A STUDY ON DETERMINING THE POTENTIAL SIZE OF A WASTE TO ENERGY PLANT IN CHATTOGRAM.

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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Certification

This is to certify that this project and thesis entitled "**title**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on   January 2021.

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Dedicated to

My Parents

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LIST OF ABBREVIATIONS

EEE	Electrical and Electronic Engineering
MSW	Municipal Solid Waste
CCC	Chattogram City Corporation
WTE	Waste to Energy
RDF	Refuse Derived Fuel
BAT	Best Available Technique
IBA	Incineration Bottom Ash
HV	Heat Value
DW	Dry Weight

LIST OF SYMBOLS

MJ	Mega Jules
KJ	Kilo Jules
NOx	Nitrogen Oxide
SO2	Sulphur dioxide
HCL	Hydrochloric acid

ACKNOWLEDGEMENT

First of all, I give thanks to Allah. Then I would like to take this opportunity to express my appreciation and gratitude to my thesis supervisor **Professor Dr. Md. Shahid Ullah , Head** of **Department of EEE** and co-supervisor **Engr. Mr. Md. Mahbub-Ud-Jaman**, Lecturer of Department of EEE for being dedicated in supporting, motivating and guiding us through this thesis. This thesis can't be done without their useful advice and helps. Also thank you very much for giving me opportunity to choose this topic.

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To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this University.

ABSTRACT

Municipal solid waste is a fast growing and a serious threat to the world as it is producing methane (CH_4) gas that is 34 times stronger than carbon dioxide (CH_2). The growing amount of waste around the world polluting ocean, soil, air and water continuously. Moreover, mounting waste dumping sites are taking more of the land's day by day. However, the world has come up with the solution by turning trash into energy using waste to energy power plants.

The goal of this study is to determine the potential size of waste to energy plant in Chattogram which is the second largest city of Bangladesh with 28 million people of whom 5 million people live in the metropolitan area. An extensive research and analysis were done on metropolitan waste to determine the calorific value of the waste thus, the potential size of waste to energy plant in Chattogram.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The crazed race of human kind towards modern life around the world generates enormous amount of municipal solid waste (MSW), because the generation rate is rising even faster than the rate of urbanization. Global MSW generation showed a remarkable increase just only within 10 years from 0.68 billion tons per year in 2000 to 1.3 billion tons per year in 2010. Moreover, it is projected to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050. This humongous waste load of urbanized society if not managed properly will certainly have a seriously negative impact on sustainable life style, environment, and human health. Severe MSW management problems are reported in a number of cities of different countries like China, India, Malaysia, Thailand, and Bangladesh because of rapid population growth, fast industrialization, and urbanization. [1]

Tremendous amount of MSW generation because of fast growing population and ongoing economic development and poor waste management is already blamed for environment pollution in Bangladesh. Chattogram, the second largest and the port city of Bangladesh has 28 million people of whom 5 million people living in the Chattogram city corporation area (CCC). The city produces about 2289 tons of MSW per day. [2] In this circumstance, a sustainable MSW management is highly required. WTE plant is one of the promising waste management solution in the present world.

Waste treatment process generating energy in the form of electricity, heat, or transport fuels is considered as waste to energy (WTE) option. Each year 2.3 billion tons of MSW will begeneratedby2025, and this is equivalent to2.58×1023 MJ of energy. So WTE is a very promising alternative energy option for the future because with this amount of energy 10% of global annual electricity need can be satisfied. [1]

1.2 Objectives

Objectives of this thesis are –

1. To determine the calorific value of municipal solid waste,
2. To determine the size of potential WTE plant.

1.3 Limitations

The study aims to determine the calorific value of municipal waste and the size of potential WTE plant if installed in Chattogram. The study also includes technology options for WTE plant.

It does not include broad details about the technology considered for this study but a brief detail and no details about connecting the plant to the electricity grid, environment effects.

1.4 Methodology

The first part of this study was to collect the data of MSW produced in Chattogram which was collected from a conference report on Solid Waste management. Later, the calorific value of the municipal solid waste was determined and a suitable technology was selected for this study. Lastly, the size of the WTE facility has been determined.

1.5 Thesis Outline

This thesis is organized as follows:

Chapter 1: Introduces the background, objective, limitations and methodology of this thesis.

Chapter 2: A global overview and overview of Chattogram MSW resources are given.

Chapter 3: Calorific value of MSW is determined.

Chapter 4: Technology options are discussed and size of the potential WTE plant is determined.

Chapter 5: The results of the thesis is discussed.

Chapter 6: A conclusion is given.

CHAPTER 2

MUNICIPAL SOLID-WASTE RESOURCES

2.1 Introduction

The world produces billions of wastes every year, some are collected and recycled but most of the wastes are not well managed and goes to landfills or ocean. In this chapter an overall scenario of the waste is discussed. This chapter also presents global data and report of Chattogram MSW.

2.2 Global scenario of MSW

Waste generation around the world is a natural product of population growth, urbanization and economic development. Cities around the world produces a huge amount of municipal solid waste every day and the rate is growing rapidly. A world bank study estimated, global waste generation was 2.01 billion tons in 2016. [3]

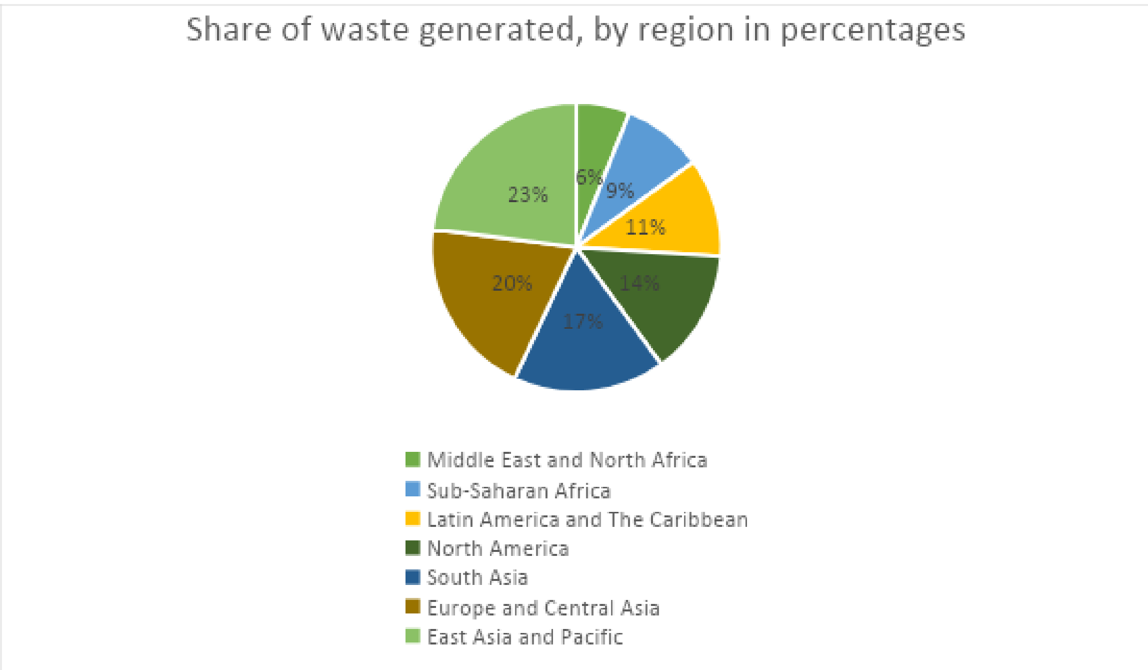


Fig 01: Share of waste generated by region in percentages.

Countries in East Asia and Pacific have the highest percentages of waste production by 23%. On the other hand, Middle East, North Africa and Sub-Saharan Africa produce the least amount of waste, together accounting for 15% of world waste.

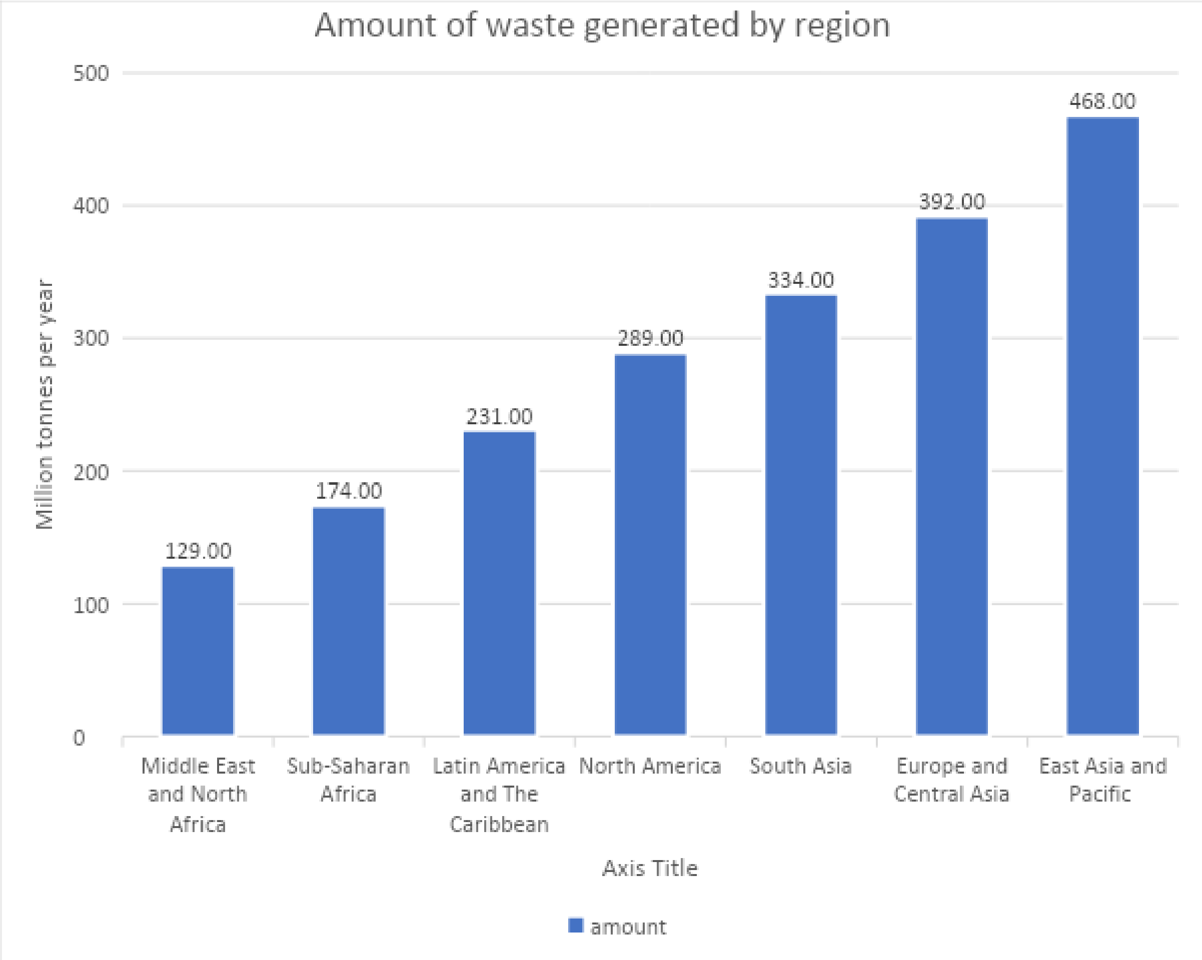
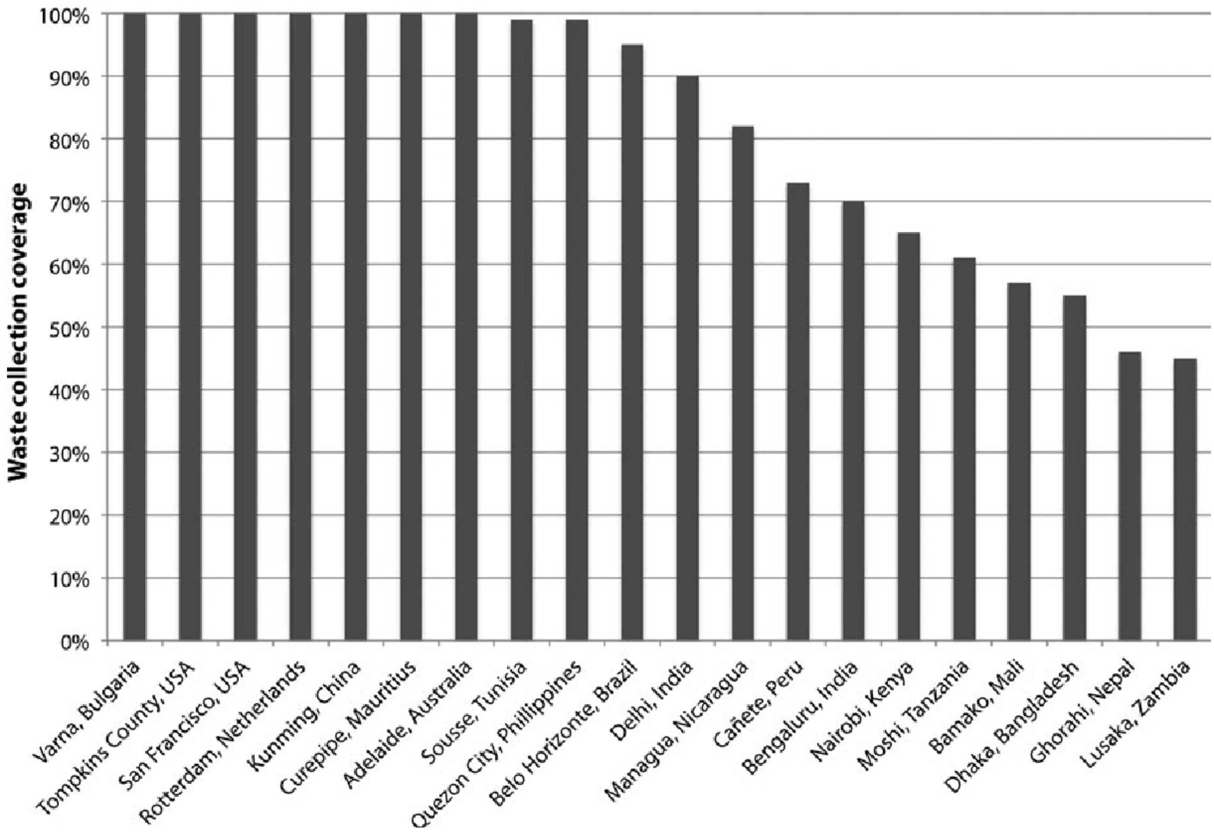


Fig 02: Amount of waste generated by region per year

East Asia and Pacific generate highest amount of waste, an estimated 468 million tons in 2016. On the contrary, countries in Middle East and North Africa produced 129 million tons of waste in 2016. Bermuda, Canada and United states produce the highest average amount of waste per capita, at 2.21 kg per day. Overall, the estimated global average for 2016 was 0.74 kilogram of waste per capita per day and total generation of solid waste was about 2.01 billion tons. [3]

The way of collecting waste play a critical role in waste management. However, the scenarios of waste collection coverage are different around the world. Economically developed



countries like USA, China, Australia have higher percentages of waste collection coverage (100%), whereas countries like Bangladesh, Nepal, Zambia have only around 55%-45% waste collection coverage.

Fig 03: Municipal solid waste collection rates for selected global cities. [4]

2.3 Overview of MSW of Chattogram city corporation

Chattogram, the second largest and the port city of Bangladesh. 28 million people live in Chattogram among them 5 million people live the city corporation area. The city produces 2289 tons waste per day though around 55% are collected properly. The amount of collected waste is around 1250 tons per day.

Table 01: Physical compositions of Solid Waste.

Location Name		Organic Matter (%)	Paper (%)	Plastic (%)	Textile & Wood (%)	Leather & Rubber (%)	Metal (%)	Glass (%)	Others (%)
Residential	East Bakalia	65.0	5.0	20.0	1.0	2.0	2.0	2.0	3.0
	Dewan Bazar	80.0	2.0	7.0	2.0	2.0	0.0	1.0	6.0
	Jamal Khan	80.0	5.0	10.0	2.5	1.0	0.0	0.5	1.0
	Agrabad Hajipara	50.0	7.0	30.0	5.0	4.0	1.0	2.0	1.0
	PC Road Rampur	74.0	10.0	7.0	3.0	2.0	0.1	1.0	3.0
	CDA-23 No	82.0	4.0	7.0	3.0	2.0	0.8	0.2	1.1
	Hathazari	85.1	4.1	2.7	1.7	0.6	0.7	1.7	3.4
	Bayezid	90.6	1.3	2.6	1.3	0.8	0.5	0.3	2.6
	Chandgong	92.2	2.0	1.6	1.0	1.0	0.7	0.4	1.0
	Average	77.7	4.5	9.8	2.3	1.7	0.6	1.0	2.5
Commercial	Enayet Bazar	75.0	12.0	8.0	2.0	1.5	0.1	0.5	1.0
	South Halsahar	82.0	4.0	7.0	3.0	2.0	0.8	0.2	1.1
	North Potenga	74.0	10.0	7.0	3.0	2.0	0.1	1.0	3.0
	Average	77.0	8.7	7.3	2.7	1.8	0.3	0.5	1.7
Industrial	Halishahar	85.0	3.0	4.0	4.0	1.1	0.7	0.3	2.0
	Madarbari Railgate	45.0	5.0	10.0	18.5	20.0	0.5	0.1	1.0
	Sadarghat	55.0	25.0	5.0	10.0	2.0	0.3	0.1	2.7
	South Potenga	50.0	7.0	30.0	5.0	4.0	1.0	2.0	1.0
	Average	58.8	10.0	12.3	9.4	6.8	0.6	0.6	1.7
Market	Mia Khan Road	83.0	6.0	5.0	1.5	0.5	1.0	1.0	2.0
	Pathantuli	82.0	7.0	3.0	2.5	1.5	1.0	0.6	2.5
	Andarkilla	78.0	12.0	3.5	2.0	1.0	0.4	0.5	2.6
	Average	81.0	8.3	3.8	2.0	1.0	0.8	0.7	2.4
Total average value		73.6	7.9	8.3	4.1	2.8	0.6	0.7	2.0

A study shows that highest portion of the waste collected in Chattogram is organic matter (73.6%), whereas the lowest portion of the waste are metal (.6%) and glass (.7%). Following table and the pie chart shows the physical composition of solid waste in Chattogram. The study also shows that per capita waste generation is between 0.31kg and 0.51kg per day. It is estimated that waste generation in 2051 will exceed 4000 tons per day. [2]

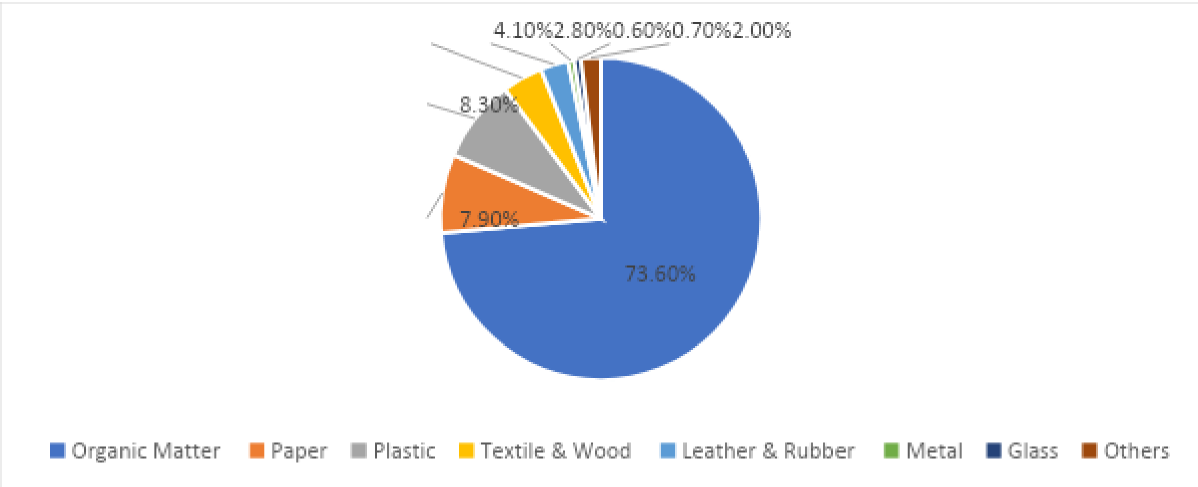


Fig 04: Physical compositions of solid waste.

2.4 Summary

The world has produced 2.01billion tons of waste in 2016 and the production rate is rising every year. East Asia and Pacific combined produces more waste than other places whereas Middle East and North Africa produce the least amount of waste.

In Chattogram, 2289 tons of wastes are produced every day. Only 55% are collected and usually dumped to landfill. The highest portion of waste is organic, that is 73.6%.

CHAPTER-3

CALORIFIC VALUE OF MSW

3.1 Introduction

Calorific value of waste, determined by measuring the heat produced by complete combustion of the waste. It is usually expressed in joules per kilogram.

3.2 Calorific value of MSW

To find the potential electricity generation capacity it is required to determine the calorific value of waste. Firstly, data of physical composition with moisture content required, also the calorific value of different types of waste. Secondly, the dry weight of waste has to be calculated using equation 1. Finally, using the equation 2 the calorific value of solid waste can be calculated.

Table 02: Average physical composition and moisture content of solid waste. [2] [1]

Material	Weight %	Moisture Content %
Organic	73.60	74.86
Plastic	08.30	00.61
Paper	07.90	03.60
Textile and Wood	04.10	07.30

Metal	00.60	00
Glass	00.70	00
Other	04.80	34.18

Table 03: Typical heat value of MSW. [5]

Material	Heat value (KJ/Kg, dry weight)
Organic	4652.02
Plastic	32564.15
Paper	16747.28
Textile and Wood	17445.08
Metal	697.80
Glass	139.56
Other	6978.03

Dry weight, $D = W - \frac{MW}{100}$. (1)

In (2), D is Dry weight, W is Wet weight, M is Moisture content MSW.

Energy content (in KJ/kg) = $\sum_{j} HV_j \times DW_j$. (2)

In (1), HVj is typical heat values of MSW component j and

DWj is dry weight fraction (%) of component j. [1]

Table 04: Dry weight of solid waste. [6]

Material	Wet weight %	Dry weight %
Organic	73.60	18.50
Plastic	08.30	8.25
Paper	07.90	7.61
Textile and Wood	04.10	3.80

Metal	00.60	0.60
Glass	00.70	0.70
Other	04.80	3.16

It is calculated that Energy content (in KJ/kg) of solid waste is 5710.21KJ/Kg i.e. 5.7MJ/Kg. (see appendix-1)

3.3 Summary

Composition of MSW found in Chattogram includes organic, plastic, paper, textile and wood, metal, glass and other materials. Taking all the material's wet weight and moisture content percentages in account dry weight of the materials are calculated, thus it is determined that energy of solid waste is 5.7MJ/Kg.

CHAPTER-4

TECHNOLOGY OPTION FOR WTE PLANT

4.1 INTRODUCTION

There are several technologies available for waste to energy plant. They all fall under three categories (I) thermal conversion (incineration, pyrolysis, gasification, production of energy from refuse derived fuel (RDF),

(ii) biological conversion (anaerobic digestion/bio-methanation and composting), and

(iii) landfilling with gas recovery. In this study incineration technology is considered and discussed. [7]

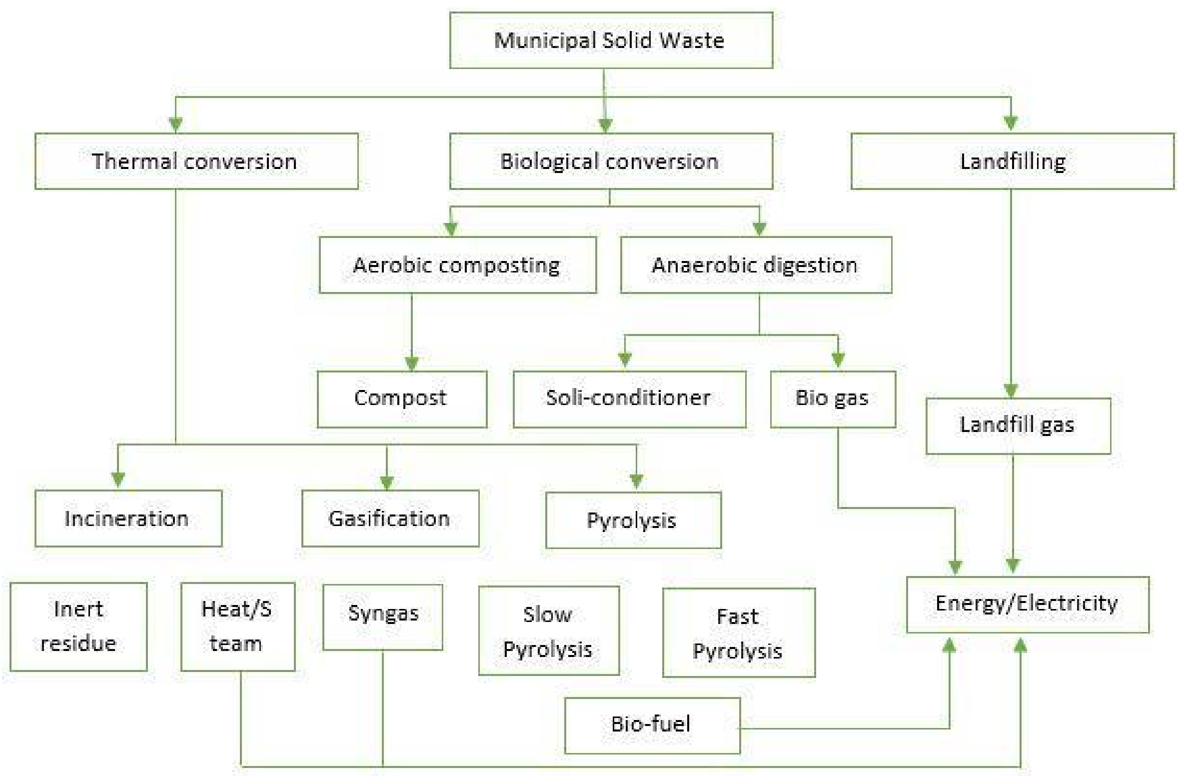


Fig 05: MSW treatment technique and their products.

4.2 Incineration technology

Incineration is a thermal process to recover energy from waste by combustion. There might be different set-ups provided by different technology provider. However, an incinerator will have the following key elements:

- Waste reception and handling,
- Combustion chamber,
- Energy recovery plant,
- Emission clean-up for combustion gasses and
- Bottom ash handling and air pollution control residue handling.

Waste reception and handling:

The main fuel to the waste to energy plant is the municipal solid waste. The wastes generated around the city are collected via waste trucks and tipped into a bunker where it is mixed up. The mixing is required to blend the waste to ensure that the energy input (calorific value of the waste feed) to the combustion chamber is as consistent as possible.

Combustion chamber:

The mixed wastes in the bunker are then fed into the furnace. In the combustion chamber the wastes are burnet under high temperature (980-1090^0 C) conditions with excess oxygen. MSW feed stock is converted into heat, flue gases and particulates, and incinerator bottom ash.

Energy recovery plant:

Here, the produced heat in the combustion chamber is used to generate steam through a boiler. 80% of the heat energy can be retrieved from boiler by producing steam. The steam is then fed into a steam turbine to produce electricity.

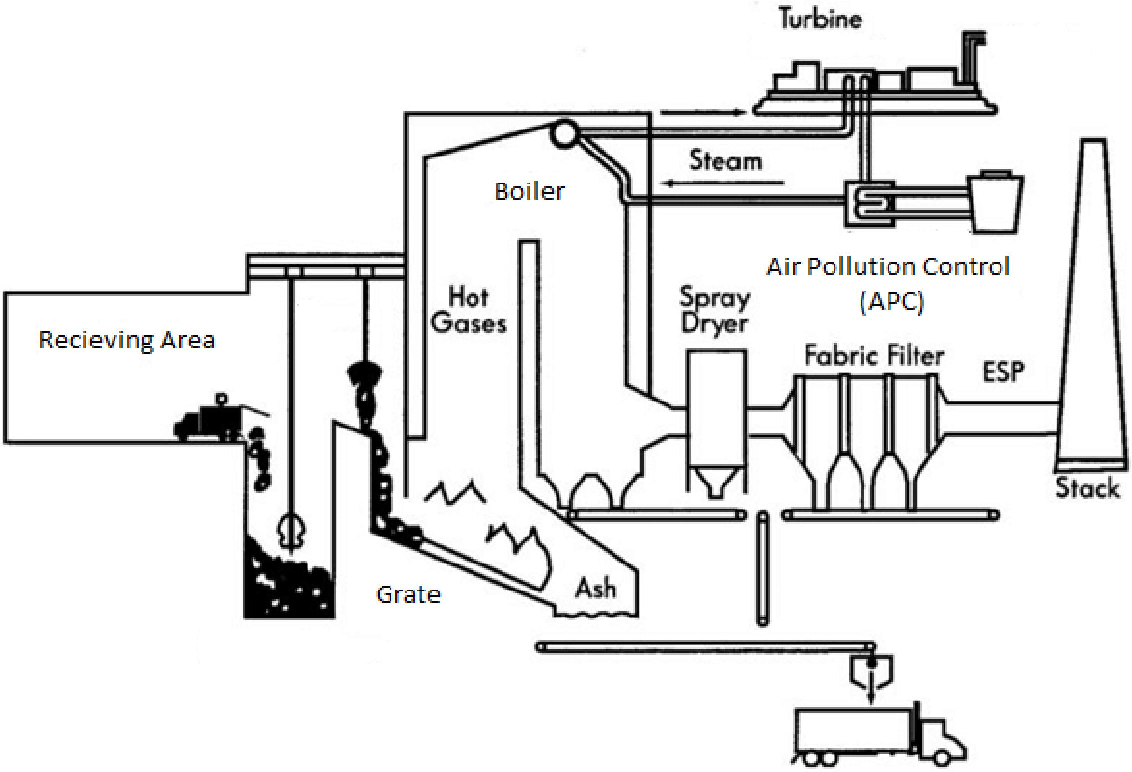


Fig 06: Schematic diagram of WTE Plant.

Emission clean-up for combustion gasses:

The emissions limits for specific pollutants that are present in the combustion products (flue gases) from the incineration of MSW are defined in the IED/WID and applied through the Environmental Permitting Regulations. To meet these emissions limits, the combustion process must be correctly controlled and the flue gases cleaned prior to their final release. The technology supplier for the Incinerator plant will define the exact emissions clean-up processes that will be employed to achieve the required standards and utilizing Best Available Techniques (BAT). A common approach for control of emissions is as follows:

- Ammonia injection into the hot flue gases for control of NOx emissions;
- Lime or Sodium Bicarbonate injection for control of SO2 and HCl emissions;

- Carbon injection for capture of heavy metals; and Filter system for removal of fly ash and other solids (lime or bicarbonate and carbon).

<u>Bottom ash handling:</u>

The main residual material from the incineration of MSW is referred to as 'bottom ash' or 'Incinerator Bottom Ash' (IBA). This is the residual material in the combustion chamber and consists of the non-combustible constituents of the waste feed. The bottom ash typically represents around 20%-30% of the original waste feed by weight, and only about 10% by volume. The bottom ash is continually discharged from the combustion chamber and is then cooled. The amount of ash will depend on the level of waste pre-treatment prior to entering the Incinerator. [8]

4.3 Size of the potential WTE plant.

From 2.3 it was determined that calorific value of mixed municipal solid waste is 5.7MJ/Kg but taking heat recovery efficiency into account it is considered in this study that the calorific value of MSW is 5 MJ/Kg.

The calorific value of waste = 5MJ/Kg

$$= 5 \times 1000 \text{ KJ/Kg}$$

$$= \frac{5000 \times 1000}{60 \times 60} \text{ KWh/Ton}$$

$$= 1388.89 \text{ KWh/Ton}$$

Out of collected 1250 tons of waste only 50% is useable for electricity generation and also considering 20% thermal efficiency, estimation of total Power production is calculated below

$$= \frac{1388.89 \times .2 \times .5 \times 1250}{24} \text{ KW}$$

= 7.23 MW

There may be interruption of solid waste due to flood, cyclone or other problems Chattogram City Corporation (CCC) has to deal with almost every year. For this and many unforeseen reasons collection of solid-waste may be hampered and therefore installation of approximately 7-MW power plant is Possible.

4.4 Summary

There are various different technologies available to transform waste into energy. Considering economic feasibility, availability, complication, environment and other issues Incineration method is selected for this thesis. Takin every factor in account it is possible to build a 7-MW WTE plant in Chattogram.

CHAPTER 5

RESULTS

5.1 Introduction

The results of this thesis are carried out in this chapter. After extensive research and analysis, the calorific value of municipal waste of Chattogram city corporation area is determined, thus the potential size of a Waste to Energy plant in Chattogram is determined considering all the factors.

5.2 Results

It is calculated that the wastes available in Chattogram City will have the calorific value of 5.7MJ/Kg.

Considering the calorific value to be 5MJ/kg and 1250 tones waste available every day of 50% are useable it is determined that a 7-MW WTE plant can be built.

5.3 Summary

Taking every factor in account and with calorific value of 5MJ/Kg a potential size of the WTE plant in Chattogram is possible.

This study can be farther extended to a feasibility study for the Waste to Energy plant if installed in Chattogram.

CHAPTER 6

CONCLUSIONS

6.1 Conclusions

A gradually rising problem in the world is production of tremendous amount of waste and poor management of it. If not managed properly this problem will rise to an extend where it will destroy our beautiful home The Earth. So, it is one of most important concerns to the world to do something effective with these billions of tons of waste. However, in many places a beautiful solution working very effectively, that is WTE plant.

This study determined that a 7-MW WTE plant can be installed in Chattogram city corporation, the second largest city of Bangladesh to solve the waste issue and transform the waste into energy.

6.2 Limitation of the study

- Collecting the waste data directly was not possible,
- Broad technological explanations are not mentioned,
- How the plant will run after being installed is not described.

6.3 Future scopes of the study

- Feasibility study can be done using this thesis,
- Environmental effect of the plant can be analyzed in future,

- How the plant affects social life of Chattogram.

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Appendix A

Table 03: Typical heat value of MSW

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Metal	00.60	0.60
Glass	00.70	0.70
Other	04.80	3.16

Energy content (in KJ/kg) = $\sum_j HV_j \times DW_j$.

$= \sum(4652.02\times18.5\%) + (32564.15\times8.25\%) + (16747.28\times 7.61\%) +$

$$= 5.7MJ/Kg.$$