POTENTIAL OF CONVERSION OF WASTE TO ENERGY IN INDIA

INTERNSHIP PROGRAMME

July 18, 2013 to August 16, 2013

Submitted to

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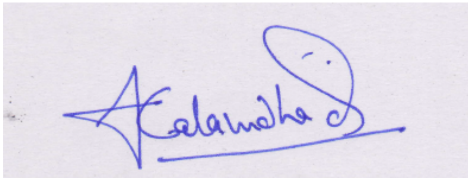
CERTIFICATE

This is to certify that the project entitled "**Potential of Conversion of Waste to Energy in India**" was carried out by "**Aayush, Amit Parashar, Anmol Kabra, Anshumat Srivastava and Vaibhav Agarwal**" of Delhi Public School, under my supervision and guidance.



Dr. Ajay S. Kalamdhad

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Chapter 1

INTRODUCTION

1.1. INTRODUCTION

India is suffering from a huge energy crisis. More than 50% of the rural India does not have access to proper electricity connections. The production of electricity from coal is not sufficient for the country. It is very polluting as more than 24 Lakh tonnes of coal is used for generating electricity emitting about 9 lakh tonnes of carbon.

On the other hand, India has been suffering from the massive waste production and its improper dumping methods. This has also resulted in the widespread epidemic in Surat, in which lakhs of people lost their lives only due to diseases caused by dumping of Municipal Waste in an unplanned and unhygienic way. India is the second largest populated nation and waste generation is directly proportional to population. So, the Municipal Solid Wastes (Management & Handling) Rules, 2000 (MSW Rules) need to be followed by every Municipal Corporation in our country to avoid such disasters.

In Europe and United States of America several firms had started Waste to Energy plants and have been very successful in doing so. The scope for producing energy from waste can only arise when waste is properly segregated, processed and disposed. For this there is a need for Solid Waste Management across the country.

1.2. DEFINITIONS

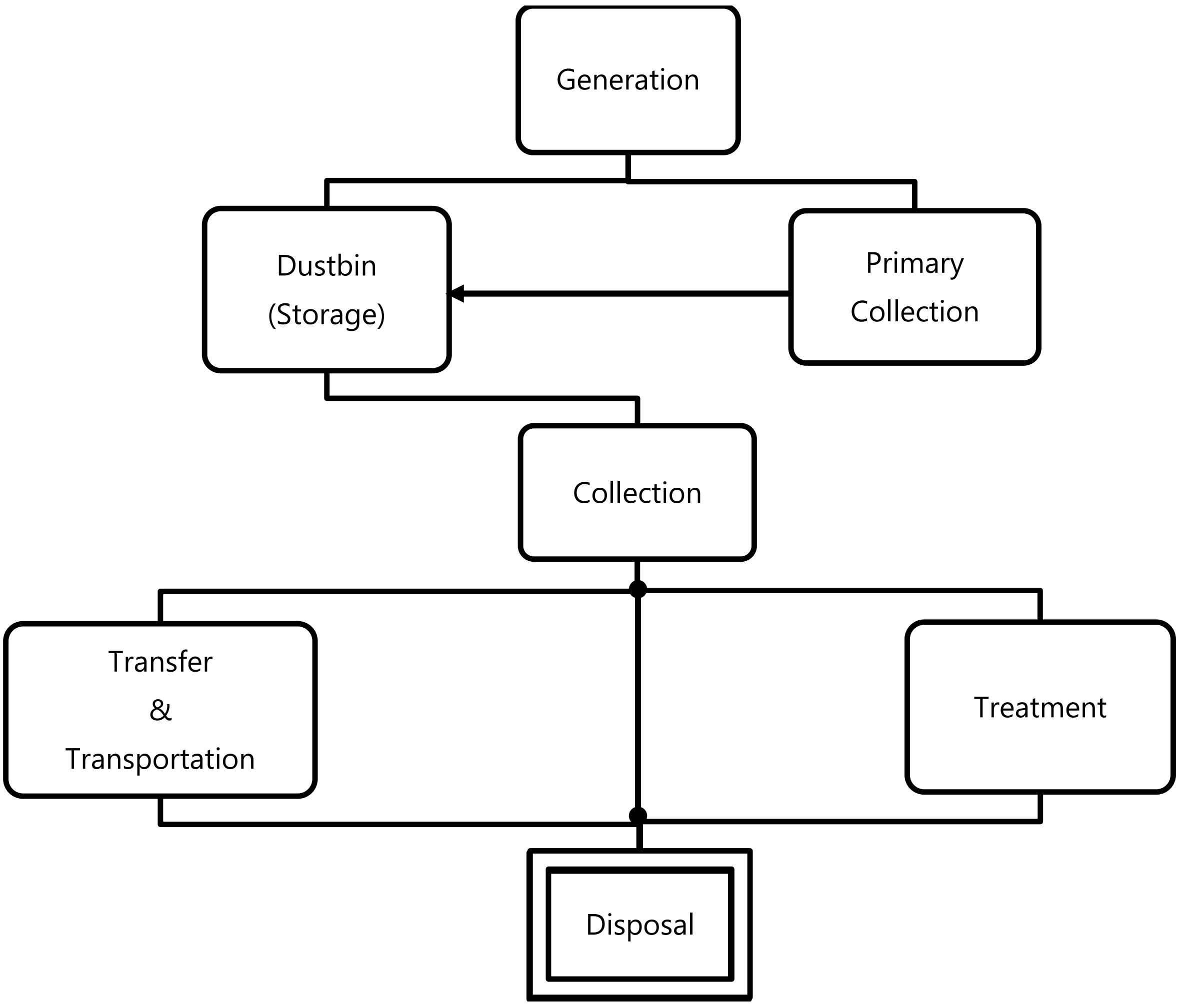


Figure 1.1: Current scenario of solid waste management in India

1.2.1. Municipal Solid Waste

Municipal Solid Waste (MSW), more commonly known as trash or garbage, consists of everyday items we use and throw away such as, plastics, clothes, paper, vegetable leftovers etc. MSW comes from residences, hospitals, entertainment facilities and everything else that generates waste or rubbish.

1.2.2. Solid Waste Management

Solid Waste Management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conversation, aesthetics and other environmental considerations and that is also responsive to public attitudes.

1.2.3. MSW (Management & Handling) Rules, 2000

- Infrastructure development for collection, storage, segregation, transportation, processing and disposal of MSW.
- Notify the waste collection and segregation schedule to the generators of these wastes, to help them comply.
- Organize awareness programmes for citizens to promote reuse or recycling of segregated materials and community participation in waste segregation.
- Processing of MSW has been given an impetus due to adverse effect on environment through air, water and land pollution.

1.3. PROCESSES

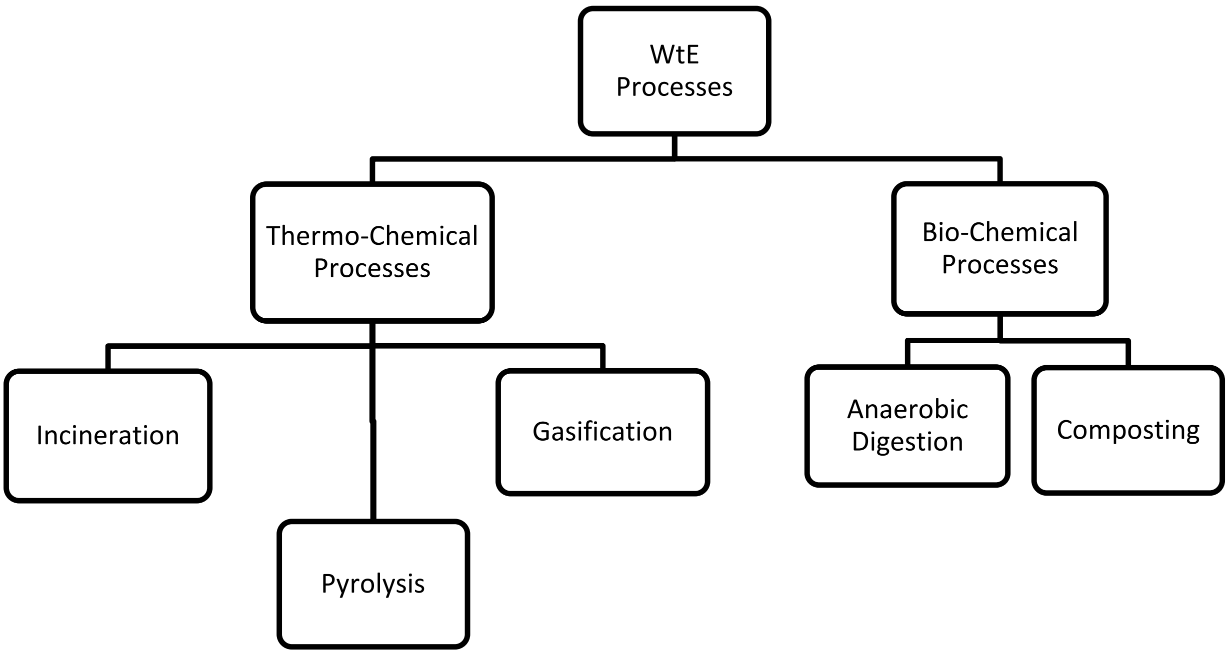


Figure 1.2: Flowchart of WtE processes

1.3.1. Incineration

It is the process of direct burning of wastes in the presence of excess air (oxygen) at temperatures of about 800^0C and above, liberating heat energy, inert gases and ash.

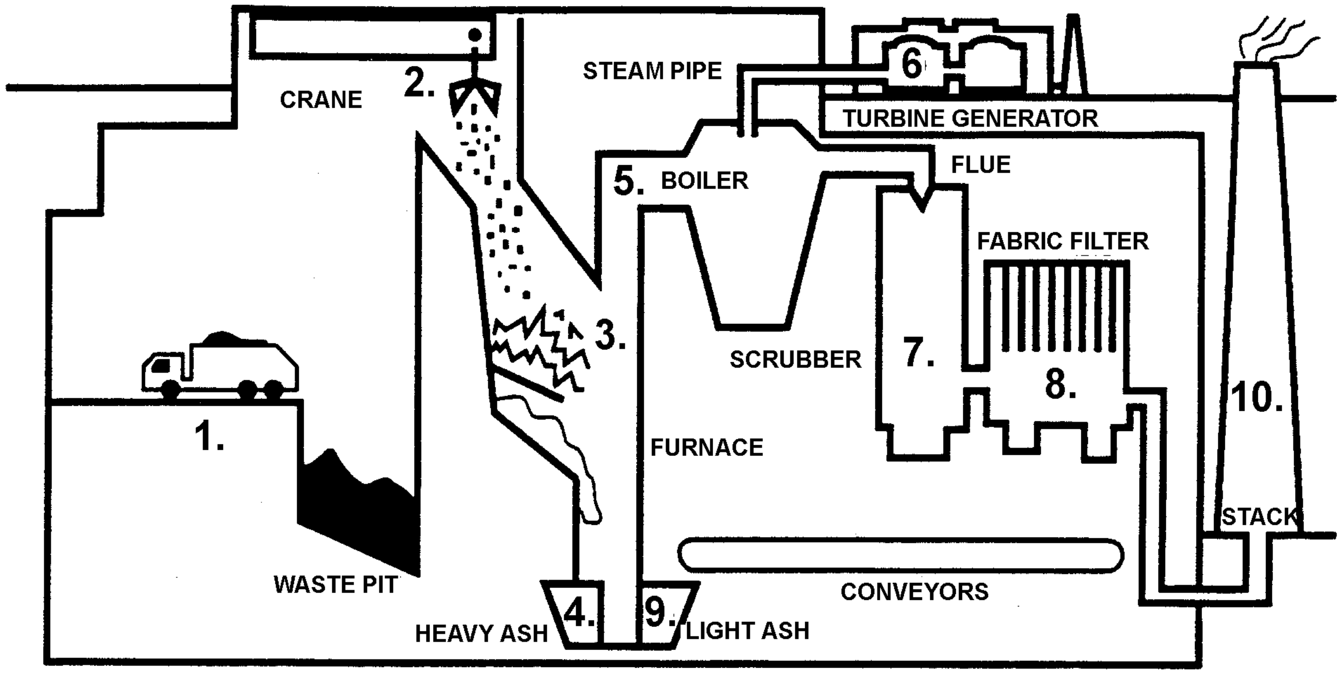


Figure 1.3: Schematic diagram of Moving Grate Incinerator

1.3.2. Gasification

Gasification is the general term used to describe the process of partial combustion in which a fuel is deliberately combusted in less than stoichiometric air. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas) or producer gas and is itself a fuel.

1.3.3. Pyrolysis

Pyrolysis is also referred to as destructive distillation or carbonization. It is the process of thermal decomposition of organic matter at high temperature (about 900^0C) in an inert (oxygen deficient) atmosphere or vacuum, producing a mixture of combustible CO, CH_4, H_2, C_2H_6 and non-combustible CO_2, H_2O, N_2 gases, pyroligenous liquid, chemicals and charcoal.

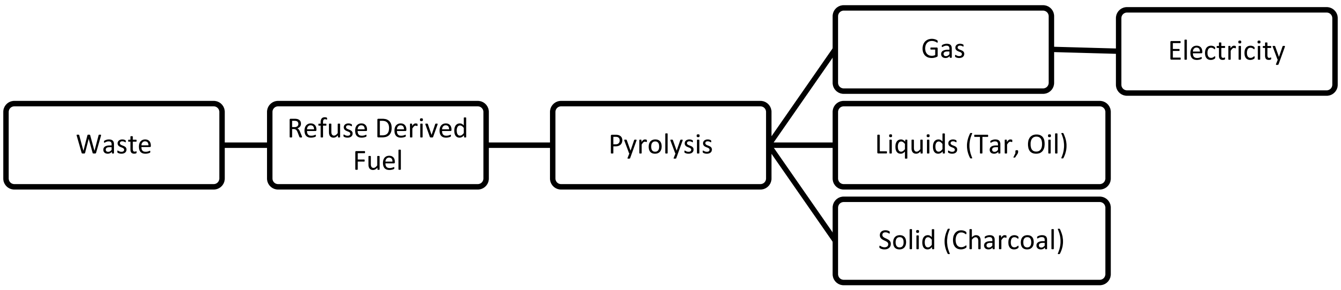


Figure 1.4: Schematic diagram of Pyrolysis

1.3.4. Anaerobic Digestion

In this process, also referred to as bio-methanation, the organic fraction of wastes is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic wastes undergo bio-degradation producing methane-rich biogas and effluent/ sludge.

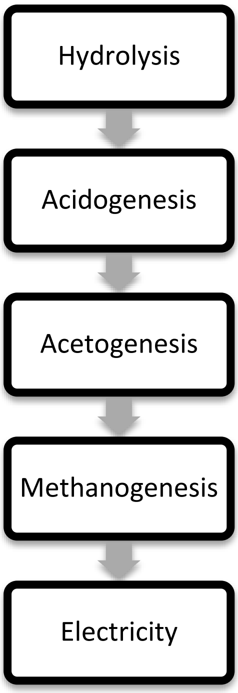


Figure 1.5: Schematic diagram of Anaerobic Digestion

1.3.5. Biogas

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen. It is a renewable energy source, like solar and wind energy. Furthermore, biogas can be produced from regionally available raw materials and recycled waste like cow dung, sludge etc. and is environmentally friendly.

1.3.6. Land Filling

Landfills are physical facilities used for the disposal of residual solid wastes in the surface soils of the earth. In the past, the term 'sanitary landfill' was used to denote a landfill in which the waste placed in the landfill was covered at the end of the each day's operations. Today, sanitary landfill refers to an engineered facility for disposal of MSW which is designed and operated to minimize public health and environmental impacts. Landfills for the disposal of hazardous wastes are called secure landfills. A sanitary landfill is also sometimes identified as a solid waste management unit. Landfilling is the process by which residual solid waste is placed in a landfill. Landfilling includes monitoring of the incoming waste stream, placement and compaction of the waste and the installation of landfill environmental monitoring and control facilities.

Hence, it can be concluded that incineration and anaerobic digestion are the most feasible solution to the waste management problem in India.

Chapter 2

METHODOLOGY

2.1. STUDY AREA

2.1.1. IIT Guwahati

Indian Institute of Technology Guwahati (Estd. 1994) is situated on the north bank of Brahmaputra River in the Amingaon area of Guwahati in Assam. It lies on 26^{0}11’14”N latitude and 91^{0}41’30”E longitude. It is 54 m above the MSL (Mean Sea Level) spreading over an area of 703 acres. It is located 1.5 km away from the Saraighat Bridge and is accessible from NH-31 as well as NH-37.

The site for integrated MSW processing and disposal facility is located at Boragaon in Guwahati city which is also the disposal site for Guwahati city’s MSW.

2.1.2. Patna

Patna is the capital city of Bihar, situated on the bank of River Ganga. It lies on 25^{0}36’39.6”N latitude and 85^{0}8’38.4”E longitude. It is 53 m above MSL. The city also straddles the rivers Sone, Gandak and Punpun. The city is approximately 35 km long and 16 km to 18 km wide. The city of about 17 lakh population (Census 2011) is demarcated by Patna Municipal Corporation (PMC) into 72 wards. The population of Patna is 20,46,652.

The MSW and sewage sludge is dumped at Ram Chak Beria which is accessible from NH-30A at a distance of 45 km from Patna Junction.

Patna Municipal Corporation has divided Patna into 4 circles, namely New Capital Circle, Bankipur Circle, Kankarbagh Circle and Patna City Circle for proper control and administration. Each circle is provided with a separate transfer station for solid waste management.

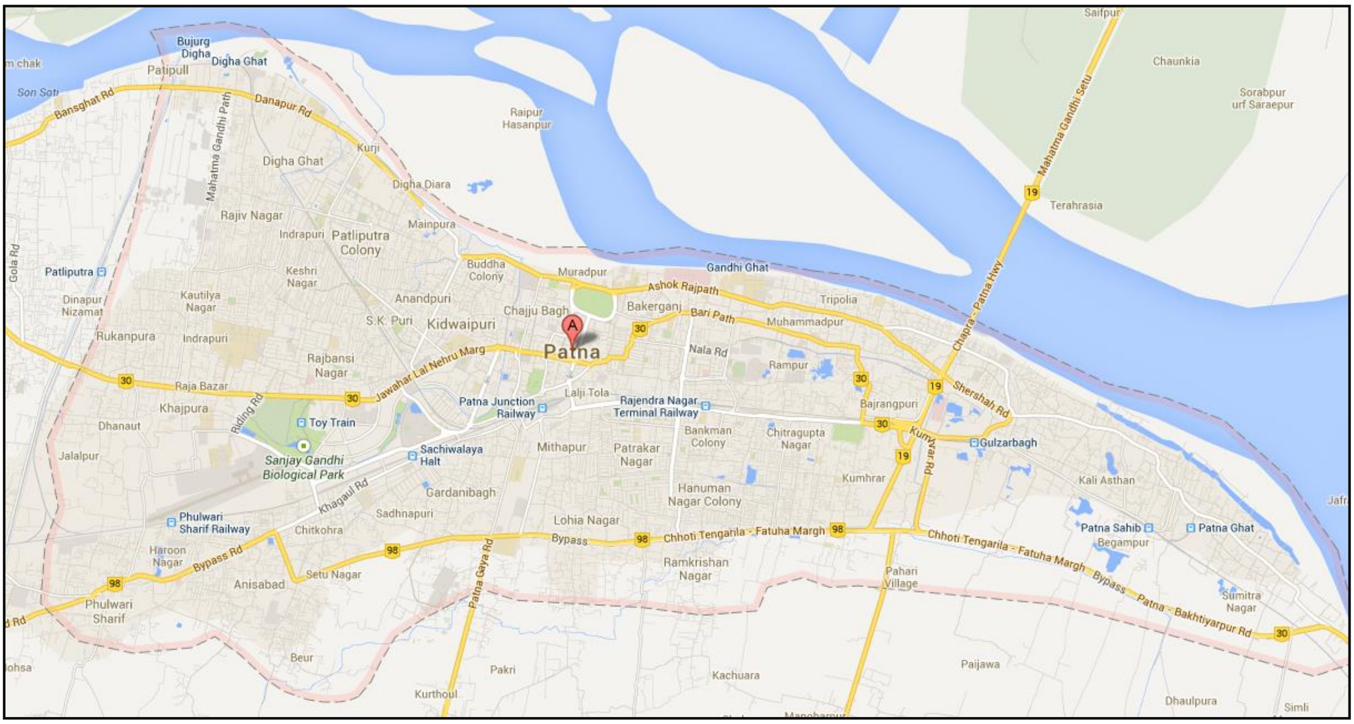


Figure 2.1: Map of Patna, Bihar

2.2. SURVEY

NATIONAL CHILDREN' SCIENCE CONGRESS

SURVEY SHEET

Name ______________________________

Profession ______________________________

Location ______________________________

Family Members ☐☐

Waste collection details of a week

Day	Organic Waste	Inorganic Waste	Paper	Total Waste
1				
2				
3				
4				
5				
6				
7				

Total Organic Waste Collected ______________

Average Organic Waste Collected _____________

____

Signature

Figure 2.2: Sample Survey sheet

Survey was basically conducted to know the Per Capita waste generation of Patna and also to find the constituents of the waste produced in households.

100 families were surveyed over 5 different localities (Patliputra Colony, Shivpuri, Kankarbagh, Rajendra Nagar and Bailey Road) of Patna for a period of 7 days. The collected waste was segregated and characterised into organic, inorganic and paper and weighed.

2.3. CHARACTERISATION OF WASTE

The main parameters which determine the potential of Recovery of Energy from Wastes (including MSW) are quantity of waste and physical and chemical characteristics (quality) of the waste.

2.3.1. Physical Characteristics of Waste

It determines the kind of treatment to be given to the waste for its disposal. This is based on sorting the collected waste into its various constituents and preparing samples for further experiments and analysis. This helps to find the composition of waste at an average and the percentage of its constituents to the total sample collected.

For physical characterisation of waste, approximately 20-25 kg of Municipal Solid Waste was taken from the dustbins of residences A- type, D-type, F-type and Married Scholars' hostel. The collected samples were physically sorted on a sorting platform into various constituents such as Kitchen Waste, Glass, Paper, Plastic etc. The individual components were kept in separate bins and weighed. The weights are expressed as a percentage of the original sample on a wet weight basis. Thereafter the sample is processed for chemical analysis.

- Sampling Location(s): 4 Dustbins (Residences A- type, D-type, F-type, Married Scholars' Hostel)
- Sampling Period: 3 Days (Monday, Wednesday, Saturday)
- Sorting Location: IIT Guwahati Campus

2.3.2. Chemical and Biological Characteristics of Waste

The important chemical parameters to be considered for determining the energy recovery potential and the suitability of waste treatment through bio-chemical or thermo-chemical conversion technologies include:

- Proximate Analysis
  - Moisture Content
  - Volatile Substance
  - Fixed Carbon
  - Ash Content

- Ultimate Analysis
  - C/N Ratio

    In case of anaerobic digestion, the desired C/N ratio is 25-30. If the C/N ratio is less, high carbon content wastes (straw, paper etc.) may be added; if it is high, high nitrogen content wastes (sewage sludge, slaughter house waste etc.) may be added, to bring the C/N ratio within the desirable range.

- Energy Content (Calorific Value)

A. Pre-treatment

500 g of each day's waste was taken and left in the sun to dry for 4-5 hours. It was then kept for 24 hours in hot air oven at 105^0C. Then it was ground in a mixer-grinder. After powdering it, it was passed through a 0.22 mm sieve.

B. Proximate Analysis

- Moisture Content:
  The initial weight of the sample is taken. Then the final weight of the waste after taking it out from the oven kept at a stable 105^{0}C, is measured and the moisture content is found by

$$Moisture\ Content\ (\%) = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight} \times 100$$

- Ash Content:
  A sample of 5 g was measured with the help of analytical balance (accuracy ±0.001 g) and a crucible was kept in a muffle furnace operating at 950^{0}C for 2 hours. The final inorganic weight after the experiment was noted down. The ash content was found by

$$Ash\ Content\ (\%) = \frac{Final\ Weight}{Initial\ Weight} \times 100$$

- Volatile Solid:
  2 samples of 5±0.001 g of sample was taken in an open crucible and kept in muffle furnace operating at 550^{0}C for 2 hours. The final weight after experiment is noted down. The volatile solids was found by

$$Volatile\ Solids\ (\%) = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight} \times 100$$

- Fixed Carbon:
  The fixed carbons was found by

$$Fixed\ Carbon\ (\%) = 100 - (Moisture\ Content + Ash\ Content + Volatile\ Solids)$$

C. Ultimate Analysis

C/N Ratio is the ratio of Total Organic Carbon (TOC) to Total Kjeldahl Nitrogen (TKN).

The TOC was found by

$$TOC\ (\%) = \frac{Initial\ Weight - Ash\ Content}{Initial\ Weight} \times 58$$

The Total Kjeldahl Nitrogen (TKN) was found by taking 0.2 g of each day's sample along with 3 g catalyst (a mixture of K_2SO_4 and $CuSO_4.5H_2O$ in a ratio of 5:1) and 10 ml conc. H_2SO_4 in a digester for 3 hours at 350^{0}C - 420^{0}C. The digested samples were diluted and mixed with 20 ml of 40 % NaOH. The samples were distilled with 25 ml boric acid and titrated with 0.02 N H_2SO_4 until a purple colour is observed. Then the TKN was found by

$$TKN\ (\%) = \frac{14 \times H_2SO_4\ Consumed \times Normality\ of\ H_2SO_4}{Sample\ Weight}$$

$$Ratio\ C/N = \frac{TOC}{TKN}$$

D. Energy Content

1 g of sample was taken in the bomb calorimeter and the water equivalent was noted down. The initial temperature was recorded and the fire button was hit. The rise in temperature after each 30 seconds was recorded until the temperature started decreasing. The maximum temperature was noted.

The Net Calorific Value (NCV) was found by

$$NCV\ (kcal/kg) = \frac{Water\ Equivalent \times\ \Delta t}{Sample\ Weight}; where\ \Delta t = Max.\ Temp. - Initial\ Temp.$$

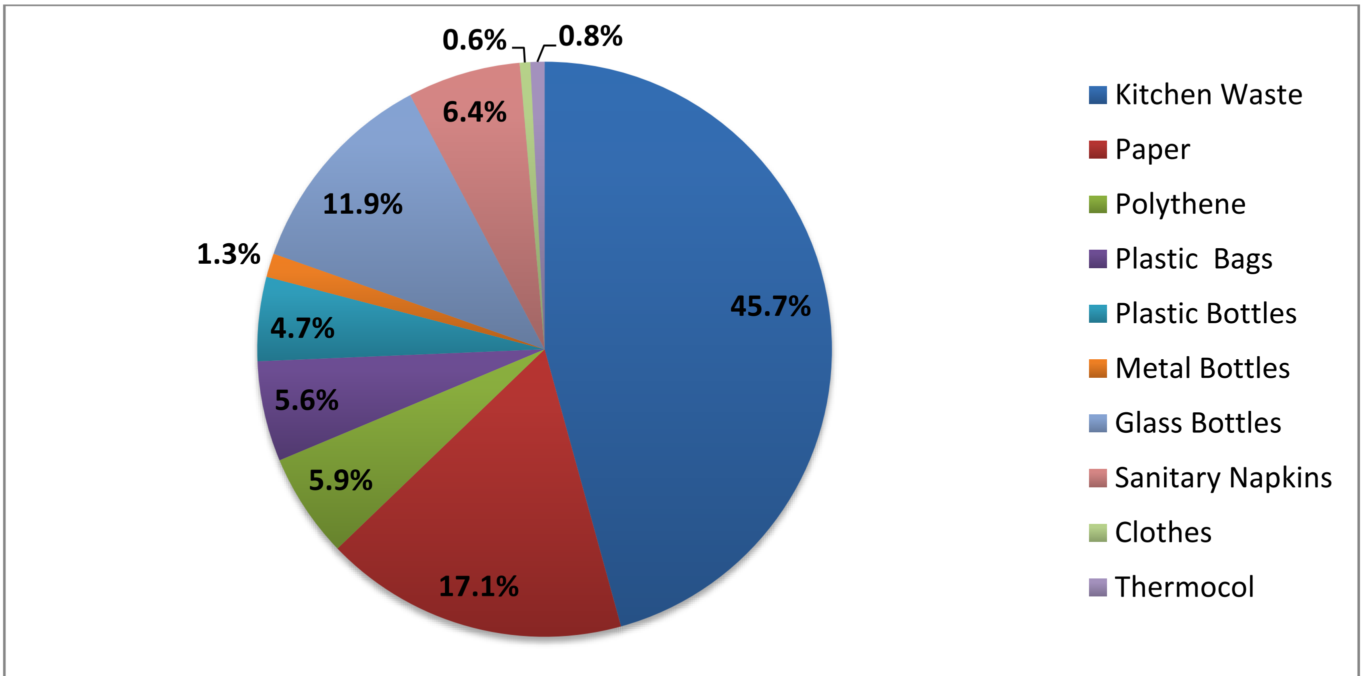
Chapter 3

DATA ANALYSIS

3.1 PHYSICAL CHARACTERISATION OF MSW

Table 3.1: Physical characterisation of collected waste samples in IITG

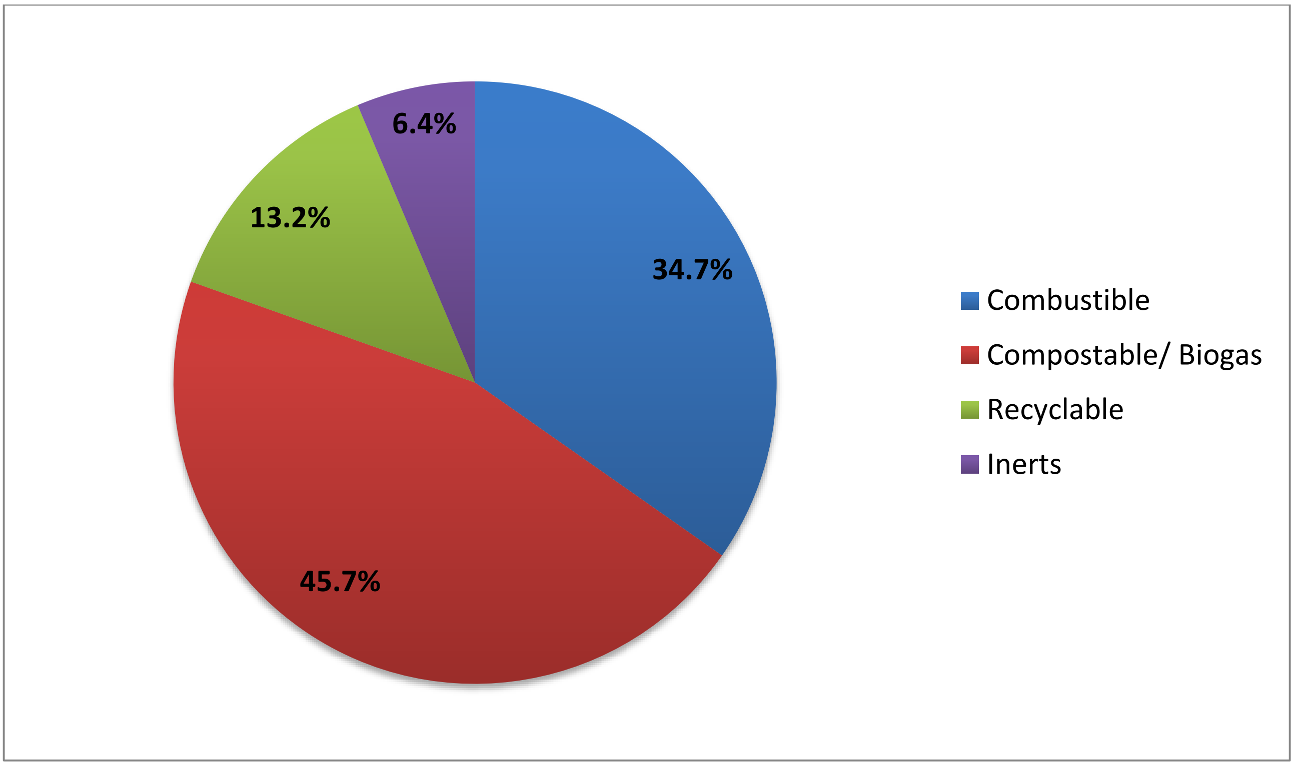
IIT Guwahati Campus Waste Collection Record										
	Waste	**Day 1 (Monday)**		**Day 2 (Wednesday)**		**Day 3 (Saturday)**		**Average**		**Final Average**
		Mass (In kg)	**%**	**Mass (In kg)**	**%**	**Mass (In kg)**	**%**	**In kg**	**%**	
1	Kitchen Waste	20	60.1	11	45.5	8	31.6	13.0	45.7	13.0±6.0
2	Paper	5	15.0	4	16.5	5	19.8	4.7	17.1	4.7±0.5
3	Polythene	1.8	5.4	2	8.3	1	4.0	1.6	5.9	1.6±0.5
4	Plastic Bags	1.6	4.8	1.5	6.2	1.5	5.9	1.5	5.6	1.5±0.1
5	Plastic Bottles	1.4	4.2	0.5	2.1	2	7.9	1.3	4.7	1.3±0.8
6	Metal Bottles	0.4	1.2	0.2	0.8	0.5	2.0	0.4	1.3	0.4±0.2
7	Glass Bottles	1.2	3.6	2	8.3	6	23.7	3.1	11.9	3.1±2.4
8	Sanitary Napkins	1.6	4.8	2.5	10.3	1	4.0	1.7	6.4	1.7±0.8
9	Clothes	0.2	0.6	0	0.0	0.3	1.2	0.2	0.6	0.2±0.1
10	Thermocol	0.1	0.3	0.5	2.1	0	0.0	0.2	0.8	0.2±0.2
	Total	**33.3**	**100.0**	**24.2**	**100.0**	**25.3**	**100.0**			



Graph 3.1: Physical characterisation of collected waste samples in IITG

Table 3.2: Physical characterisation of waste collected in IITG in four types

IIT Guwahati Campus Waste Collection Record										
	Waste	**Day 1 (Monday)**		**Day 2 (Wednesday)**		**Day 3 (Saturday)**		**Average**		**Final Average**
		Mass (kg)	**%**	**Mass (kg)**	**%**	**Mass (kg)**	**%**	**In kg**	**%**	
1	Combustible	10.1	30.3	8.5	35.1	9.8	38.7	9.5	34.7	10.1±0.8
2	Biogas	20	60.1	11	45.5	8	31.6	13.0	45.7	13.0±6.0
3	Recyclable	1.6	4.8	2.2	9.1	6.5	25.7	3.4	13.2	3.4±2.5
4	Inerts	1.6	4.8	2.5	10.3	1	4.0	1.7	6.4	1.7±0.8
	Total	**33.3**	**100**	**24.2**	**100**	**25.3**	**100**			



Graph 3.2: Physical characterisation of waste collected in IITG in four types

3.2 CHEMICAL CHARACTERISTIC OF MSW

Table 3.3: Moisture Content of mixed samples

Moisture Content				
Days	**Initial Weight (g)**	**Final Weight (g)**	**Moisture Content (g)**	**Moisture Content (%)**
1	500.00	178	322	64.4
2	500.00	176	324	64.8
3	500.00	172	328	65.6
AVG	**500.00**	**175.3**	**324.7**	**64.9**

Table 3.4: Volatile Solids of mixed samples

Volatile Solids				
Days	**Initial Weight (g)**	**Final Weight (g)**	**Volatile Solids (g)**	**Volatile Solids (%)**
1	5.000	2.438	2.562	51.2
2	5.000	2.356	2.644	52.9
3	5.000	2.521	2.479	49.6
AVG	**5.000**	**2.438**	**2.562**	**51.2**

Table 3.5: Ash Content of mixed samples

Ash Content				
Days	**Sample No.**	**Initial Weight (g)**	**Final Weight (g)**	**Ash Content (%)**
1	**1**	5.000	2.251	45.02
	2	5.000	2.412	48.24
	AVG	**5.000**	**2.332**	**46.63**
2	**1**	5.000	2.246	44.92
	2	5.000	2.321	46.42
	AVG	**5.000**	**2.284**	**45.67**
3	**1**	5.000	2.354	47.08
	2	5.000	2.357	47.14
	AVG	**5.000**	**2.356**	**47.11**
Average		**5.000**	**2.324**	**46.47**

Table 3.6: Fixed Carbon of mixed samples

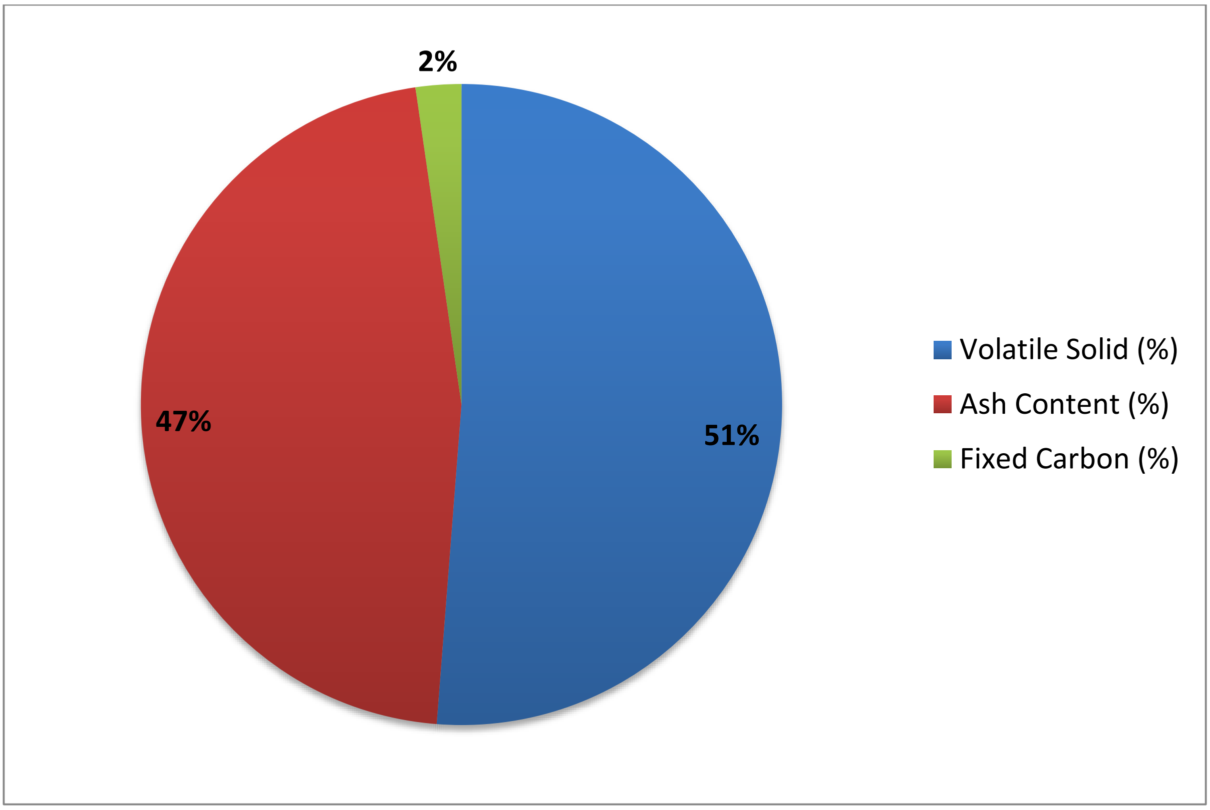
Fixed Carbon			
Days	**Volatile Solid (%)**	**Ash Content (%)**	**Fixed Carbon (%)**
1	51.24	46.63	2.13
2	52.88	45.67	1.45
3	49.58	47.11	3.31
AVG	**51.23**	**46.47**	**2.30**

Table 3.7: Proximate analysis of samples

Proximate Analysis				
Days	**Moisture Content (%)**	**Volatile Solid (%)**	**Ash Content (%)**	**Fixed Carbon (%)**
1	64.4	51.24	46.63	2.13
2	64.8	52.88	45.67	1.45
3	65.6	49.58	47.11	3.31
AVG	**64.9**	**51.23**	**46.47**	**2.30**

Table 3.8: Average of proximate analysis

Volatile Solid (%)	Ash Content (%)	Fixed Carbon (%)
51.23	46.47	2.30



Graph 3.3: Proximate Analysis

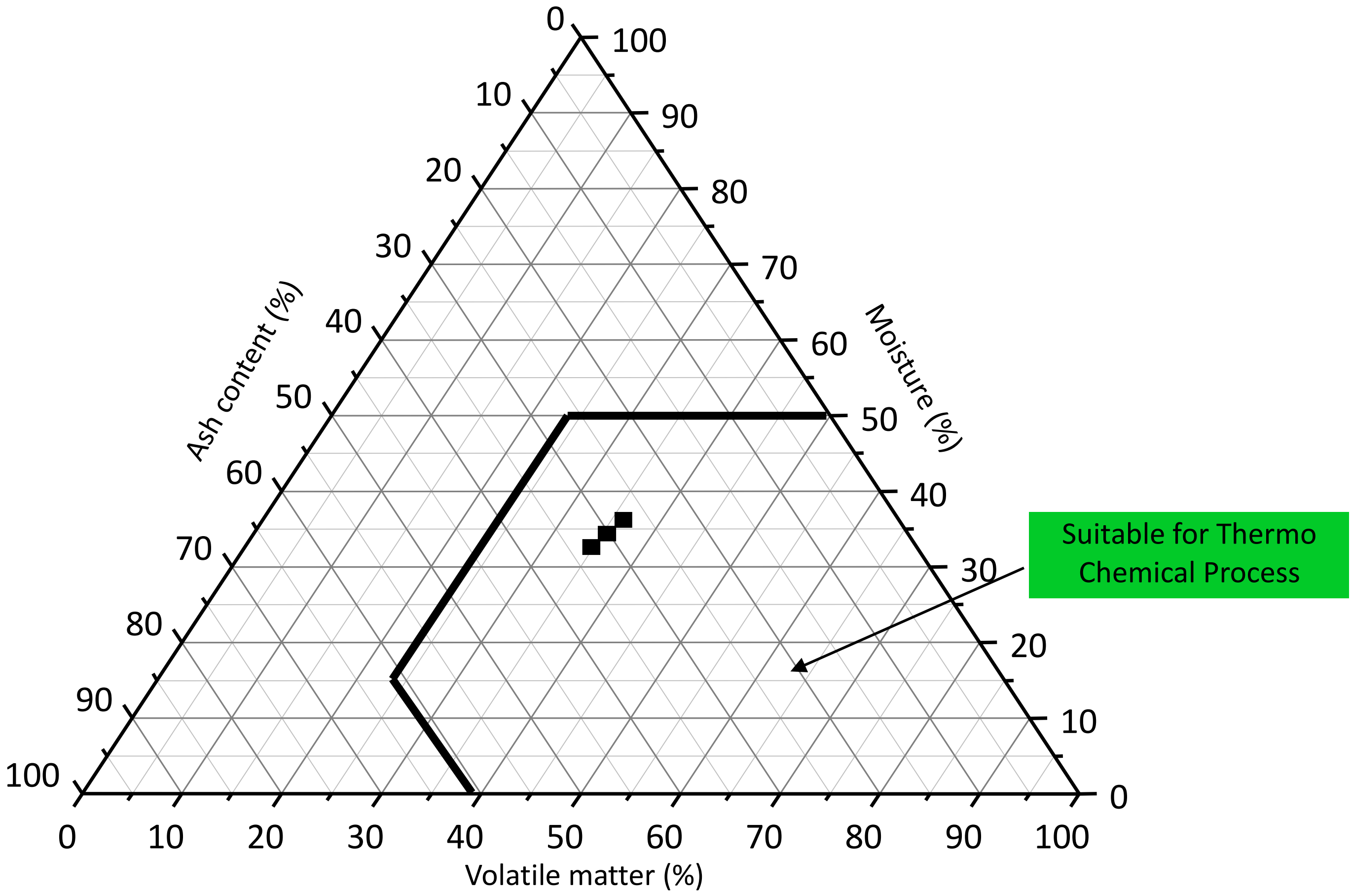


Figure 3.1: Tanner's diagram

Table 3.9: Total Organic Carbon (TOC) of degradable samples

Total Organic Carbon				
Days	**Initial Weight (g)**	**Ash Content (g)**	**TOC (g)**	**TOC (%)**
1	5.000	1.149	2.234	44.68
2	5.000	0.894	2.381	47.63
3	5.000	0.641	2.528	50.56
AVG	**5.000**	**0.895**	**2.381**	**47.62**

Table 3.10: Total Kjeldahl Nitrogen (TKN) of degradable samples

Total Kjeldahl Nitrogen (TKN)				
Days	**Weight of Sample (g)**	**Normality of H_2SO_4**	**H_2SO_4 Used for Sample (ml)**	**TKN (%)**
1	0.2	0.02	1.2	1.68
2	0.2	0.02	1.5	2.10
3	0.2	0.02	1.2	1.68
AVG	**0.2**	**0.02**	**1.3**	**1.82**

Table 3.11: C/N Ratio of degradable samples

C/N Ratio			
Days	**TOC (%)**	**TKN (%)**	**C/N**
1	44.68	1.68	26.59
2	47.63	2.10	22.68
3	50.56	1.68	30.10
Average	**47.62**	**1.82**	**26.17**

Table 3.12: Energy Content (Calorific Value) of samples

Energy Content (Net Calorific Value)							
Days	**Weight of Sample (g)**	**Water Equivalent (WE)**	**Initial Temp. (^{0}C)**	**Max Temp. Reached (^{0}C)**	**Change In Temp. (Δt)**	**NCV (cal/g)**	**NCV (kJ/kg)**
1	1.000	2568.293	25.94	27.42	1.48	3801.074	15964.509
2	1.000	2568.293	27.69	29.22	1.53	3929.488	16503.851
AVERAGE NET CALORIFIC VALUE						3865.281	16234.18

Chapter 4

CONCLUSION

The composition and the quantity of MSW generated form the basis on which the solid waste management system needs to be planned, designed and operated. Table 4.1 represents the physical and chemical analysis of waste generated in Patna:

Table 4.1: Conclusion

S. No.	Description	Quantity
1	Total Waste Generation	1105 TPD
2	Per Capita Waste generation	0.60 ± 0.09 kg/capita/day
3	Total Waste Generation(2018)	1385 TPD
4	Total Waste Generation(2023)	1737 TPD
5	Waste Composition • Combustible (%) • Waste transformable into biogas (%) • Recyclable (%) • Inerts (%)	 34.7 45.7 13.2 6.4
6	Proximate Analysis • Moisture Content (%) • Ash Content (%) • Volatile Substance (%) • Fixed Carbon (%)	 64.90 46.47 51.20 2.30
7	Ultimate Analysis • Carbon (%) • Nitrogen (%) • C/N Ratio	 46.62 1.82 26.17
8	Energy Content • Calorific Value (kJ/kg)	 16234.18

Thus, it can be concluded that waste to energy is a feasible and practical solution to both the energy deficit and the waste management problem only if <u>segregation at source is followed</u>.

Chapter 5

RECOMMENDATIONS

1. Segregation at Source

Waste should be segregated at source into wet and dry waste by the individuals and it should be collected accordingly by the authorized personnel of the municipal corporation.

2. Collection of Waste

The waste will be collected daily in the two dustbins by the method of door to door collection between 7:00 AM and 10:00 AM every day and dumped in community bins.

- The collection frequency of the waste from community dustbins by trucks will be:
  Wet Waste: Every day from 11:00 PM to 4:00 AM
  Dry Waste: Twice a week (Wednesday and Saturday) from 12 Noon to 4:00 PM
- The minimum wage for the labourers working will be:
  Daytime: 200/day (8 hrs.)
  Night time: 250/day (6 hrs.)
- The number of dustbin required for collection of waste will be as follows:

Table 5.1: No. of dustbins required for the proposed waste collection method

No. of Dustbin		
Haul type container for wet waste	Stationary type container for dry waste	No. of trips
402	374	776

3. Overview of proposed waste collection setup in Patna

- The local waste management authority or the governing body will provide 1 dustbin to each household and 1 dustbin must be purchased by each and every household. One dustbin will be meant for wet waste (kitchen waste) and the other for dry waste (other rubbish including paper, plastics, metal, glass, leather etc.).
- The WCOs (Waste Collection Officers) will strictly collect waste segregated at the source into wet and dry and throw these into curb dustbins. These curb dustbins will be located at every 500 m on the road network and will be accessible from each and every household.
- The waste from curb dustbins will be collected by rickshaw pullers deployed for waste collection and the same will be deposited in community dustbins which will be located at the road nodes on major city roads accessible by heavy vehicles.
- Trucks operating at unique routes will collect waste from the community bins at the allotted time slots and dump the same at the transfer stations which are allotted to each circle.
- Big trucks will then take away the waste to waste management facility at Ram Chak Beria.

4. <u>The waste upon reaching the disposal site will be treated as follows:</u>

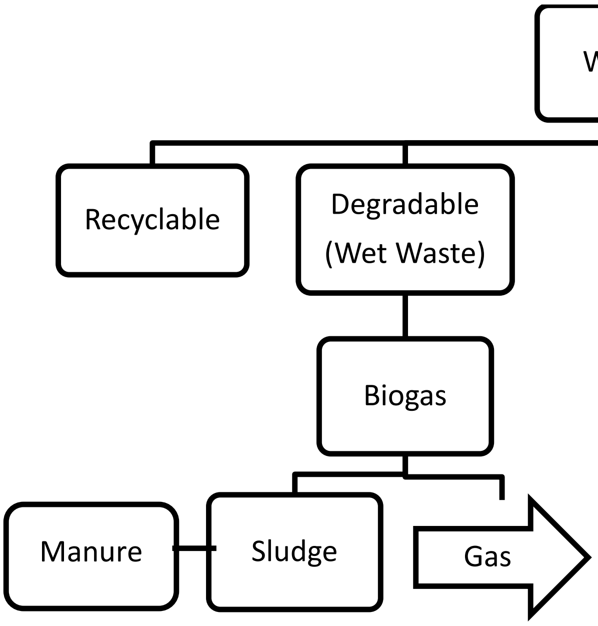


Figure 5.1: Flowchart of our proposed waste disposal plan

The technique followed for the thermo chemical processing of combustible waste will be moving grate incineration as:

- It is a well proved technology and can accommodate large variations in waste compositions and heating values.
- It can be built in very large units (upto 50 T/h) and its maintenance and installation cost is relatively lower in comparison to other thermo-chemical techniques.

The technique followed for the bio-chemical processing of degradable waste will be anaerobic digestion to produce biogas which will be later processed to electricity.

5. <u>The Energy Recovery Potential of waste will be:</u>

Table 5.2: Electricity potential from combustible waste

Total waste quantity	1105 T
Combustible percentage	35 %
Hence, Combustible waste quantity	385 T
Net minimum Calorific Value	3500 k-cal/kg.
Energy recovery potential (kWh)	NCV x W x 1000/860 = 3000 x 385 x 1000/860
Power generation potential (kW)	NCV x W/24 x 1000/860 = 3000 x 385/24 x 1000/860
Conversion Efficiency	25%
Net power generation potential (kW)	3000 x 385/24 x 1000/860 x ¼ = 13961.9 kW

Therefore, a 14 MW plant can be set with the combustible waste of Patna.

Table 5.3: Electricity potential from degradable waste

Total waste quantity	1105 T
Total Biodegradable part	45%
Hence, Total biodegradable quantity	500 T
Typical digestion efficiency	60%
Typical bio-gas yield: (A)	0.80 m^3 / kg
Biogas recovery potential	0.80 x 0.60 x 500 x1000 = 240000 m^3
Calorific Value of bio-gas	5000 kcal/m^3 (typical)
Energy recovery potential (kWh)	A x 5000 / 860
Power generation potential (kW)	A x 5000 / 860 x 1/24
Typical Conversion Efficiency	30%
Net power generation potential (kW)	A x 5000 / 860 x 1/24 x 0.30 = 17441.9

Therefore, a 17 MW plant can be set with the degradable waste of Patna.

6. Sustainability
Current population growth rate of Patna: 3.017 %
Current waste growth rate of Patna: 1.41 %

Table 5.4: Sustainability

Year	Population	Per Capita Waste (kg)	Waste (Tonne)
2013	1683200	0.66	1105
2018	1967446	0.70	1385
2023	2299694	0.76	1737
2028	2688049	0.81	2177
2033	3141987	0.87	2729
2038	3672582	0.93	3422
2043	4292780	1.00	4289

Hence, 4289 tonne of waste will be produced at the end of 2043, so the plant must be designed accordingly.

7. The cost involved in the setup of the plant would roughly be:

- The setup cost for the power plant (approx.) is Rs 30,49,00,000 (as per GWMCPL report). Setup cost includes land, civil works, plant and machinery, electricity consumption, safety equipment, lighting, transport and labour costs.

Table 5.5: Maintenance and Operation Cost (Per Annum)

	Operating Cost (Rs.)
Manpower Cost	1,35,00,000
Consumables Cost	15,00,000
Spares Cost	1,00,00,000
Running Cost	1,00,00,000
Total Cost	3,50,00,000

These details are a rough estimate and may vary from year to year (inflation) and place to place (transportation cost, labour cost and other various factors).

Table 5.6: Estimated final cost of Pyrolysis Plant

Capacity of the plant: 14 MW
Electricity required by the plant: 2 MW
Electricity salable: 12 MW
Operating hours of plant per day: 10 Hrs.
Efficiency: 40%
Therefore, Energy produced in one day: 48 MWh
1st year tariff: Rs 5/kWh
Operating days in a year: 250-260
Amount earned per year: Rs. 6 – 6.25 Crores

- The setup cost for the biogas power plant (approx.) is Rs 32,75,00,000. Setup cost includes land, civil works, plant and machinery, electricity consumption, safety equipment, lighting, transport and labour costs. Maintenance and Operation Cost (Per Annum) is roughly Rs. 4,50,00,000.

These details are a rough estimate and may vary from year to year (inflation) and place to place (transportation cost, labour cost and other various factors).

Table 5.7: Estimated final cost

Capacity of the plant: 17 MW
Electricity required by the plant: 2 MW
Electricity salable: 15 MW
Operating hours of plant per day: 10 Hrs.
Efficiency: 60%
Therefore, Energy produced in one day: 90 MWh
1st year tariff: Rs 4.5/kWh
Operating days in a year: 250-260
Amount earned per year: Rs. 10-11 Crores

Chapter 6

REFERENCES

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Appendix I

Proposed Waste Collection Setup in Patna

PRE-FUNCTIONING REQUIREMENTS

The local waste management authority or the governing body will provide 1 dustbin to each household and 1 dustbin must be purchased by each and every household. One will be meant for wet waste (kitchen waste) and the other for dry waste (other rubbish including paper, plastics, metal, glass, leather etc.).

OVERVIEW OF PROPOSED WASTE COLLECTION SETUP IN PATNA

- The governing body will levy a 'waste handling tax' which would be a surcharge collected by the municipal authorities very much like the other taxes levied by the Municipal Corporation. This amount will be the total initial setup cost for waste management + maintenance cost + monthly salary of staff, divided by the population. The tax will vary according to the monthly income of the waste generator.
- The WCOs (Waste Collection Officers) will strictly collect waste segregated at the source in wet and dry categories and throw the waste in curb dustbins. These curb dustbins will be located at every 500 m on the road network and will be accessible from each and every household.
- The waste from curb dustbins will be collected by rickshaw pullers deployed for waste collection and the same will be deposited in community dustbins which will be located at the road nodes on major city roads accessible by heavy vehicles.
- Trucks operating at unique routes will collect waste from the community bins at the allotted time slots and dump the same at the transfer stations which are allotted to each circle.
- Big trucks will then take away the waste to waste management facility at Ram Chak Beria which is 45 km away from the city centre.

DETAILED STAGE-I WASTE COLLECTION BY WCOs

- The curb dustbins will be placed at every 250 m on alleys and by-lanes making it easier for WCOs to deposit waste. The curb dustbins will also function as the common dustbins for the locality, thus keeping the locality clean and tidy.
- These curb dustbins will be haul-type and will be temporarily mounted on electric poles for easy hauling by WCRs. The capacity of these dustbins will be at most 75 litre each, for wet and dry waste.

  Calculation:

  Wet Waste generated per capita per day: 0.3 kg (approx.)
  Thus, Wet Waste generated per family per day: 0.3 kg x 5 = 1.5 kg (approx.)
  No. of families assigned per WCO = 30
  Thus, Wet Waste collected by each WCO = 30 x 1.5 kg = 45 kg (approx.)
  Similarly, Dry waste collected by each WCO = 30 kg

- A group of apartments or bungalows (decided by the authority for convenience in waste collection) will be assigned with a WCO who will daily collect wet and dry waste in two bins separately in the morning between 0700 and 1000 hrs. The household which will be unavailable at the time of waste collection will keep both the dustbins outside the house without fail. If the household fails in doing so, the household will be responsible for depositing its waste in the curb dustbins for the next 2 days.

- An estimate of 30 families will be assigned to each WCO.
- The Waste Collector on Rickshaw (WCR) will supervise the work of 3-4 WCOs for proper functioning and if the WCO is failing to work properly, the WCR will report to the local circle office of the Municipal Corporation.

DETAILED STAGE-II WASTE COLLECTION BY WCRs

- The WCRs will operate on a daily basis and collect both wet and dry waste from curb dustbins in the afternoon between 1200 and 1500 hrs.
- The rickshaw to be used for collection will be divided into 3:2 ratio into wet and dry bins. The total maximum capacity of these rickshaws will be around 200 kg.
- The WCRs will empty the curb dustbins into respective rickshaw bins and place them back in their original place. After collecting from 3-4 curb dustbins, the WCRs will deposit the waste in the community bins placed on the main roads.

DETAILED STAGE-III WASTE COLLECTION BY TRUCKS FOR WET WASTE

- Since wet waste degrades at a very high pace and leaving it unhandled and in open would attract pests and stray animals, it will be collected and treated daily. So, trucks which will operate on a daily basis for wet waste at night between 2300 hrs. and 0400 hrs. to facilitate fast collection.
- The dustbins for wet waste will be haul-type and the capacity will be 1 tonne for proper handling and hygienic issues. Accordingly, the capacity of the trucks will be decided on the basis of number of trips and cheaper options.

DETAILED STAGE-III WASTE COLLECTION BY TRUCKS FOR DRY WASTE

- Since dry waste is compactable and its density is low, compacter trucks will be used for collection of dry waste on Wednesdays and Saturdays during the afternoon between 1200 hrs. and 1600 hrs.
- The dustbins for dry waste will be stationery-type and the capacity 1 tonne (the volume of the waste will be high due to low density).

The trucks will dump the waste at transfer stations which are defined by the Municipal Corporation.

Thereafter, big trucks will carry the waste from the transfer stations by the pre-defined routes to Ram Chak Beria where processing and disposal will take place.