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Municipal Solid Waste Management of Pabna Municipality and Prospect of Electricity Production from the Collected Waste

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Abstract: *Municipal solid waste is a serious environmental problem in many cities of Bangladesh. Currently a massive volume of waste is being generating every day in many cities of Bangladesh. Pabna, a district of Bangladesh, is one of the populated and rapidly developing city, also facing the MSW management problem. This paper attributes on the existing and an improved MSW management system of Pabna Municipality. The collected data (primary and secondary sources) shows that the type of solid waste generated in Pabna has a high percentage of organic matter which is suitable for thermo-chemical conversions. The calculation shows that the recoverable electrical energy from MSW is 519.14 KWh/day approximately. Furthermore, the paper recommends the appropriate technology for SW disposal in the area of Pabna Municipality to attain its goal.*

Keywords: *Calorific value, Energy recovery, Municipal Solid waste (MSW), Pyrolysis, Solid waste management.*

I. Introduction

Municipal solid waste management (MSWM) constitutes a serious problem in many cities of Bangladesh. Most cities do not collect the totality of wastes generated, and, of the wastes collected, only a fraction receives proper disposal. The insufficient collection and inappropriate disposal of solid wastes represent a source of water, land and air pollution, and pose risks to human health and the environment. The cities of Bangladesh have undergone a rapid urbanization during the past thirty years. The number of urban dwellers is expected to double between 1987 and 2015. Nearly 90% of this increase will take place in the cities, where growth rates exceed 3% a year, three times that of the industrialized countries [1].

Urbanization in Bangladesh implies the expansion of slum areas and the creation of new ones. Population growth intensifies the pressure on urban infrastructure in many cities already overburdened with the provision of urban services. Most cities lack the resources to meet the demand for services such as water, sanitation, and solid waste management. The insufficiency of services results in a deterioration of the urban environment in the form of air, water and land pollution that poses risks to human health and the environment. Pabna, a city of over 0.199 million people, only 10% of the population is served by sewers. Raw sewage generated by Pabna residents regularly pollutes water supplies, canals, lagoons.

The term MSW describes the stream of solid waste ("trash" or "garbage") generated by households and apartments, commercial establishments, industries and institutions. MSW consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries [2]. It does not include medical, commercial and industrial hazardous or radioactive wastes, which must be treated separately.

The solid waste disposal system deals with the collection and proper disposal or recycling of the solid wastes. The disposal techniques may include land filling, burning, composting etc [3]. The solid wastes also need to be treated within lesser time, because it cannot be piled up. Electricity can be produced by thermal-conversion of "municipal solid waste" (MSW) as a fuel. MSW power plants, also called waste to energy (WTE) plants, are designed to dispose of MSW and to produce electricity as a byproduct of the thermal conversion operation. Burning MSW can generate energy, while reducing the volume of waste by up to 90 percent.

This paper presents an overview of current MSWM in Pabna city, and identifying constrains providing several recommendations for system improvement. This study may be beneficial for municipal authorities and researchers to work towards redefining present MSWM system.

II. MSWM in Pabna City: An Overview

2.1 A Brief on Pabna City:

Pabna is a city of Pabna District, Rajshahi Division, Bangladesh and the administrative capital of eponymous Pabna District. It is located on the north bank of Padma River. A summary of Pabna City is described in Table-1.

Table-1: A brief on Pabna city [4]

S.N	Description		Nos
1	Area		27.20 square km
2	Wards		15
3	Holding No		29,724
4	Population		0.199 Million
5	Industry	Heavy	04
		Medium	45
		Light	291
6	Hospital		36
7	School, college, University		139

2.2 Waste management facilities in Pabna City:

Table-2: Waste management facilities [5]

S.N	Vehicles	Nos
1	Van	60
2	Truck	7
3	Manpower	80

Dumping Zone: 1. Fokirpur, 2. Chetoner Mor

2.3 Waste generation in Pabna City:

The rate of generation, quantity and characteristics of solid waste depend upon number of factors such as architecture, food habits, cultural traditions, socio-economic and climate conditions, geographic and physical conditions, public attitudes and legislation, source reduction and Rs activities. The quantity of waste by source of generation is important in establishing the collection design and the financial strategies. Waste has been measured by tonnage at the point of disposal, rather than by when and where it was generated. Total amount of waste generated and dumped in last seven years of Pabna city is listed below in Fig. 1.

Fig. 1: Waste generated and dumped in last seven years of Pabna city [5]

Waste generation per day in a specific area and percent composition of various waste components are the two most important types of data. This information is necessary in order to identify waste components to target for finding resource of energy and recycling programs [3]. In order to meet this demand waste generation per day is estimated. The average percent fraction of total generated solid waste of Pabna City collected from different sources at different location of the city is given in Table-4.

Table-3: Amount of waste generation per day in Pabna* [5]

Sources	MSW generation (Kg/day/capita)	MSW from different sources/day (%)
Household waste	0.179	76.20
Institutional Waste	0.042	14.28
Street Waste	0.005	1.20
Civic amenity services waste	0.001	0.50
Drain waste	0.002	0.75
Treatment plant waste	0.001	0.5
Sanitation waste	0.008	1.78
Mineral waste	0.001	0.50
Agricultural waste	0.007	1.56
Bulky waste	0.004	1.00
Healthcare waste	0.003	0.74
Industrial waste	0.004	1.00
Total	**Waste generation 0.257 kg per day**	**100%**

*Estimated

2.4 Composition of solid waste:

Municipal solid wastes are not homogeneous and do not have consistent characteristics. Nature and composition of municipal solid waste is changing with development of cities. The composition of municipal solid waste includes organic food waste, paper and paper products, wood, metal, glass, plastics including hospital waste, construction waste, industrial waste, dust, firewood, rags and other torn fabrics, garment materials and many other trashes. The pie chart shows the composition of solid waste in percentage basis in residential, commercial and industrial area where the average values are used for constructing pie chart.

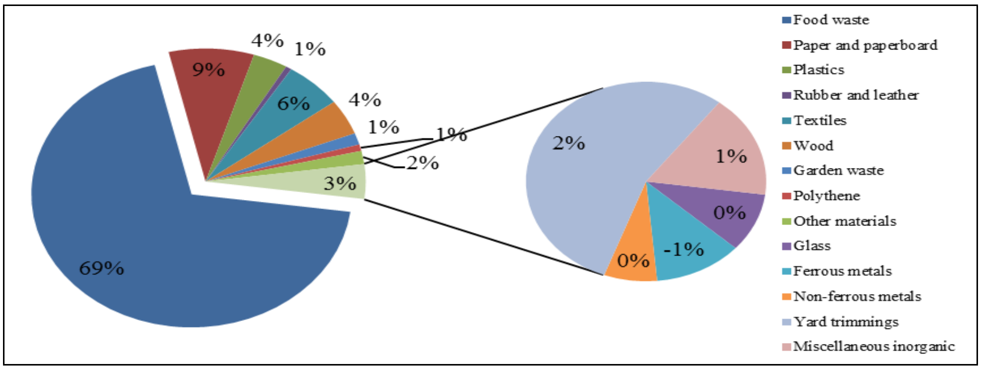

Fig. 2: Total MSW generation by material

2.5 Current Problems:

Collecting, transporting, and disposing of MSW represents a large expenditure for Pabna city: waste management usually accounts much for municipal operational budgets. Despite these high expenses, many cities collect less than half of the refuse generated. In Pabna, for instance, less than 30% of the refuse generated is collected [1]. Waste disposal receives even less attention: as much as 90% of the MSW collected in Pabna city end up in open dumps. In areas that lack refuse collection—usually low-income communities—residents tend either to dump their garbage at the nearest vacant lot, public space, creek, or river, or simply to burn it in their backyards. Uncollected waste may accumulate on the streets and clog drains when it rains, which may cause flooding. Wastes can also be carried away by runoff water to rivers, lakes, and seas, affecting those ecosystems. Alternatively, wastes may end up in open dumps, legal and illegal—the most common disposal method in the Pabna.

Open dumping of solid wastes generates various environmental and health hazards. The decomposition of organic materials produces methane, which can cause fire and explosions, and contributes to global warming. The biological and chemical processes that occur in open dumps produce strong leachates, which pollute surface and groundwater. Fires periodically break out in open dumps, generating smoke and contributing to air pollution [1]. Fires at open dumps often start spontaneously by the methane and heat generated by biological decomposition. Dump managers in Pabna city deliberately set periodic fires at the dumps in order to reduce the volume of the wastes, which allows more wastes to be disposed there and thus extends the life of the dumps. Human scavengers may also cause intentional fires, since metals are easier to spot and recover among the ashes after the fires than among piles of mixed wastes. Food leftovers and kitchen wastes attract birds, rats, flies and other animals to the dumps. Animals feeding at the dumps may transmit diseases to humans living in the vicinity. Biodegradation of organic materials may take decades, which may limit the future use of the land on which open dumps are located.

2.6 Problem Management of Municipal solid waste for Pabna City:

Generation of solid waste has been increasing, especially in urban areas, in conjunction with accelerated population growth with changing habit and quality of life [3]. 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, take up the matter seriously. Rs such as refuse, return, repair, re-hauling, re-manufacture, reconditioning, replace, renew, recharge, recovery, refill have to be utilized in Pabna partially or fully as much as possible to lessen solid waste.

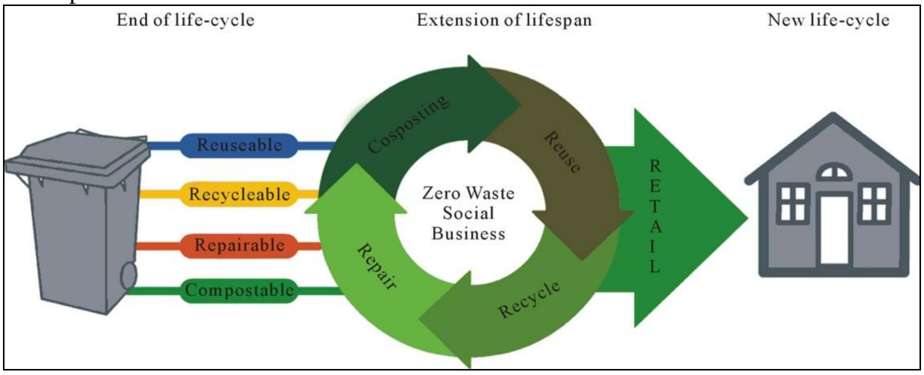

Fig. 3: Top most priority for Rs

Rs are very effective solution of rapid generation of solid waste. If the technique is applied in the daily life, a significant amount of waste can be minimized. Based on the advantages of the process system and application level the following waste minimization hierarchy can be developed as shown-

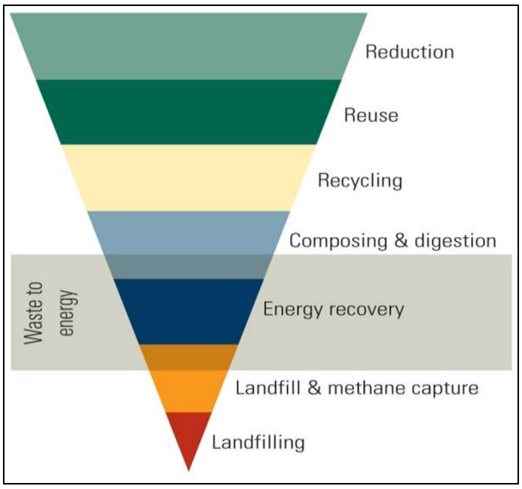

Fig. 4: Waste minimization hierarchy for effective solid waste management

Now-a-days the annual power consumption grew at a higher rate than the population of the city and this trend is expected to continue in the future. 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. Thus if the thermal treatment can be applied the solid waste can lead to a reduction of original volume and weight of the combustible fraction by up to about 95 percent and 75 percent respectively and energy can be recovered from the burning process or processing them in especially designed process.

III. MSW as the Potential of Energy

Waste management is a major challenge in urban areas. Without an effective and efficient waste management program, the waste generated from various human activities, both industrial and domestic, can result in health hazards and have a negative impact on the environment. Understanding the waste generated, the availability of resources, and the environmental conditions of a particular society are important to developing an appropriate waste-management system. The problem of disposal of the solid waste has forced to search new ways and means to solve it. Various practices followed are land filling, burning, recycling, composting etc. But processes such as land filling are creating problems due to the saturation of the dumping grounds. In this context, solid waste can be utilized for the generation of power. WTE can solve the problem of MSW disposal with energy recovery from the waste and can improve environmental quality, lifestyle of city dwellers. Considering the amount of solid waste generated in the study area, the amount of power that can be generated has been calculated [3]. The calorific value of solid waste can be used for heating purposes and electricity can be produced from this energy. More than 70% of the waste is food or vegetable waste with moisture content of more than 60%. Consequently, MSW can be used as alternative sources of electricity generation in Pabna.

Table-4: The Calorific values of various components of municipal solid waste [3]

Waste component	Energy content (KJ/kg)	Waste component	Energy content(KJ/kg)
Food	4000	Yard waste	6500
Paper & cardboard	16000	Wood	18500
Plastics	32000	Glass	140
Textiles	17000	Metals	700
Rubber	23000	Ash	7000
Leather	17000	-	-

Chemical composition is an important parameter in the selection of various wastes process especially carbon to nitrogen ration which is an important factor for composting as it controls biological conversion activity of the wastes. Chemical composition of primary chemical components of solid waste such as carbon, hydrogen, oxygen, nitrogen, sulfur and ash in various typical solid waste components of solid waste is represented in Table-7.

Table-5: Chemical components of solid waste [3]

MSW components	Chemical components in percentage by dry weight					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Food	45-75	6-12	20-40	1-2	0.2-0.4	4-5
Paper & cardboard	30-60	5-10	30-40	0-0.3	0.1-0.2	5-10
Plastics	50-80	8-10	15-20	<0.1	<0.1	6-10
Textiles	40-50	5-8	30-40	1-2	0.1-0.2	3-4
Rubber	60-70	8-10	-	-	1-2	15-20
Leather	50-60	6-8	10-12	8-10	0.2-0.4	8-10
Yard waste	45-50	4-6	30-40	3-4	0.3-0.4	6-8
Wood	45-50	5-6	40-50	0.1-0.2	<0.1	0.5-1.5
Glass	0.5-0.6	0.1-0.2	0.2-0.4	<0.1	-	98-99
Metals	4-5	0.4-0.6	3-4	<0.1	-	90-95
Ash	20-30	3-5	3-4	0.4-0.6	0.1-0.3	60-70

IV. Estimation of Power Generation from MSW

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 [6]. 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 [7, 8].

Modified Dulong's Formula:

$$\text{Heat Energy} = 4.18 \times (78.4 \times C + 241.3 \times (H - \frac{O}{8}) + 22.1 \times S)$$

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

$$\text{Heat Energy, } E_H \text{ (KJ/kg)} = 4.18 \times (78.4 \times 0.505 + 241.3 \times (0.0713 - \frac{.4035}{8}) + 22.1 \times 0.0)$$
$$= 186.53 \text{ KJ/kg}$$

Steam energy available, $E_S = 0.70 \times E_H = 130.5$ KJ/kg
Electric power generation, $E_P = E_S/11395$ KJ/KWh = 0.01145 KWh/kg
Waste generation of Pabna = 0.199 × 0.256 × 1000000 = 50944 kg/day
Total electric power generation, TE_P = (0.01145 × 50944) kWh/day= 583.30 KWh/day
Station service allowance, $S_A = 0.06 \times TE_P = 34.99$ KWh/day
Unaccounted heat loss, $U_H = 0.05 \times TE_P = 29.17$ KWh/day

Net electric power generation, $E_{NP} = TE_P - S_A - U_H$
$= 583.30 - 34.99 - 29.17$
$= 519.14$ KWh/day

The net electric power has been estimated to 519.14 KWh/day approximately.

V. Appropriate and Feasible Technology for Electricity Production from MSW

There are many processes available such as Incineration, Pyrolysis/Gasification, Anaerobic digestion and Landfill Gas Recovery for energy recovery from MSW. 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 [3, 8]. But at present, incinerators are facing public demand for the reduction of dioxins emission, high-efficiency thermal recovery and stabilization through melting processes. For the disadvantages of Incineration process, we suggest Pyrolysis as the energy recovery system from MSW of Pabna as well as other cities of Bangladesh. Pyrolysis has been examined as an attractive alternative to incineration for municipal solid waste (MSW) disposal that allows energy and resource recovery.

5.1 Pyrolysis gas melting system:

In the flash pyrolysis system, numerous operational problems were encountered. In an analysis of the system the following problems were attributed: i. Failure of the front-end system to meet purity specifications for aluminum and glass which affect the economics of the system, ii. Failure of the system to produce saleable pyrolysis oil. To overcome such problems, an advanced pyrolysis system Pyrolysis gas melting system for waste treatment technology is introduced. Main feature of pyrolysis gas melting system are: stable pyrolysis, low emission, recovery of valuable, increased reduction in volume, high quality slag.

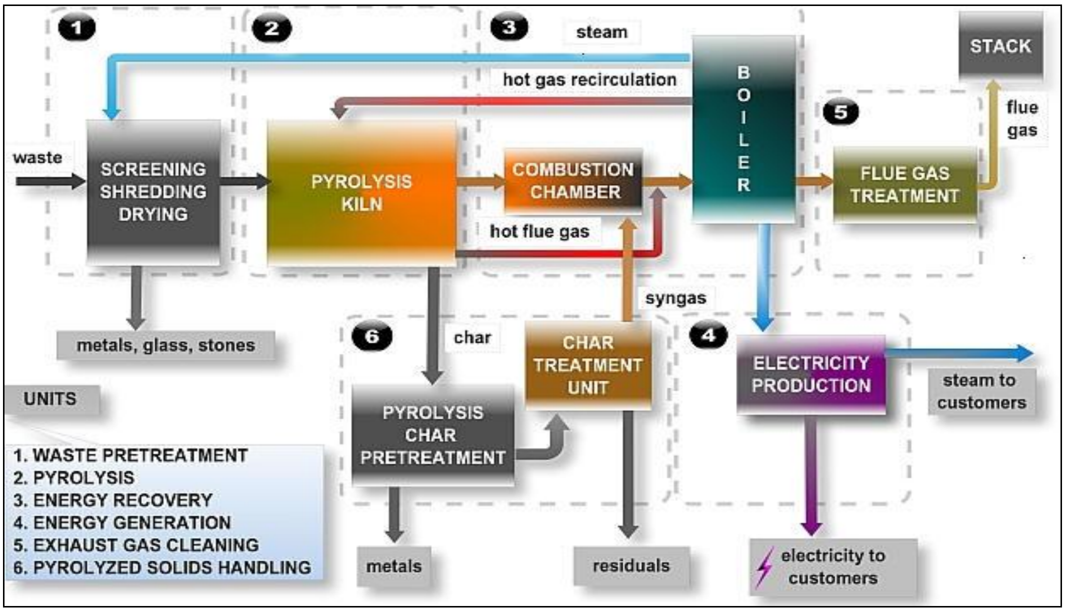

Fig. 5: Schematic diagram of Pyrolysis gas melting system [25]

5.1.1 Characteristics of main components:

Pyrolysis drum/kiln: As the waste is heated, it is divided into "Pyrolysis gas" and "Pyrolysis residue". The pyrolysis reaction (weight reduction) progresses quickly within the temperature range of 250°C to 470°C. The pyrolysis drum is arranged with the heating tube, to assure the uniform heating, which allows the refuse to be heated up to the temperature of 470°C under the reduction atmosphere. The pyrolysis drum is inclined by approximate 0.5degree, and the residence time is approximate one hour. The stabilized pyrolysis is assured by residence time of one hour [3, 11].

Combustion chamber: At the combustion chamber, pyrolysis gas, carbon and the dust collected by the waste heat boiler and bag filter are fed from the top, and are burned and melted spirally. Combustion air is injected at 3 stages. The molten slag falls from the tap hole into the submerged conveyor, and is discharged as water-quenched slag.

Dioxins: System can achieve the low dioxins emission with high temperature combustion, turbulence and adequate residence time.

VI. Conclusion

Municipal solid waste has been swelling rapidly in Pabna due to the urban population and GDP growth. There is a seasonal fluctuation in waste generation, however the average MSW generation per capita is 0.257 kg /day. For the improvement of the problems, it is needed to implement laws and regulations in the proper way. Need to upgrade the concept of solid waste management and improve the system of entire management. Waste to energy solves the problem of solid waste disposal while recovering the energy from the waste materials with the significant benefits of environmental quality, increasingly accepted as a clean source of energy. As the waste generated in Pabna have sufficient thermal energy to produce electricity; 519.14 KWh/day, thus experimentally a 1-2 MW WTE (Pyrolysis based) power plant may be installed based on the quality and current generation of solid wastes.

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