanization and population growth. These increasing rates of MSW create an adverse effect on environment as well as social and professional life of city residents, urban planners, developers and other concerned stakeholders [1]. The primary sources of MSW are residential, institutional and commercial waste, and municipal services wastes (street sweeping). Residential wastes are high in quantity and vary with time and season whereas the compositions of industrial and commercial wastes remain relatively steady over the years [2, 3]. Urban population in Bangladesh are increasing at a very sharp rate of about 6% and are concentrated mostly in six major cities which are nearly 13% of total population and 55-60% of total urban population [4, 5]. These large urban populations are producing huge amount waste in those urban areas. MSW generation scenario in the major cities (DCC-Dhaka City Corporation, CCC-Chittagong City Corporation, KCC-Khulna City Corporation, RCC-Rajshahi City Corporation, BCC-Barisal City Corporation, SCC-Sylhet City Corporation and RM- Rangpur Metropolitan) in Bangladesh is shown in Fig.1 However, waste disposal and management system is very poor in urban area in the country and only major cities have some garbage disposal system.

A major portion of population do not get waste collection services and only a minor amount of the generated wastes are collected by door-to-door collection system introduced in late 90's. However, MSW management system is still in developing stage due to lack of motivation, awareness, commitment, expertise as well as money and a considerable portion (40-60%) of wastes are not properly stored, collected or disposed [6, 7]. In the major cities of country, per capita solid waste generation is about 0.5 kg /day whereas only 0.2 kg/day of them is carried to the final disposal and rest is disposed-off locally due to the poor waste management system [8].

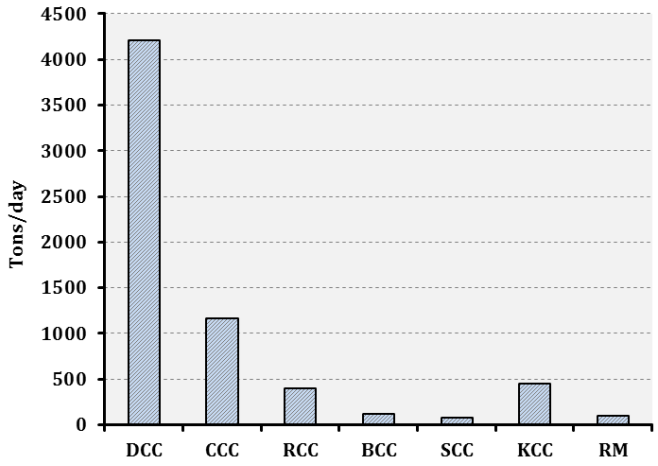

Fig. 1. MSW generation scenario in the major cities in Bangladesh

Therefore, these unmanageable large quantities of MSW create massive environmental problems that include diseases and economic transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance losses [9]. Thus, private and Non-Governmental Organizations (NGOs) are taking some community-based initiatives that play an important role in waste management. Waste Concern, a NGO started a community-based low-cost solid waste composting project in Mirpur in Dhaka in 1995 is a good example of how composting can be a viable option to a conventional solid waste management model. A solid waste composting plant of capacity 3 ton per day requires 20 workers of which 6 workers are employed for waste collection and rest 14 are employed for composting [10]. Accordingly, it will create the job for about 50000 people in 2025 if only 20% of the organic waste bring under composting project [11-13]. Moreover, a 5 MW power plant has been established in Chittagong city.

Though solid waste management is one of the imperative mandatory functions for improvement of urban lifestyle however, this essential service of RCC is not efficiently and properly performed by the local bodies and the people are not aware about this problem. This unsatisfactory scenario arises due to the lack of financial resources, institutional weakness, improper selection of technology, transportation systems, and public awareness. The paper finds out the better management system and energy potential of solid waste in RCC.

2. Rajshahi City Corporation (RCC)

Rajshahi city is on the northern bay of the river Padma and is surrounded by Poba district. It is the divisional headquarters of Rajshahi division and generally known as Silk City and Education City. The geographical location of the city is 24.05'to 25.14' north latitude and 88.09' to 89.25' east longitude. The city corporation was formed in 1987 and it has a total area of 96.69 km^2 with a total population of 0.75 million [14]. Total Literacy rate of Rajshahi city is 30.61%. It consists of 4 Thanas, 35 Wards and 175 Mahallahs [15]. Fig.2 shows the location of RCC [16]. There are number of schools, colleges and universities in RCC and a large number of students are read in those educational institutes. Thus electricity is the basic need for RCC. However, only 25 MW is supplied by Power Development Board against a demand of 65MW causes huge load-shedding. Therefore, it is necessary to find out the alternative and renewable source of power generation immediately.

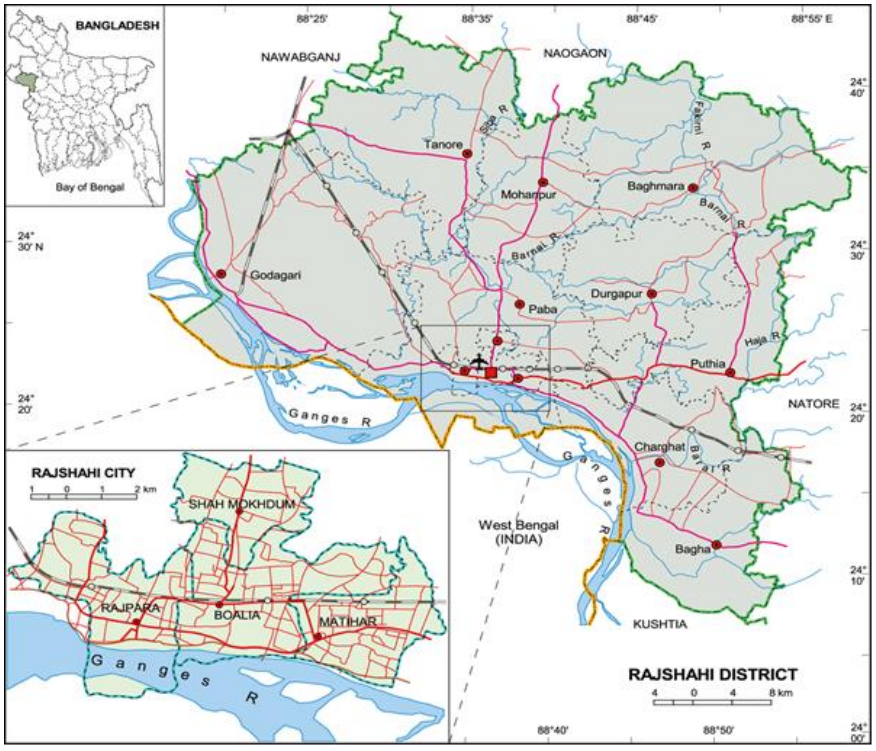

Fig. 2. Location of Rajshahi City Corporation

3. Municipal Solid Waste (MSW) generation and its management in RCC

The people live in the RCC produce 400 ton waste/day. Solid wastes are produced from different sources such as residential, medical, industrial, construction and demolition, agricultural, institutional and municipal. Among the wards less than 50% (15) wards are covered by 'door to door waste collection' facilities however RCC is trying to provide this service to all the wards in the near future. There is one dumping site of 3.5 feet deep with an area of 15.98 acre at 'Nawdapara' and 35 secondary collection points. Of the total, 280 metric ton/day wastes are collected and disposed-off in the waste disposal area and rest 120 metric ton/day wastes are collected by public for the purpose of producing compost in order to use in the agricultural works. The waste spreads all over the disposal site that produces unpleasant odor and air pollution due to improper landfilling as shown in Fig.3. Therefore, solid disposal is becoming the major problem for the city authority. However, Waste to energy (WTE) can solve the problem of MSW disposal in RCC.

For management of solid wastes in RCC area, 14 trucks/trucktors, 210 vans and 150 wheel bars are used to collect wastes from different point of the city. RCC provides 1,073 waste management manpower to collect wastes from households [19]. The resent solid waste management system in RCC is shown in Figure 5. Recently, RCC is implementing four pilot projects for solid waste management and has been started to collect medical solid waste. Two of these are in ward 14, one in ward 6 (Laxmipur) and another one in ward 20, 21 and 23.

Fig. 3. Improper waste disposal at Naodapara, Rajshahi

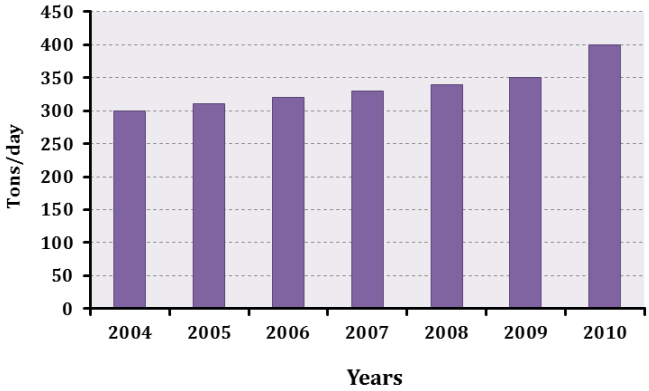

Fig. 4. Waste generation trend in RCC

Fig. 5. Existing waste management system in RCC

Among the 8 hospitals, 47 clinics and 22 diagnostic centers only 3 hospitals, all clinics and diagnostic centers are covered by RCC collection system. Gauge/bandage, syringe, saline bag, papers, medicine packet and rapping, food waste, urine, placenta, ampoule, sanitary pad, cotton, etc. are the common waste generated from the hospitals/clinics/diagnostic centers [17]. All the wastes are burned in incinerator of the Rajshahi medical college hospital as the wastes have very harmful effects on human body. Accordingly, all medical centers together generate about 22 kg pathological waste, 30 kg plastic waste, 20 kg soft waste, 7 kg sharp waste and 320 kg general waste per day. Rajshahi Medical College Hospital generates the largest amount of waste compared to other hospitals and clinics. Medical waste covers the major portion of solid generated in RCC. Therefore, it can be suggested that the priority should be given to large and government hospitals to introduce proper in-house management system [18]. Moreover, residential and industrial wastes are the other source of waste in RCC. The municipal solid waste generation in RCC is shown in Fig.4.

4. Waste characterization

Characterization of MSW is also important to evaluate its possible environmental impacts on nature as well as on society. Waste of RCC contains about 70% organic material as shown in Table 1. Decision-makers of any specific area consider the per capita waste generation and composition as the most important information [20]. For this the organic components of MSW are needed to prepare for chemical analysis to determine the percentage of nutrient contents. Plant organic materials are first dried at normal temperature then grinded into powder form.

Table 1. Solid waste category in RCC

Waste category	Waste components	Percentage (%)
Organic matter	Waste from food such as food and vegetable refuse, fruit skin, and manure	70
Garden waste Wood, Straw	Stem of green, corncob, leaves and grass, waste products from Desk, chair, bed board, coconut shell	6
Paper	Paper, paper bags, cardboard, corrugated board, box board, newsprint, magazines, tissue, office paper and mixed paper	9
Plastic,Textile, Rubber, Leather	Waste from wrapping film, plastic bag, polythene, plastic bottle, plastic hose and plastic string, cotton, wool, nylon, cloth and waste from ball, shoes, purse, rubber band and sponge.	9
Metal, Glass	Waste from tin can, wire, fence, knife, bottle cover, aluminium can and other aluminium, foil, ware and bi-metal and glass made products like bottles, glassware, light bulb and ceramics	3
Others	Yard waste, batteries, large appliances, nappies/sanitary products, medical waste, rock dirt etc.	3

4.1. Physical composition of waste

Physical composition of waste in any country is greatly affected by the economic development of the country, increased habitation, density of population, changing food habit, social and cultural habits, education, effect of globalization, etc. and is changing over the years [21]. Physical composition of solid waste of various locations in RCC is shown in Table 2.

Table 2. Physical composition of waste

	Location	Food waste (%)	Plastic (%)	Polythene (%)	Wood (%)	Cloth (%)	Garden waste (%)	Paper product (%)	Glass (%)	Metal (%)	Leather (%)	Others (%)
Residential	Helanabad	80.74	4.56	3.89	2.67	1.11	0.33	3.45	1.22	0.44	0.04	1.55
	Terokhadia	76.99	5.00	5.02	2.33	1.57	0.67	3.30	0.67	1.77	0.24	2.44
	Fire service	70.44	4.34	5.55	1.44	1.33	3.33	5.57	0.67	1.33	-	6.00
	Average	76.06	4.63	4.82	2.15	1.34	1.44	4.11	0.85	1.18	0.09	3.33
Commercial	Shaheb bazar	81.74	4.33	3.44	4.00	0.67	0.67	3.11	-	0.57	0.05	1.42
	Railway station	75.48	5.33	4.44	1.33	0.89	0.33	3.78	1.11	0.67	0.64	6.00
	Ruet gate	74.99	4.67	4.55	0.67	0.89	0.22	5.89	2.35	0.44	-	5.33
	Talaimari	77.99	3.67	3.78	2.67	1.11	0.67	4.78	-	1.11	-	4.22
	Average	77.55	4.5	4.05	2.17	0.89	0.47	4.39	0.87	0.70	0.17	4.24
Industrial	Motpukur	68.22	6.67	5.78	1.89	0.44	0.67	4.22	5	2.44	0.11	4.56
	Sopura	58.01	4.33	5.11	2.44	5.77	5.11	1.22	5.55	7.57	0.07	4.82
	Vodra	57.67	5.33	4.22	1.89	5.44	4.44	2.22	5.11	7.44	0.34	5.90
	Kadirgonj	79.89	4.67	3.78	0.67	1.33	3.89	0.45	1.57	1.78	0.19	1.78
	Average	65.95	5.25	4.72	1.72	3.25	3.53	2.03	4.31	4.81	0.18	4.23
	Total average value	73.19	4.79	4.53	2.01	1.83	1.81	3.51	2.01	2.23	0.15	3.93

4.2. Chemical composition

Chemical properties of solid waste are the most significant data for the estimation equipment needs, systems and management programs and plans. Moreover, the implementation of disposal and energy recovery options of solid waste is entirely dependent on the chemical properties of solid waste [22]. Table 3. shows the chemical composition of waste in RCC. Solid waste in RCC contains about 50.23 % carbon and 40.17 % oxygen in weight of total waste.

It has been considered that, about 50–60% moisture content of the total weight of waste is suitable for energy recovery for the developing countries like Bangladesh [2, 3].The average moisture content found in RCC is above 60%

which is favorable for the country. However, maximum moisture content 73 % is found in Fire service. Moisture content of MSW of various locations in RCC in presented in Fig.6

Table 3. Chemical composition

Elements	Weight (%)
Carbon	50.23
Nitrogen	1.85
Sulpher	0.01
Hydrogen	7.52
Oxygen	40.17
Others	0.22

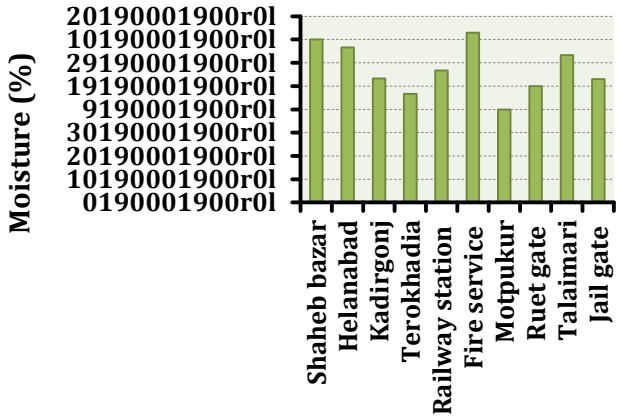

Fig. 6. Moisture content of waste in various locations in RCC

5. MSW as the potential of energy

Municipal solid waste is normally treated as waste, but these MSW can be the source of energy. The calorific value of solid waste can be used for heating purposes and electricity can be produced from this energy. WTE can solve the problem of MSW disposal with energy recovery from the waste and can improve environmental quality, lifestyle of city dwellers. More than 70% of the waste is food or vegetable waste with moisture content of more than 60%. It is estimated that, the MSW of RCC has a calorific value of 15.51 MJ/kg which is enough for producing electricity. Consequently, MSW can be used as alternative sources of electricity generation in RCC.

Firstly, the energy content of MSW is estimated by using modified Dulong's formula and finally, available electricity that can be produced from this MSW energy is calculated [23].

Modified Dulong's Equation:

$$\text{Heat energy} = 337\text{C} + 1428(\text{H} - \text{O}/8) + 9\text{S (kJ/kg)} \quad (1)$$

where, C = Carbon (%),
H = Hydrogen (%),
O = Oxygen (%),
S = Sulfur (%).

$$\therefore E_S = 0.7 \times E_H, \quad (2)$$

where, E_S = Steam energy available,
E_H = Heat energy.

$$\text{Again, } 11395\ E_P = E_S, \quad (3)$$

where, E_P = Electric power generation.

$$S_A = 0.06 \times E_P \quad (4)$$

where, S_A = Station service allowance.

$$U_H = 0.05 \times E_P \quad (5)$$

where, U_H = Unaccounted heat loss.

$$\therefore E_{NP} = E_P - (S_A + U_H), \quad (6)$$

where, E_{NP} = Net electric power generation.

Total municipal solid waste generation in RCC is 400000 kg/day. Accordingly, the net electric power has been estimated to 4.482MWh/day approximately.

6. Appropriate and feasible technology and Proposed Waste management system for RCC

There are many processes available in the world such as Incineration, Pyrolysis/Gasification, Anaerobic digestion and Landfill Gas Recovery. Since Bangladesh is a developing country, a simple and less costly process is needed for producing electricity from solid wastes. Incineration is considered as a mature and simpler technology among the other technologies and is commonly used in majority of WTE plants in Asia [24, 25]. Incineration transforms heterogeneous wastes into more homogeneous residues and high temperature and continuous air supply is necessary for complete combustion of the MSW. This process produces much higher electricity than other; though some extra fuel is needed to run the process however drying of wastes in rainy season is the only problem in this process. On the other hand, other technologies require dry land and solid wastes of low moisture content. Therefore, the incineration technology may be the best technology in RCC for solid waste management as well as electricity generation. A new waste management system is proposed for RCC after monitoring the existing system as shown in Fig.7.

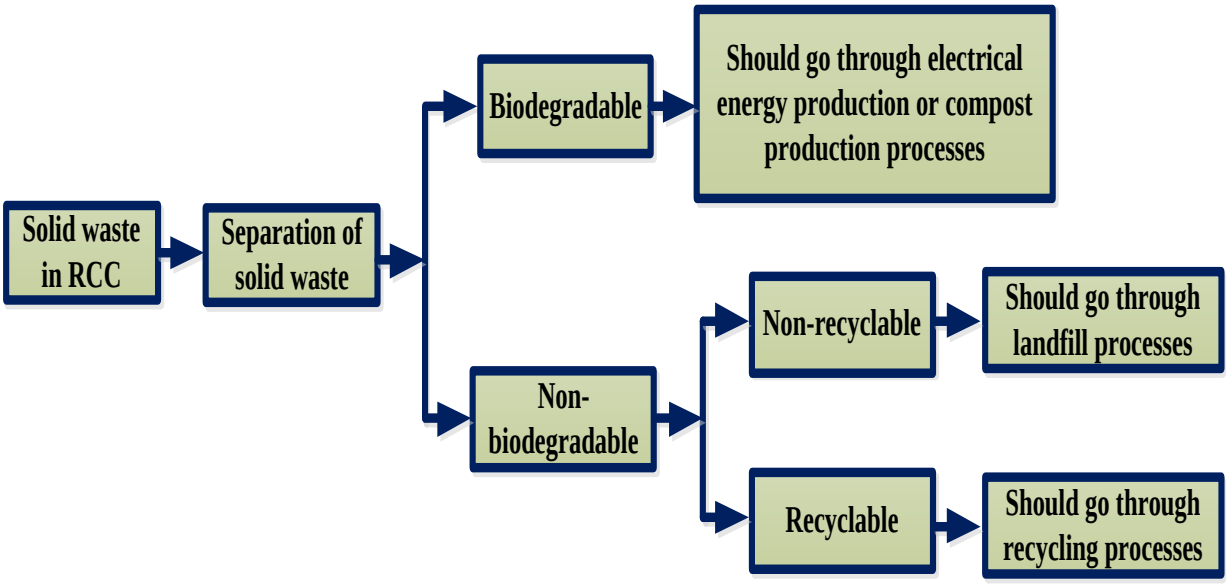

Fig. 7. Proposed waste management system for RCC

7. Conclusion

Municipal solid waste has been increasing rapidly in RCC due to the urban population and GDP growth. There is a seasonal fluctuation in waste generation however the average MSW generation per capita is 0.40kg/person/day, which is close to many developing countries. Low calorific value and high moisture content characterize RCC's solid waste, which helps to determine the suitable waste management option. Based on these characteristics an improved management system has been proposed for RCC. The energy recovery from solid waste has been shown in the improved management system. Approximately, 4.482MWh/day electrical energy has been found from the solid waste of RCC depends on the physical and chemical characteristics of solid waste. In conclusion, a 5-10 MW power plant can be installed based on the present generation of solid wastes in RCC to produce electricity as well as to reduce adverse impact of solid waste on environment.

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