MUNICIPAL SOLID WASTE MANAGEMENT AND POTENTIAL ENERGY GENERATION FROM MYMENSINGH CITY CORPORATION IN BANGLADESH

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ABSTRACT

This study delves into the escalating global challenge of solid waste management, particularly impacting developing nations, with a specific focus on Mymensingh City Corporation (MCC), Bangladesh. It examines MCC's waste dynamics using a threefold approach: general surveys, calorific value determination, and energy generation potential assessment-revealing significant mismanagement issues. To address this, the research proposes a Waste-to-Energy (WTE) strategy, emphasizing anaerobic digestion. Through door-to-door surveys, it establishes MCC's daily waste generation at 206.44 tons, approximately 0.430 kg/person/d, a substantial portion being biodegradable.The calorific value of the waste has been found to be 35.3 MJ/kg, whereas the moisture content of the MSW has been investigated to be 45.239%. The probable power generation is found out to be 230.16 MWh/d which is electrical energy converted from steam energy. The suggested WTE solution aims to reduce waste and generate energy, projecting a daily potential of 22,050 m3 of biogas and 37 tons of compost fertilizer. Economic analysis indicates the viability of an Anaerobic Digestion (AD) plant with a 4.6-year payback period and 2.18 MW of Electrical energy can be produced from the proposed plant. These findings stress the need for sustainable waste management in MCC, providing not only energy solutions but also a template for similar urban areas, ultimately envisioning a more environmentally sound future for MCC through innovative waste-to-energy solutions.
By addressing the challenges of waste mismanagement through waste-to-energy initiatives, MCC and other urban areas in Bangladesh can not only improve their waste management practices but also harness the potential of waste as a sustainable energy source for the benefit of their communities and the environment.

Keywords: *municipal solid waste management, waste-to-potential energy, anaerobic digestion.*

1. INTRODUCTION

The exponential growth of urban populations worldwide has presented a profound challenge: the effective management of municipal solid waste (MSW). Urbanization's rapid pace demands innovative solutions for waste management that not only address logistical concerns but also prioritize environmental sustainability and public health. Waste-to-Energy (WTE) technologies have emerged as a promising avenue in the pursuit of sustainable waste management, aiming to mitigate waste disposal challenges while generating renewable energy sources.

This paper undertakes an in-depth exploration of MSW management practices within the Mymensingh City Corporation (MCC), focusing on the potential for energy generation from waste. The current MSW management of MCC is quite frustrating. Only one method of MSW decomposition i.e. Landfilling is in practice. The site is located in Char-iswardia and already around 90% of the site has been filled up. The investigation could not find any other established system of energy regeneration or resource recovery. Also, the investigation revealed the shortage of manpower management and up-to-date technologies in MSW management which is really alarming for the citizens as they are facing severe problems like water clogging, air pollution etc. Through a multidisciplinary lens encompassing environmental science, engineering, and social sciences, this study aims to illuminate the complexities of solid waste management systems within urban contexts like the MCC jurisdiction.

The research's primary objective is to widely assess current MSW management practices in MCC and ascertain the feasibility of harnessing energy from waste resources. Chapters within this paper delve into detailed analyses of waste management stages and empirical investigations. By blending primary and secondary data collection methods, including surveys and waste composition analyses, this research aims to unravel the sources of waste generation and management dynamics within the urban landscape of Mymensingh City Corporation (MCC).

2.METHODOLOGY

The methodology employed in this study is designed to comprehensively investigate and analyse the intricate dynamics of solid waste management in the context of Mymensingh City Corporation while exploring the potential for energy generation from the waste streams. The entire process was split into three parts: a broad survey, figuring out the calorific value of waste, and, finally, exploring the potential for energy and power generation from MSW. Figure 1 depicts the research methodology flowchart.

2.1 GENERAL SURVEY

2.1.1 PRIMARY DATA COLLECTION

To find out the solid waste management practice in study area, the primary data is collected from various classes of people of the selected area and the respondents are selected randomly. The main data is gathered by surveying day laborers, rickshaw and van pullers, businessmen, students, job holders, and housewives through questionnaires. This aims to evaluate the current state of solid waste management, supplemented by direct field observations. Primary data is also collected by visited the waste collection process and the selected dumping area in Char-iswardia. Primarily a hundred households of different types throughout MCC were selected for a survey. Details such as family size, the interviewee's education level, daily waste production, household type, and more were meticulously recorded for in-depth analysis. These factors will be carefully examined in subsequent analysis.

2.1.2 SECONDARY DATA COLLECTION

Secondary data about population, volume of waste generation, activities exiting on solid waste management in selected study area were collected. It was collected from Mymensingh municipality.

2.2 PRESENT SCENARIO OF MSW MANAGEMENT OF MCC

To investigate the overall scenario of the MSW management of Mymensingh City Corporation, the author conducted a questionnaire survey regarding the household waste management. The primary survey was conducted in 14 wards (5,7,26,16,6,1,27,20,3,13,10,4,14,30). The investigative survey regarding the present scenario of MSW management has revealed that to collect household waste(s) the authority has arranged 31 hand trolleys and 150 vans to collect waste from door to door. Besides, Door to door collection there are arrangement of only 100 dustbins to collect wastes from outdoor areas. There is arrangement for 22 conservancy power trolley and 23 conservancy truck (3 to 5) ton to deliver and convey the collected wastes to the only dumping station located at Char-iswardia which is 6.5 acre in area , and currently it is 95% filled which is alarming news for the dwellers of the city (corporation m. c., 2023). Table 1 shows the manpower for solid waste management in MCC and Figure 2 shows the present scenario of MSW management of MCC.

2.3 PROPOSED MSW MANAGEMENT OF MCC

The present scenario paints a bleak picture of solid waste mismanagement in MCC, highlighting the urgent need for better waste management practices. A streamlined process for managing municipal solid waste (MSW) that incorporates waste-to-energy (WTE) conversion comprises several sequential stages. Figure 4 shows the several sequential stages of municipal solid waste management and treatment.

2.4 ESTIMATION OF MSW GENERATION

A comprehensive survey was conducted involving a hundred households of diverse types to gain insights into the Municipal Solid Waste (MSW) generation patterns within the MCC (Mymensingh City Corporation) area. This survey encompassed various household types, including some student residences of considerable size, and the resulting data is presented in Table 2 It is evident that MSW generation varies significantly based on various factors, such as dietary preferences, monthly income, and educational levels.

Within the 100 households surveyed, which collectively housed 693 individuals, the total waste generated amounted to 298.05 kilograms. Consequently, the average waste production was determined to be 0.430 kilograms per person per day. According to information provided by the Mymensingh City Corporation authority, the city's population is estimated to be around 0.48 million (Khan et al., 2018). Using this data, an approximate total daily waste generation figure for MCC was calculated at 206.44 tons. As the population within the city corporation continues to grow steadily, it is expected that the daily total of Municipal Solid Waste (MSW) generated will slightly surpass the figures reported here. Table 3 present the total waste generation per day in MCC.

2.5 WASTE COLLECTION

Out of the 100 households surveyed, 6 were selected for waste collection to represent different types of families, including semi-pucca, pucca, owned, and rented households. The solid waste was gathered randomly, with assistance from the city corporation's cleaner. After the collection, the total weight of the gathered waste was determined to be 8.35 kilograms.

2.6 PHYSICAL COMPOSITION OF MSW IN MCC

After conducting a survey of 100 households, six families were chosen to represent various household types in MCC for the purpose of analyzing the physical composition of the MSW (Municipal Solid Waste) generated by these families. In total, these six families collectively generated 8.35 kilograms of waste. Notably, a significant portion of the solid waste primarily originates from food and vegetables, accounting for an average of approximately 70.94%. Plastics contribute to waste generation at a rate of about 5.49% and the overall moisture content for MSW in MCC was calculated to be 45.239%. Table 4 shows the composition of Municipal Solid Waste (MSW) in terms of various categories and the percentage of each category for different families (Family 1 to Family 6).

2.7 CHEMICAL COMPOSITION (DRY) OF MSW AT MCC

Understanding the chemical makeup of MSW is crucial for implementing effective waste management strategies. The chemical composition analysis of MSW was conducted at the Bangladesh Council of Scientific and Industrial Research (BCSIR) through five repetitions to ensure accuracy. The analysis revealed the elemental composition, including carbon (C), hydrogen (H), nitrogen (N), sulfur (S), and oxygen (O) contents.The research will utilize these average values for subsequent analysis. The figure indicates that the mean oxygen content in MSW within MCC stands at 18.69%, while the carbon content averages 69.90%, surpassing all other elements found in MSW. The analysis report from BCSIR shows in Table 5.

2.8 CALORIFIC VALUE AND POTENTIAL POWER GENERATION FROM MSW

The data obtained from 100 households during the survey will be used to calculate the calorific value of MSW, and probable electrical energy that can be generated from it. Firstly, the calorific value of MSW will be calculated using modified Dulong's formula (S.Peavy R. , 2020). Secondly, elemental analysis of MSW will be carried out at the Bangladesh Council of Scientific and Industrial Research (BCSIR). A CHNSO elemental analyzer (model no.: Vario Micro Cube, Elementary) will be used to determine elemental weight percentages of MSW. Figure 3 displays the setup of the experimental apparatus. It is estimated that 70% of total heat energy can be converted into steam energy [19]. Then, from steam energy, net output electrical power can be calculated (P. Halder, 2014). Table 6 shows the net electrical power from MSW in MCC.

2.9 POTENTIAL TREATMENT OF CONVERSION TECHNOLOGIES

WTE technologies can be categorized based on their operation modes, namely thermochemical and biochemical technologies, (World Energy Council, 2013).

2.9.1 THERMOCHEMICAL TECHNOLOGIES

INCINERATION

Incineration is a waste treatment method that involves the combustion of organic substances in waste materials. It is commonly used to dispose of municipal solid waste (MSW), hazardous waste, and industrial waste. The process involves burning the waste at high temperatures, typically in the presence of excess air.

GASIFICATION

Gasification is a thermochemical process that converts carbon-containing materials into syngas (synthesis gas) by reacting them with a controlled amount of oxygen or steam at high temperatures. This versatile process is applied to various feedstocks, including biomass, municipal solid waste, and coal.

PYROLYSIS

Pyrolysis is a thermal decomposition process in the absence of oxygen, leading to the conversion of organic materials into bio-oil, biochar, and gases. This process is utilized for the treatment of biomass, plastic waste, and organic materials.

2.9.2 BIOCHEMICAL TECHNOLOGIES

ANAEROBIC DIGESTION

Anaerobic digestion is a biological process that decomposes organic matter in the absence of oxygen, facilitated by a consortium of microorganisms. This process is commonly employed for the treatment of organic waste, such as agricultural residues, food waste, and wastewater sludge.

2.10 PROPOSED WTE CONVERSION TECHNOLOGY

Among the various treatment processes mentioned in the preceding section, each method presents its own set of technological challenges. Incineration is very common in WTE plants in Asia (Yuan, Xiao, & Li, 2008) . However, the main issues with incineration are ensuring proper treatment of the exhaust gases and finding effective ways to capture and store carbon dioxide. Although, pyrolysis is one of the most common methods for WTE conversion, the major disadvantage is the requirement of a very small particle size for fluidizer bed reactors (Das, Islam, & Huda, 2019) . Tar removal technology is one of the main technological challenges of the gasification process (Purnomo, Kurniawan, & M., 2021). The pretreatment process is very costly in the gasification process (Rana, 2016).

The majority (70.94%) of the overall waste consists of biodegradable items, specifically food and vegetables. Consequently, employing anaerobic digestion (AD) emerges as a compelling method for energy recovery to generate electricity. However, it is worth noting that the upgrade of biogas in the context of AD poses significant challenges. The implementation of this approach not only aids in diminishing landfill waste but also addresses the substantial electricity demand in MCC. Another advantage of anaerobic digestion is that it produces both biogas (CH4 and CO2) and digestate (innocuous liquid and solid residues) at the same time (Melville, Weger, Wiesgickl, & Franke, 2014). Utilizing biogas for power generation is a viable option, and the resulting digested can undergo further modification to create compost for land use. This approach carries a lower environmental footprint since the byproducts of the process are transformed into compost. A visual representation of the waste management process proposed for MCC is depicted in the accompanying Figure 5.

Wastes that are neither recyclable nor biodegradable are recommended for either incineration or landfill disposal.

Table 8 shows the energy recovery potential from anaerobic digestion. It has been observed that about 22050 m3 of biogas can be generated per day from MSW in MCC, which can be used for power generation, as well as other uses, such as cooking. In addition, about 37 tons of compost fertilizer can be produced per day from MSW. Considering that the price of compost fertilizer is BDT 10/kg, about BDT 0.37 million can be saved with the produced compost.

2.11 TECHNO-ECONOMIC ANALYSIS OF THE PROPOSED AD PLANT

In conducting a techno-economic analysis of the AD plant, certain assumptions have been incorporated. It is assumed that the construction period will span a duration of 3 years (Habib, 2021). The typical lifespan of AD technology ranges between 25 and 30 years (Hadidi & Omer, 2017) ((IRENA), 2012). In this instance, the plant is assumed to have a lifespan of 20 years. The total number of operating days is set at 365 days, and the operating hours are assumed to be 7,446 hours. A summary of the analysis is outlined in Table 9. The analysis reveals that the AD plant has a payback period of 4.6 years.

3 ILLUSTRATIONS

3.1 FIGURES AND GRAPHS

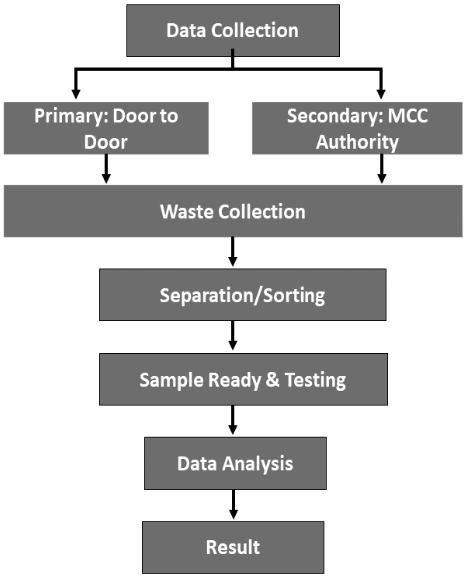

Figure 1: Flowchart of research methodology

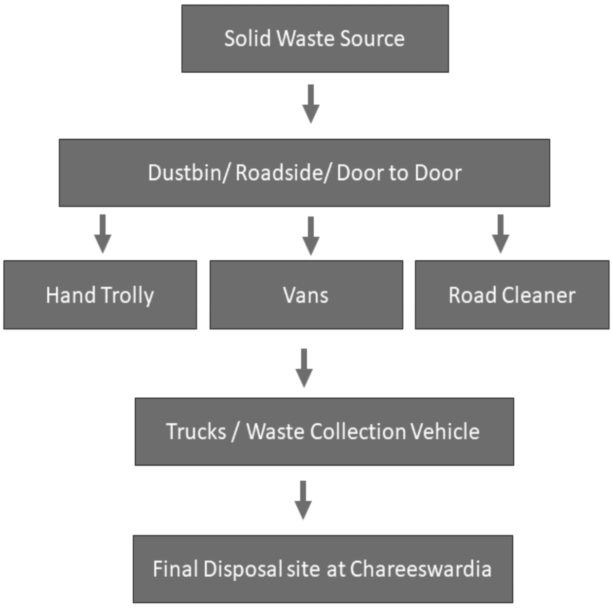

Figure 2: The present scenario of MSW management of MCC

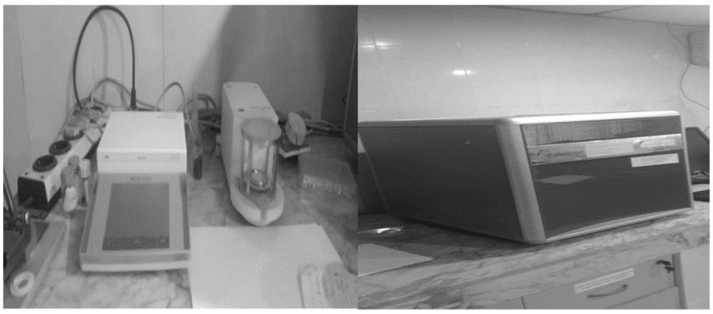

Figure 3: Experimental apparatus for elemental analysis of MSW (Vario Micro Cube Elementary)

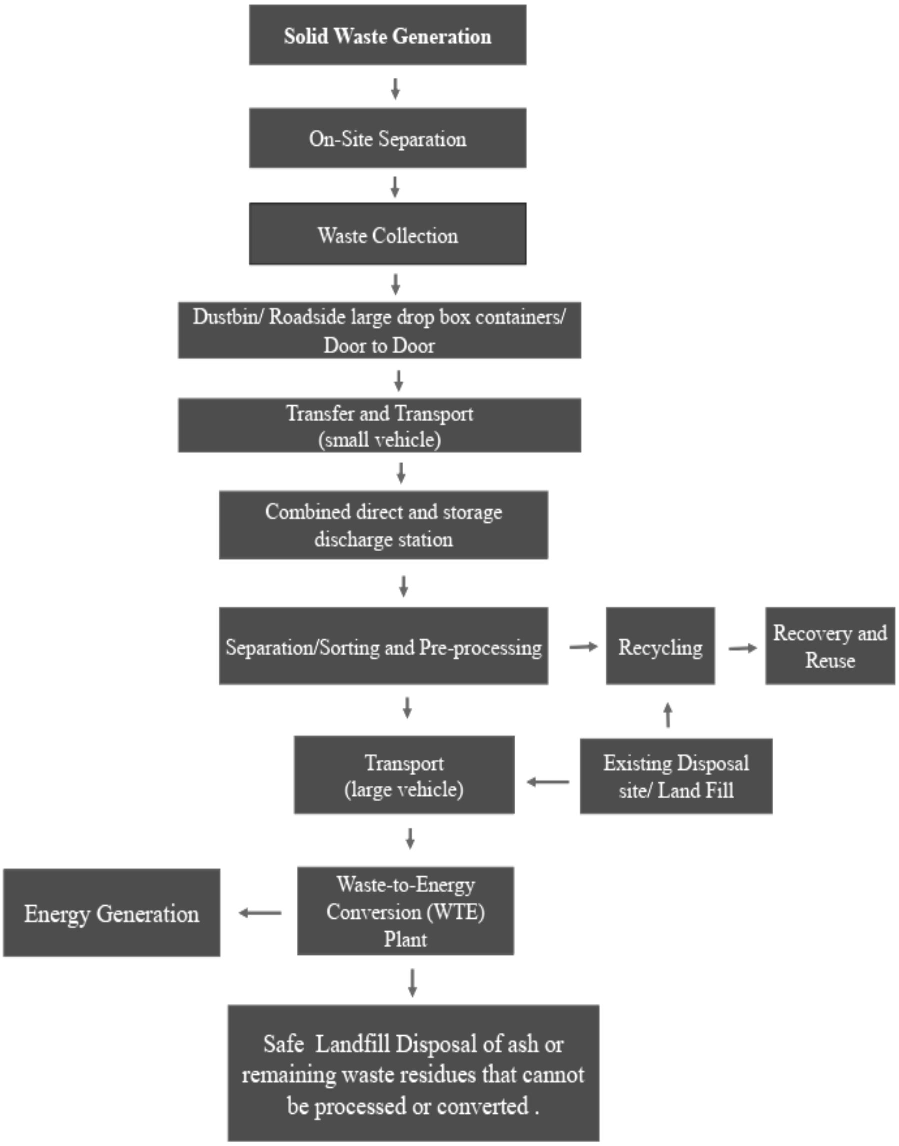

Figure 4: The several sequential stages of municipal solid waste managemant and treatment.

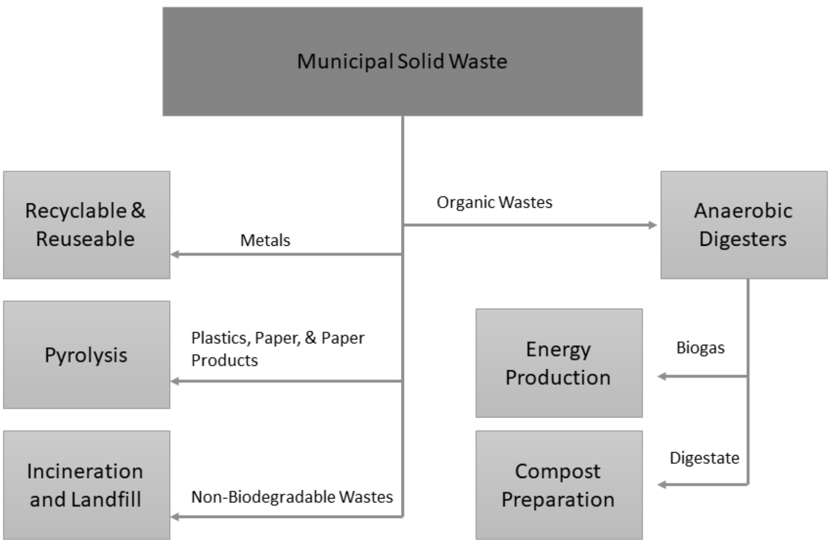

Figure 5: A schematic of the proposed waste management process in MCC

3.2 EQUATIONS

3.2.1 DETERMINATION OF CALORIFIC VALUE AND POTENTIAL ELECTRICAL ENERGY

Modified Dulong's formula **(S.Peavy R. , 2020)**,

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

where, C, H, O and S are the carbon, hydrogen, oxygen and sulfur contents (weight %), respectively, in the collected MSW.

Heating Value(MJ/Kg) = 337*69.9 + 1428(10.6 – 18.69/8) + 9*0.01 = 35.3 MJ/Kg.

3.2.2 COST ANALYSIS OF COMPOST FERTILIZER

Consider, compost fertilizer price is 10tk/kg.

Total price = 37*1000*10 = 0.37 million tk/day .

Urea price in Bangladesh = 22tk/kg in August 2022

Equivalent Urea price = 37*1000*22 = 0.82 million tk.

Compost fertilizer price is almost 30% of equivalent Urea price.

3.3 TABLES

Table 1: the manpower for solid waste management in MCC

Serial no.	Designation	No. of person
1	Permanent officer and staff	06
2	Master role staff	195
3	Total cleaner	636

Table 2: Data on waste collection from various residences in Mymensingh City (O = Owned, R = Rented, PE = Primary Education, JE = Junior Education, SE = Secondary Education, HE = Higher Secondary Education, BD = Bachelor's Degree, MD = Master's Degree, N/A= Never went to school, SP = Semi-Pucca/Semi-Concrete, P = Pucca/Concrete),

Ward No.	Residence Type	No. Of People	Amount Of waste (kg)	Educational Status of Interviewees	Amount being paid for Waste collection(BDT)	Condition of Residence	Per capita waste
5	Family(O)	4	0.9	JE	50	SP	0.225
5	Family(O)	3	1.3	PE	0	SP	0.433
5	Family(R)	5	1.6	BD	100	P	0.320
5	Family(O)	2	1.1	BD	150	P	0.550
5	Family(O)	4	0.8	HE	50	SP	0.200
5	Family(O)	6	1.2	MD	50	SP	0.200
5	Family(O)	3	1.0	SE	0	SP	0.333
5	Family(R)	7	1.5	BD	100	P	0.214
5	Family(R)	4	1.2	MD	100	P	0.300
5	Family(O)	5	1.4	SE	150	P	0.280
7	Family(R)	6	1.3	BD	100	P	0.216
7	Family(R)	2	1.1	PE	0	SP	0.550
7	Family(R)	4	1.5	HE	100	P	0.375
7	Family(R)	3	1.0	HE	50	P	0.333
7	Family(O)	4	0.9	JE	50	P	0.225
7	Family(R)	5	1.2	BD	100	P	0.240
7	Family(R)	3	1.1	PE	0	SP	0.360

7	Family(O)	4	0.8	BD	50	P	0.200
7	Family(R)	7	1.6	HE	100	P	0.228
7	Family(R)	6	1.4	SE	150	P	0.233
26	Family(O)	5	1.3	BD	100	P	0.260
26	Family(R)	7	1.5	HE	150	P	0.214
26	Family(R)	3	0.9	PE	0	SP	0.300
26	Family(R)	4	1.2	BD	50	P	0.300
26	Family(O)	6	1.1	BD	100	P	0.183
26	Family(R)	4	1.3	HE	50	SP	0.325
26	Family(O)	5	1.0	SE	100	P	0.200
26	Family(R)	7	1.4	HE	150	P	0.200
26	Family(R)	6	1.6	BD	100	P	0.266
26	Family(R)	3	1.2	BD	50	SP	0.400
16	Family(O)	4	0.9	JE	50	SP	0.225
16	Family(O)	3	1.3	PE	0	SP	0.433
16	Family(R)	5	1.6	JE	100	P	0.320
16	Family(O)	2	1.1	BD	50	P	0.5500
16	Family(O)	4	0.8	SE	50	SP	0.200
16	Family(O)	6	1.2	HE	50	SP	0.200
6	Family(R)	6	1.8	HE	100	P	0.300
6	Family(O)	4	2.1	PE	0	SP	0.525
6	Family(O)	5	1.5	HE	100	SP	0.300
6	Family(R)	4	1.2	BD	50	P	0.300
6	Family(O)	6	2.0	SE	100	SP	0.333
6	Family(O)	4	1.45	HE	0	SP	0.362
1	Family(R)	5	1.7	PE	0	SP	0.340
1	Family(O)	6	2.2	HE	100	P	0.366
1	Family(O)	4	1.1	JE	50	SP	0.275
27	Family(R)	4	1.3	BD	50	P	0.325
27	Family(R)	6	2.3	HE	50	SP	0.383
27	Family(O)	5	1.6	SE	100	P	0.320
27	Family(R)	2	1.1	N / A	0	SP	0.550
27	Family(O)	4	0.8	HE	100	P	0.200
27	Family(R)	6	2.2	JE	50	SP	0.366
20	Family(O)	3	1.0	BD	50	SP	0.333
20	Family(R)	7	2.5	HE	150	P	0.357
20	Family(O)	4	1.2	PE	0	SP	0.300
20	Family(R)	5	1.7	JE	50	SP	0.340
20	Family(O)	6	1.7	MD	100	P	0.283
20	Family(O)	2	1.1	HE	50	SP	0.550
20	Family(O)	4	1.5	SE	100	P	0.375
20	Family(O)	3	1.0	MD	50	P	0.333
20	Family(R)	4	0.9	SE	0	SP	0.225
3	Family(O)	5	1.2	MD	100	P	0.240
3	Family(O)	3	1.2	JE	50	SP	0.400
3	Family(R)	2	1.1	HE	50	P	0.550
3	Family(O)	4	1.6	SE	50	SP	0.400
3	Family(R)	3	0.9	BD	50	SP	0.300
3	Family(O)	4	1.2	BD	50	P	0.300
13	Family(O)	6	2.1	JE	50	SP	0.350
13	Family(O)	4	1.3	MD	50	P	0.325
13	Family(R)	5	2.0	SE	100	SP	0.400
13	Family(O)	7	2.8	MD	150	P	0.400
13	Family(O)	6	2.6	PE	0	SP	0.433
13	Family(O)	3	1.2	BD	50	P	0.400
10	Family(R)	4	0.9	N / A	100	SP	0.225
10	Family(O)	3	1.3	BD	50	P	0.433
10	Family(R)	5	1.9	JE	50	SP	0.380
10	Family(O)	2	1.1	HE	50	P	0.550
10	Family(O)	3	0.9	MD	100	SP	0.300
10	Family(R)	4	1.2	MD	100	P	0.300
10	Family(O)	6	1.7	JE	0	SP	0.283
4	Family(R)	4	1.3	BD	100	P	0.325
4	Family(O)	8	3.0	N / A	50	SP	0.375
4	Family(R)	5	1.9	MD	150	P	0.380
4	Family(R)	3	1.5	HE	50	SP	0.500
4	Family(O)	4	1.6	BD	100	P	0.400
4	Family(O)	6	2.1	JE	0	SP	0.350
14	Large Family(O)	12	6.5	MD	150	P	0.541
14	Large Family(O)	10	5.5	N / A	50	SP	0.550
14	Large Family(R)	14	8.0	HE	150	P	0.571

14	Large Family(O)	12	7.2	HE	150	P	0.600
14	Large Family(O)	15	9.5	SE	100	SP	0.6333
14	Large Family(R)	23	14.5	HE	150	P	0.630
14	Large Family(O)	18	13.0	SE	150	P	0.722
30	Large Family(O)	110	31	BD	0	P	0.281
30	Large Family(R)	12	9.0	HE	150	P	0.750
30	Large Family(O)	16	13.5	PE	0	SP	0.843
30	Large Family(O)	20	18.5	HE	150	P	0.925
30	Large Family(R)	15	12.0	SE	100	SP	0.800
05	Large Family(O)	12	8.5	JE	150	P	0.708
05	Large Family(R)	10	8.0	HE	100	SP	0.800
05	Large Family(O)	15	13.5	SE	150	P	0.900
	Total	693	298.05				38.50

Table 3: Total waste generation per day

No. Households	**No. of People**	**Waste Generated, kg**	**The avg.Waste Generated, kg/person/day**	**Total Population of MCC, million**	**Total Waste Generation,tons/day**
100	693	298.05	0.430	0.480	206.44

Table 4: physical composition of MSW collected from six different families

MSW Composition	**Family 1**	**Family 2**	**Family 3 %**	**Family 4**	**Family 5**	**Family 6**	**Average MSW Composition (%)**
Vegetables and food	70.46	70.2	77.5	69.5	62.4	75.6	70.94
Paper and paper products	7.34	6.2	4.6	6.5	5.5	5.8	5.99
Polyethylene/Plastics	4.9	5.6	4.55	5.9	7.4	4.6	5.49
Textiles and wood	4.4	4.4	3.8	5.2	5.2	3.9	4.48
Leather and rubber	1.2	1.5	0.9	0.65	1.8	0.8	1.15
Metals	3.9	3.9	3.7	4.9	6.4	5.5	4.72
Glass and ceramics	0.3	0.4	0.45	2.5	1.5	0.56	0.95
Dust, ash and mud products	7.5	7.8	4.5	4.85	9.8	3.24	6.29
Total							100

Table 5: The analysis report from BCSIR

Lab ID	**Particular of supplied Sample**	**Parameters**	**Results**	**Test Method**
A-247	Waste (Elemental Analysis)	Nitrogen (N)	0.81%	Elemental Analyzer
		Carbon (C)	69.9%	Elemental Analyzer
		Hydrogen (H)	10.6%	Elemental Analyzer
		Sulphur (S)	0.01%	Elemental Analyzer
		Oxygen(O)	18.69%	Elemental Analyzer

Table 6: Determination of net electrical power from MSW in MCC

Heat Energy (MJ/kg)	**Steam Energy (MJ/kg)**	**Electrical Power, EP (kWh/kg)**	**Station Service Allowance, SA (kWh/kg)**	**Net electrical Power ENP (kWh/kg)**	**Moisture Content , %**	**The Amount of Dry Waste , kg/hr**	**Total Electrical Power, MW**	**Electrical Energy Generated in MCC, MWhr**
35.3	24.71	2.168	0.130	2.038	45.239	4710.33	9.59	230.16

Table 7 Potential treatment of MSW

Treatment Technique	Category of Solid Waste	Percentage of Total Waste
Composting/anaerobic digestion/incineration	Vegetable and food wastes	70.94%
Landfilling	Dust, ash, mud, brick, concrete, stone, glass, ceramic, etc.	7.24%
Pyrolysis/gasification	Paper, paper product, polyethylene, wood, rubber, etc.	11.48-17.10%
Recycling	Metals	4.72%

Table 8 Energy recovery potential from Anaerobic Digestion(AD).

Total MSW Generation	**206.44 tons/day**
Food and Vegetables	147 tons/day (70.94%)
Total Biogas Generation *	22050 m3
Compost Fertilizer **	37 tons/day

* From 1 ton of MSW, 150 m3 biogas can be produced by anaerobic digestion (Rana, 2016). ** 250 tons of compost fertilizer can be produced from 1000 tons of MSW by anaerobic digestion (Rana, 2016).

Table 9 Techno-economic analysis of anaerobic digestion technology

Input Parameters	Values
Beginning design year	2023
Construction duration	3 years
Year of the beginning of operation	2026
Lifetime	20 years
Year of the end of operation	2046
Electricity generation from 1 ton of organic waste ((IRENA), 2012) (Hadidi & Omer, 2017)	0.992 MWh
Operating days in a year	365days
Operating hours in a year (Hadidi & Omer, 2017)	7446hr
Waste capacity per year	(147*365) or 53655 tons
Plant capacity factor ((IRENA), 2012) (Hadidi & Omer, 2017)	85%
Facility annual throughput per year	45607 tons
Electricity generation efficiency (Hadidi & Omer, 2017) ((IRENA), 2014,2015)	36%
Electricity production per year	(45607*0.992*36%) or 16287MWh
Plant capacity	(16287/7446) or 2.18MW
Capital expenditure per MW (Hadidi & Omer, 2017) ((IRENA), 2014,2015)	USD 4,339,000 or BDT 478 million
Capital expenditure (CAPEX)	(478*2.18) or BDT 1045.55 million
Fixed operating cost (% of CAPEX/year) (Hadidi & Omer, 2017) ((IRENA), 2014,2015)	3%
Fixed operating cost	(1045.55*3%) or BDT 31.36 million
Variable operating cost (USD 4.4*MWh) (Hadidi & Omer, 2017) ((IRENA), 2012)	(4.4*16287) or USD 71,662.8 or BDT 7.9 million
Revenue from compost per day	BDT 0.37 million
Revenue from compost per year	BDT 135.05 million
Cost of electricity (assumed)	BDT 8 per KWh (generally varies in between BDT 6.8 to 10.24)
Annual revenue from electricity	(8*16287*1000) or BDT 130 million
Annual net cash inflow	(130 + 135.05 – 31.36 – 7.9) or BDT 226 million
Payback period (CAPEX/annual net cash inflow)	(1045.55/226) or 4.6 years

4. CONCLUSIONS

This comprehensive study thoroughly examines municipal solid waste (MSW) management within Mymensingh City Corporation (MCC), revealing intricate challenges while proposing sustainable solutions. Waste-to-Energy (WTE) technologies are highlighted for their potential in addressing waste disposal issues and meeting energy demands. The study unveils an estimated electrical energy potential of 230.16 MWh, considering MCC's daily waste generation of 206.44 tons, notably including 147 tons of food and vegetable waste capable of producing 22050 cubic meters of biogas and 37 tons of compost daily. Through anaerobic digestion technology, an annual electricity production of 16287 MWh is projected from a 2.18 MW plant capacity.
Implementation success pivots on balanced considerations of technological feasibility, environmental impact, economic viability, and community engagement. The study highlights a handsome revenue: BDT 0.37 million daily and BDT 135.05 million annually from compost sales, with an additional BDT 130 million yearly revenue from electricity generation and annually fixed operating cost BDT 31.36 million. Impressively, the anticipated payback period for this substantial project is a relatively short 4.6 years, affirming its viability.
The entirety of this emphasizes the need for a strategic approach, advocating for well-defined regulations in managing waste, improved collection methods, innovative technologies to address it, and raising awareness about its significance. It highlights a collective effort involving government, businesses, and citizens to move beyond mere waste management, aiming for a more environmentally friendly and energy-rich future for areas similar to Mymensingh City Corporation (MCC).

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REFERENCES

Yuan, K., Xiao, H., & Li, X. (2008). Development and application of municipal solid waste incineration in China. *Nengyuan Gongcheng, 5*, 43-46.

M. M. Mian, A. K. (n.d.). (2010) Solid Waste Management Practice in Mymensingh Municipal Area,. *J. Environ. Sci. & Natural Resources*.

International Renewable Energy Agency (IRENA). Biomass for Power Generation. (2012).Availableonline:https://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis_BIOMASS

Council, W. E. (2013).

Halder, P., Paul, N., Hoque, M., Hoque, A., Parvez, M., Rahman, M., & Ali, M. (2014). Municipal Solid Waste and its Management in Rajshahi City, Bangladesh: A Source of Energy. *Int. J. Renew. Energy Res., 4*(1).

Melville, L., Weger, A., Wiesgickl, S., & Franke, M. (2014). *Anaerobic Digestion.* Hoboken, NJ, USA: John.

International Renewable Energy Agency (IRENA). Biomass for Power Generation. 2014,2015.

Rana, M. (2016). *Feasibility of Study Waste to Energy and Power Generation of Dhaka city.* dhaka: University of Dhaka.

Hadidi, L., & Omer, M. (2017). A financial feasibility model of gasification and anaerobic digestion waste-to-energy (WTE) plants in Saudi Arabia. *Waste Manag., 59*, 90–101.

Khan et al., (2018)

Das, P., Islam, M., & Huda. (2019). N. Feasibility analysis of municipal solid waste (MSW) for energy production in Rajshahi City Corporation. *AIP Conf. Proc.* Rajshahi.

S.Peavy, R. (2020). *A Textbook of Environmental Engireening.* Singapore: McGraw-Hill Book Company.

Habib, M. A. (2021). "Municipal Solid Waste Management and Waste-to-Energy Potential from Rajshahi City Corporation in Bangladesh". *MDPI*.

Purnomo, C., Kurniawan, W., & M., A. (2021). *Technological review on thermochemical conversion of COVID-19-related medical wastes.*

corporation, m. c. (2023).