MAJOR PROJECT-II

FEASIBILITY ANALYSIS OF MUNICIPAL SOLID WASTE FOR ELECTRICITY PRODUCTION USING WASTE TO ENERGY INCINERATION TECHNOLOGY

(A CASE STUDY OF ROORKEE (UTTARAKHAND) CITY)

Submitted in partial fulfillment of the requirement for the award of the degree of

Master of Technology In

Renewable Energy Technology

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DECLARATION

I hereby declare that the work, which is being presented in this dissertation, entitled **"FEASIBILITY ANALYSIS OF MUNICIPAL SOLID WASTE FOR ELECTRICITY PRODUCTION USING WASTE TO ENERGY INCINERATION TECHNOLOGY (A CASE STUDY OF ROORKEE (UTTARAKHAND) CITY)."** towards the partial fulfillment of the requirements for the award of the degree of Master of Technology with specialization in Renewable Energy Technology, from Delhi Technological University Delhi, is an authentic record of my own work carried out under the supervision of **Prof. R. S. Mishra,** Professor, Department of Mechanical Engineering, at Delhi Technological University, Delhi.

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This is to certify that the dissertation titled "**Feasibility Analysis of Municipal Solid Waste for Electricity production using Waste to Energy Incineration Technology (A Case Study of Roorkee (Uttarakhand) City).**" submitted by Shubham Gupta (Roll no. 2K14/RET/15), student of M.Tech (Renewable Energy Technology), for the partial fulfillment of the requirements for the award of the degree of Master of Technology under my guidance and supervision.

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ABSTRACT

With rapid economic growth and massive urbanization in India, many cities face the problem of municipal solid waste (MSW) disposal. Improper management of municipal solid waste causes hazards to inhabitant. In an emerging economy like India, rapid population growth has further added to the intensity of waste generation. There has been increasing pressure in India to reduce green- house gases and CO_2 emissions. The growth of Municipal Solid Waste (MSW) has been skyrocketing as a result of growing urban population and industrialization. The MSWM (municipal solid waste management) system comprises with generation, storage, collection, transfer and transport, processing and disposal of solid wastes. The conversion of municipal solid waste (MSW) to energy can conserve more valuable fuels and improve the environment by lessening the amount of waste that must be landfilled and by conserving energy and natural resources. With the lack of space for new landfills, five technologies for waste to energy generation, namely biomethanation, incineration, gasification/pyrolysis, Refused Derived Fuel (RDF) and plasma arc gasification are playing an increasingly important role in waste management have been compared.

Roorkee City being under holy district Haridwar is a target place of the government to clean it under “Swach Bharat Abhiyan” and “Ganga Bachao” programme, so in order to be part of these programmes Roorkee city is selected for the dissertation work. Effective waste management has been a big challenge in most developing cities including Roorkee. Collection and sorting of municipal wastes at source in Roorkee with the hope of reducing the indiscriminate dumping of wastes has never been realized. A study on the potential of generating green energy from municipal solid waste at Roorkee is presented in this dissertation. Roorkee is also a big generation city of MSW as city comprises of Industrial Area & Colleges also. The population of Roorkee city as per the census 2014 is 1.4 lakh. The study is conducted by collecting data from waste collection points of Roorkee city. The waste generation per day is around 200 tonne per day. The work represents study of current municipal solid waste management technique of Roorkee City and comparison of different Waste to Energy technologies.

CHAPTER 1 INTRODUCTION

1.1 Municipal Solid Waste Management

The consumption habits of modern consumer lifestyle are causing a huge worldwide waste problem. Having overfilled local landfill capacities, many first world nations are now exporting their refuse to third world countries. This is having a devastating impact on ecosystems and cultures throughout the world. Some alternative energy companies are developing new ways to recycle waste by generating electricity from landfill waste and pollution. With rapid industrialization, the world has seen the development of a number of items or units, which generate heat. Until now this heat has often been treated as a waste, making people wonder if this enormous heat being generated can be transformed into a source of electric power (alternative-energy-news). Waste management is the "generation, prevention, characterization, monitoring, treatment, handling, reuse and residual disposition of solid wastes". There are various types of solid waste including municipal (residential, institutional, commercial), agricultural, and special (health care, household hazardous wastes, sewage sludge).The term usually relates to materials produced by human activity, and the process is generally undertaken to reduce their effect on health, the environment or aesthetics. Traditionally Landfill is used to dispose of waste generated.

1.2 Power Scenario in India

India has the 5th largest power generation portfolio worldwide. Coal and Gas are the popular sources and account for 58% and 9%, share, respectively. The country transitioned from being the world's 7th largest energy consumer in 2000 to the 3rd largest one within a decade. The sector enjoys favourable regulatory policies, especially in the generation segment. The government has approved 100% FDI.

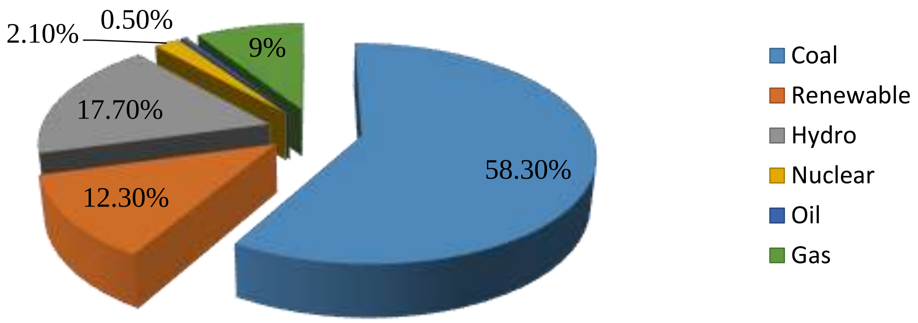

Figure 1: Break-up of installed power generation capacity (Source: CEA, Ernst & Young analysis; as on 31 March 2014)

1.3 Renewable Energy actual installation and target

Table 1: Renewable Energy actual installation and target Grid Interactive (Source: MNRE)

Renewable Technology	2013-2014		2014-15		Cumulative Achievements
	Target (MW)	Actual (MW)	Target (MW)	Actual (MW)	(as on 31.03.2015)
Wind power	2500	608	2000	2312	23444
Small Hydro	300	74.50	250	251.61	4055.36
Bio Power & Gasification	100	-	100	45	1410.20
Bagasse Cogeneration	300	250	300	360	3008.56
Waste to Power	20	1	20	8.50	115.08
Solar Power	1100	152.6	1100	1112.07	3743.97
Total	4325	835.26	3770	4089.18	35776.96

1.4 Waste to Energy (WTE)

1.4.1 Waste Energy from Biomass

Biomass, includes all new plant growth, residues and wastes, agricultural and forest residues, kitchen and city garbage, sewage etc. furthermore, To meet the growing demand of energy, it is necessary to focus on efficient production and use of biomass resources to meet both traditional and high energy demand. The biomass production for fuel, food, fibre and fodder, requires sustainable land use and integrated planning approaches at all levels in the country. The estimated potential of various biomass resources is: Biomass energy 17,000 MW, Co-generation 8000MW and energy from waste [MSW, etc.] 1000MW. The generation of municipal solid waste (MSW) increases with socio-economic development of urban population. In an emerging economy like India, rapid population growth has further added to the intensity of waste generation. Uncontrolled dumping of wastes on the outskirts of towns and cities has created overflowing landfills, which have environmental impacts in the form of pollution to soil, groundwater, and air, and also contribute to global warming. It is estimated that there is a potential of generating about 1500MW of power from urban and municipal wastes and about 1000MW from industrial wastes in the country, which is likely to increase further with economic development.

1.4.2 Types

- Mass burn Process/Incineration
- Biomass gasification
- Biogas Digester
- Pyrolysis (Plasma Arc Gasification)

1.4.3 Mass Burn process/Incineration

Mass burn, also called incineration, is the most common waste-to-energy technology. Garbage is combusted in a mass-burn facility with no or minimal pre-processing. Incineration is the combustion of organic material such as waste with energy recovery, is the most common WtE implementation. The method of using incineration to convert municipal solid waste (MSW) to energy generally entails burning waste (residual MSW, commercial, industrial and RDF) to boil water which powers steam generators that make electric energy and heat to be used in homes, businesses, institutions and industries.

1.4.3.1 Major zones of plant

- MSW receiving, handling, and storage systems.
- The combustion and steam generation system (a boiler).
- A flue gas cleaning system.
- The power generation equipment (steam turbine and generator).
- A condenser cooling water system.
- A residue handling and storage system.

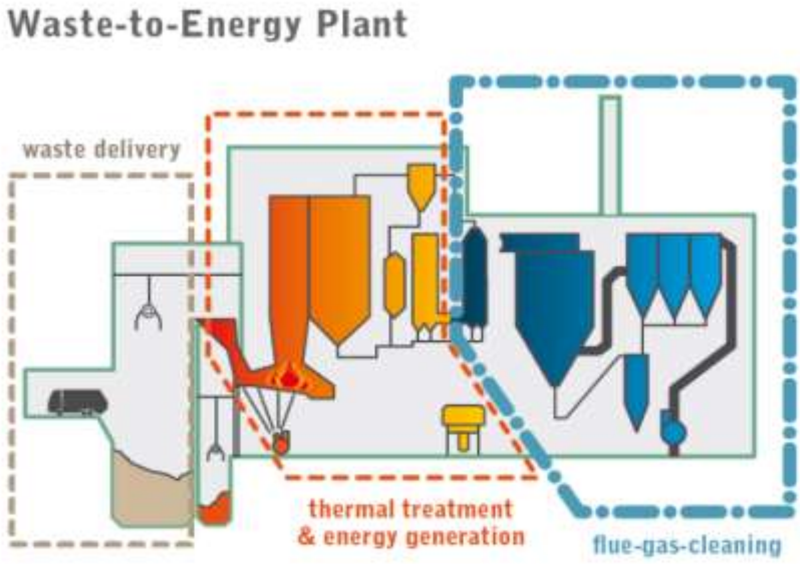

Figure 2: Different Zones of Incineration plant (Source: www.ramboll.com)

1.4.3.2 Working of Incineration

At MSW combustion facility, MSW is unloaded from collection trucks and placed in a trash storage bunker. An overhead crane is used to sort the waste and then lift it into a combustion chamber to be burned. The heat released from burning is used to convert water to steam. The steam is then sent to a turbine generator to produce electricity. The remaining ash is collected and taken to a landfill. Particulates are captured by a high-efficiency bag house (a filtering system). As the gas stream travels through these filters, more than 99 percent of particulate matter is removed. Captured fly ash particles fall into hoppers (funnel-shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger where they are wetted to prevent dust and mixed with the bottom ash from the grate. The ash residue is then conveyed to an enclosed building where it is loaded into covered, leak-proof trucks and taken to a landfill designed to protect against groundwater contamination. Ash residue from the furnace can be processed for removal of recyclable scrap metals. The diagram illustrates how the energy recovery process works.

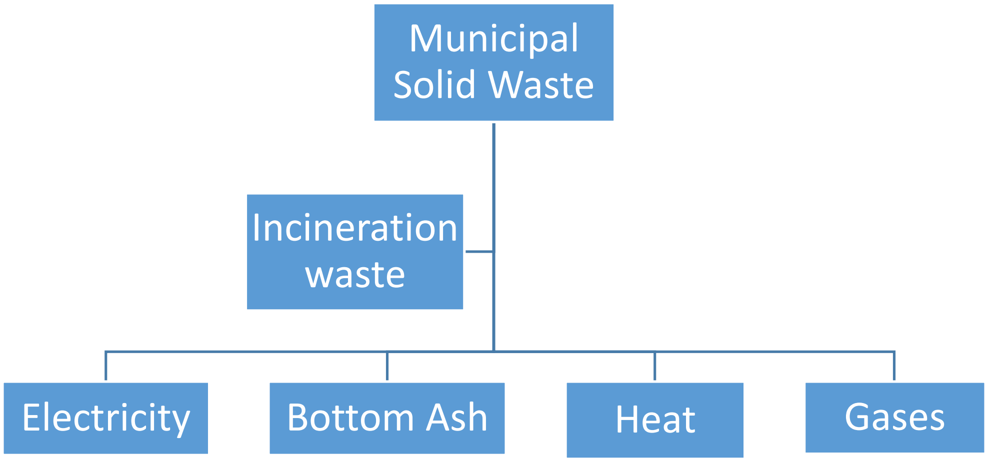

Figure 3: Flow Chart of Incineration plant

1.4.3.3 Operation of Energy-from-Waste Plant

- Municipal waste is delivered to our facilities and stored in a bunker.
- The waste is transferred to a combustion chamber where self-sustaining combustion is maintained at extremely high temperatures. We maintain the building around the tipping and bunker area under negative pressure and use this air in the combustion process to control odour.
- The heat from the combustion process boils water.
- The steam from the boiling water is used directly.
- More frequently, the steam drives a turbine that generates electricity.
- Electricity is distributed to the local grid.
- Ash from combustion is processed to extract metal for recycling. It is then combined with residue from the air pollution control process.
- The combined ash is either disposed of in a monofill (where only ash is stored) that receives only that waste, used as cover material at a conventional landfill, or land filled with other waste.
- All gases are collected, filtered and cleaned before being emitted into the atmosphere. We manage gas from the combustion process with state-of-the-art air pollution control technology that operates to state and federal standards.
- It controls emissions of particulate matter primarily through a bag house (fabric filter).

- It monitors criteria and other pollutants and operating parameters to ensure compliance with permit conditions.

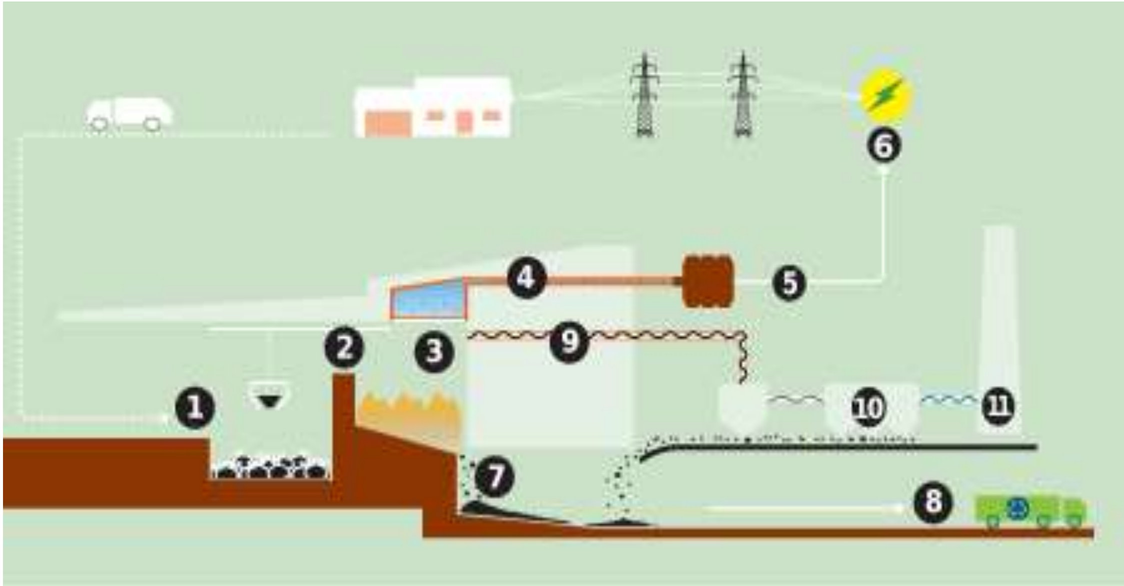

Figure 4: Operation of Incineration plant (Source: www.pollutionissues.com)

1.4.3.4 Advantages

- Contributing to security of energy supply providing energy from our residual waste and Helping to reduce dependence on (expensive) fossil fuels imports and preserve natural resources.
- Saving millions of tonnes of CO_2.
- Sustainable, local, low carbon, cost-effective and reliable energy.
- Helping to divert waste from landfills.
- Avoid the creation of methane - a potent greenhouse gas.
- Harness the energy content of residual waste.
- Save space (Waste-to-Energy reduces the volume of waste by 90%).
- Protect soil and groundwater from contamination.

1.4.3.5 Disadvantages

- High Capital Cost.

- Difficult to handle emissions such as dioxins.

1.4.4 Biomass Gasification

1.4.4.1 Introduction

Modern agriculture is an extremely energy intensive process. However high agricultural productivities and subsequently the growth of green revolution have been made possible only by large amount of energy inputs, especially those from fossil fuels. With recent price rise and scarcity of these fuels there has been a trend towards use of alternative energy sources like solar, wind, geothermal etc. However these energy resources have not been able to provide an economically viable solution for agricultural applications.

Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition), can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, methanol – an extremely attractive chemical which is useful both as fuel for heat engines as well as chemical feedstock for industries. Since any biomass material can undergo gasification, this process is much more attractive than ethanol production or biogas where only selected biomass materials can produce the fuel.

1.4.4.2 Chemical reactions

1. The dehydration or drying process occurs at around 100 °C. Typically the resulting steam is mixed into the gas flow and may be involved with subsequent chemical reactions, notably the water-gas reaction if the temperature is sufficiently high enough.

2. The *pyrolysis* (or devolatilization) process occurs at around 200-300 °C. Volatiles are released and char is produced, resulting in up to 70% weight loss for coal. The process is dependent on the properties of the carbonaceous material and determines the structure and composition of the char, which will then undergo gasification reactions.

3. The *combustion* process occurs as the volatile products and some of the char reacts with oxygen to primarily form carbon dioxide and small amounts of carbon monoxide, which provides heat for the subsequent gasification reactions. Letting **C** represent a carbon-containing organic compound, the basic reaction here is $\mathrm{C} + \mathrm{O}_2 \rightarrow \mathrm{CO}_2$.

4. The *gasification* process occurs as the char reacts with steam to produce carbon monoxide and hydrogen, via the reaction $\mathrm{C} + \mathrm{H}_2\mathrm{O} \rightarrow \mathrm{H}_2 + \mathrm{CO}$.

5. In addition, the reversible gas phase water-gas shift reaction reaches equilibrium very fast at the temperatures in a gasifier. This balances the concentrations of carbon monoxide, steam, carbon dioxide and hydrogen. $CO + H_2O \leftrightarrow CO_2 + H_2$.

In essence, a limited amount of oxygen or air is introduced into the reactor to allow some of the organic material to be "burned" to produce carbon dioxide and energy, which drives a second reaction that converts further organic material to hydrogen and additional carbon dioxide. Further reactions occur when the formed carbon monoxide and residual water from the organic material react to form methane and excess carbon dioxide ($4CO + 2H_2O = CH_4 + 3CO_2$). This third reaction occurs more abundantly in reactors that increase the residence time of the reactive gases and organic materials, as well as heat and pressure. Catalysts are used in more sophisticated reactors to improve reaction rates, thus moving the system closer to the reaction equilibrium for a fixed residence time.

1.4.4.3 Types

- **Updraft Gasifier**:

Here, the biomass moves down from the top of the gasifier while the gases released being light move up, resulting in a counter-current. The quality of producer gas obtained from the up-draft gasifier is fair since it has impurities like tar. However, this resultant producer gas has a higher capacity to generate heat on burning (due to the impurities) and can be used well for heat generation activities.

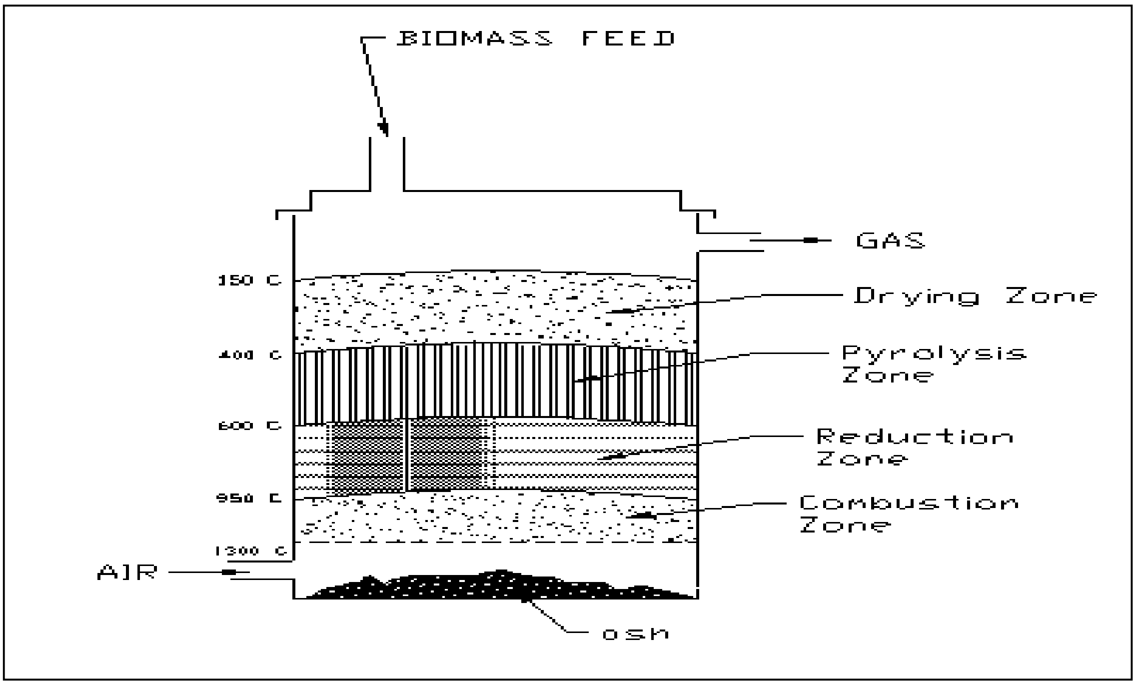

Figure 5: Updraft Gasifier (Source: www.knowledgepublications.com)

- **Downdraft Gasifier:**

Here the biomass moves down from the top of the gasifier and the resultant gas also moves downward—a co-current process. The gas quality is good though it generates less heat on burning. The gas released from such gasifiers is used mainly for electricity generation.

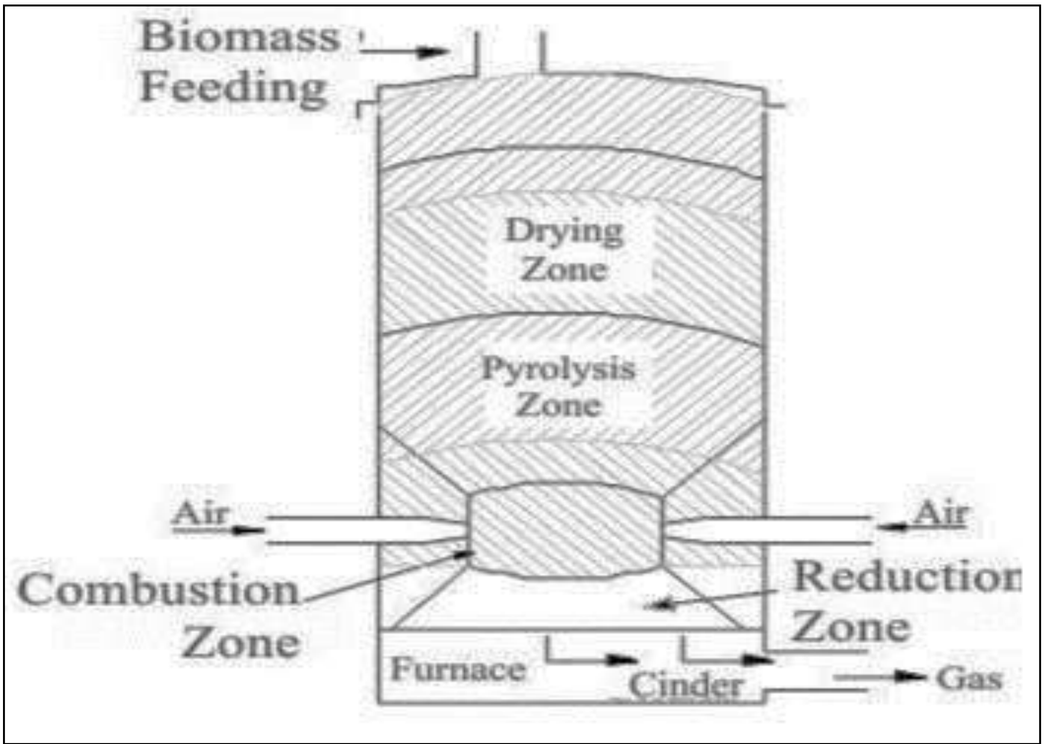

Figure 6: Downdraft Gasifier (Source: www.knowledgepublications.com)

1.4.5 Biogas

1.4.5.1 Introduction

Biomass is renewable organic matter derived from plants or from human, animal and municipal or industrial waste. It is an abundant and carbon-neutral source of energy, which has a potential to meet 15 to 50% of the world energy need by 2050. In India, 32% of the primary energy need is met from biomass and 70% of the rural population uses biomass for energy needs. The energy derived from biomass is called bio-energy and the bio-energy technologies convert raw biomass into a higher-grade energy such as electricity, gas or bio-fuel. The three main technologies for utilizing biomass are

- Bagasse cogeneration
- Biomass combustion
- Biomass gasification

for thermal and electrical applications.

Biogas digesters yield two useful products from animal manure: methane gas (CH4) and a liquid fertilizer.

(i) Biomass cost, (ii) operational costs including maintenance, labour etc. and (iii) capital recovery. Biomass gasification based power generation is often found to be financially unattractive for replacing grid electricity and most of the biomass gasification power plants in India are dependent of the additional revenue from carbon credits, irrigation water system, etc.

In rural areas, biogas plants mainly use cattle manure for cooking and lighting. Since the introduction of the programme over 4 million biogas plants have been installed, as of 2004, against a potential 12 million.

Biogas technology provides an excellent opportunity for carbon mitigation through the following:

- Replacing firewood for cooking.
- Replacing kerosene for lighting and cooking.
- Replacing chemical fertilizers.

1.4.5.2 Types

1. **Floating type**
2. **Fixed type**

In the past, floating-drum plants were mainly built in India and are therefore referred to as Indian drum biogas digesters or Indian floating cover biogas digesters.

Floating-drum plants are used chiefly for digesting animal and human faces on a continuous-feed mode of operation, i.e. with daily input. They are used most frequently by small- to middle-sized farms (digester size: 5-15 m^3) or in institutions and larger agro-industrial estates (digester size: 20-100 m^3).

A floating-drum plant consists of a cylindrical or dome-shaped digester and a moving, floating gas-holder, or drum. The gas-holder floats either directly in the fermenting slurry or in a separate water jacket. The drum in which the biogas collects has an internal and/or external guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back.

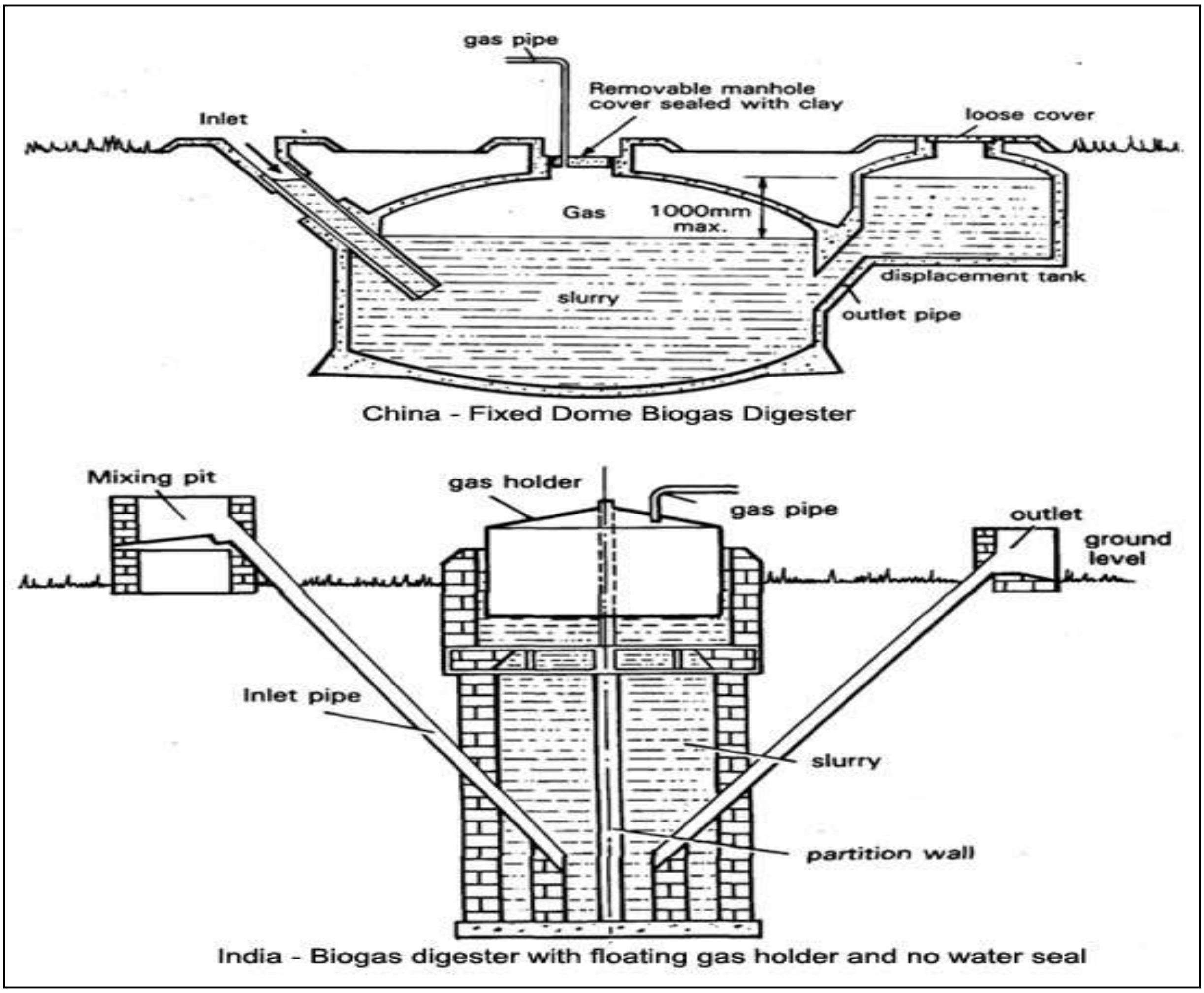

Figure 7: Biogas Plant (Source: www.knowledgepublications.com)

1.4.5.3 Advantages

Floating-drum plants are easy to understand and operate. They provide gas at a constant pressure, and the stored gas-volume is immediately recognizable by the position of the drum. Gas-tightness is no problem, provided the gasholder is de-rusted and painted regularly.

1.4.5.4 Disadvantages

The steel drum is relatively expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substrates are used, the gas-holder shows a tendency to get "stuck" in the resultant floating scum.

1.4.6 Pyrolysis (Plasma Arc Gasification)

1.4.6.1 Introduction

Plasma gasification is a process which converts organic matter into synthetic gas electricity and slag using plasma. A plasma torch powered by an electric arc is used to ionize gas and catalyze organic matter into synthetic gas and solid waste (slag). It is used commercially as a form of waste treatment and has been tested for the gasification of biomass and solid hydrocarbons, such as coal, oil sands, and oil shale.

1.4.6.2 Process

A plasma torch itself typically uses an inert gas such as argon. The electrodes vary from copper or tungsten to hafnium or zirconium, along with various other alloys. A strong electric current under high voltage passes between the two electrodes as an electric arc. Pressurized inert gas is ionized passing through the plasma created by the arc. The torch's temperature ranges from 4,000 to 25,000 °F (2,200 to 13,900 °C). The temperature of the plasma reaction determines the structure of the plasma and forming gas. This can be optimized to minimize ballast contents composed of the by-products of oxidation: CO2, N, H2O, etc..

The waste is heated, melted and finally vaporised. At these conditions molecular dissociation can occur by breaking down molecular bonds. Complex molecules are separated into individual atoms. The resulting elemental components are in a gaseous phase. Molecular dissociation using plasma is referred to as "plasma pyrolysis."

1.4.6.3 Feedstock

The feedstock for plasma waste treatment is most often municipal solid waste, organic waste, or both. Feedstock may also include biomedical waste and hazmat materials. Content and consistency of the waste directly impacts performance of a plasma facility. Pre-sorting and recycling useful material before gasification provides consistency. Too much inorganic material such as metal and construction waste increases slag production, which in turn decreases syngas production. However, a benefit is that the slag itself is chemically inert and safe to handle (certain materials may affect the content of the gas produced, however Shredding waste before entering the main chamber helps to increase syngas production. This creates an efficient transfer of energy which ensures more materials are broken down.

For better processing, air and/or steam is added into plasma gasificator.

1.4.6.4 Yields

Pure highly calorific synthetic gas consists predominantly of Carbon monoxide (CO), H_2, CH_4, among other components. The conversion rate of plasma gasification exceeds 99%. Non-flammable inorganic components in the waste stream are not broken down. This includes various metals. A phase change from solid to liquid adds to the volume of slag.

Plasma processing of waste is ecologically clean. The lack of oxygen prevents the formation of many toxic materials. The high temperatures in a reactor also prevent the main components of the gas from forming toxic compounds such as furans, dioxins, nitrogen oxides, or sulfur dioxide. Water filtration removes ash and gaseous pollutants.

The production of ecologically clean synthetic gas is the standard goal. The gas product contains no phenols or complex hydrocarbons however circulating water from filtering systems is toxic. The water removes toxins and the hazardous substances which must be cleaned.

Metals resulting from plasma pyrolysis can be recovered from the slag and eventually sold as a commodity. Inert slag is granulated. This slag grain is used in construction. A portion of the syngas produced feeds on-site turbines, which power the plasma torches and thus support the feed system. This is self-sustaining electric power.

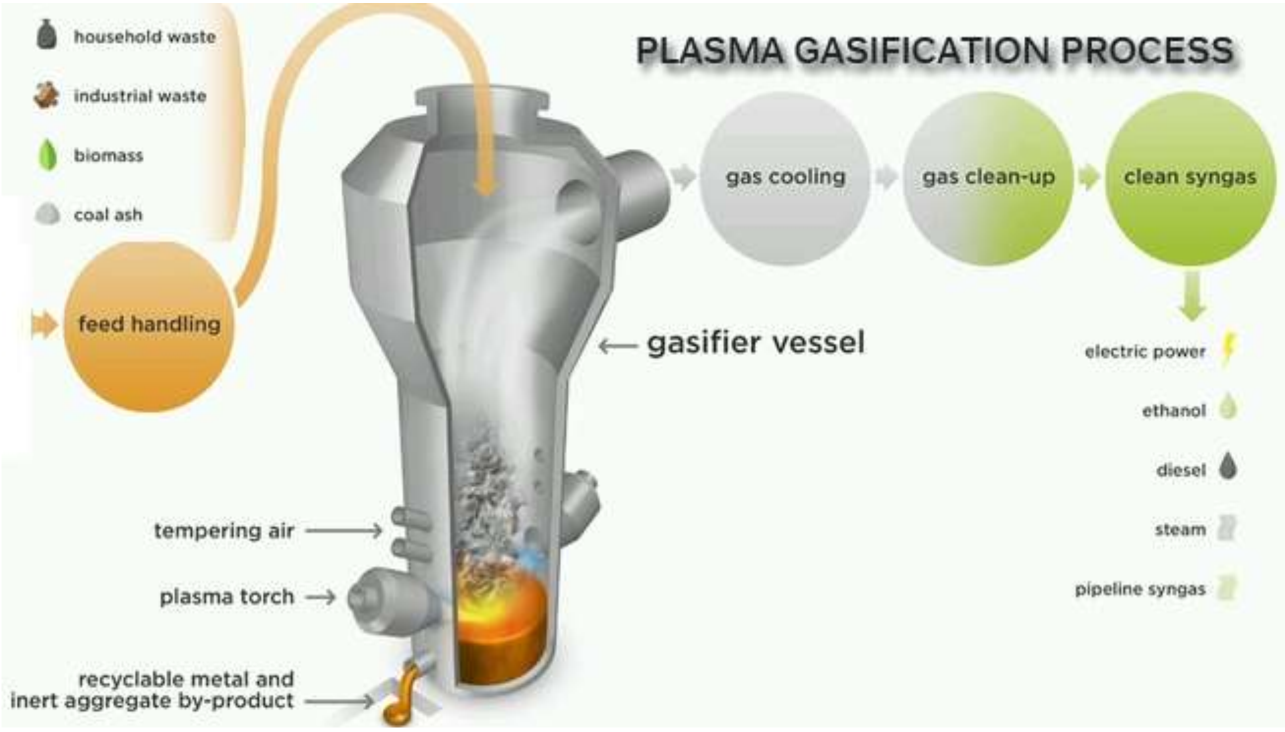

Figure 8: Pyrolysis Gasification (Source: www. wppenergy.com)

1.4.6.5 Advantages

- Clean destruction of hazardous waste.
- Preventing hazardous waste from reaching landfills
- No harmful emissions of toxic waste
- Production of clean alloyed slag which could be used as construction material
- Processing of organic waste into combustible syngas for electric power and thermal energy and production of value-added products (metals) from slag.

1.4.6.6 Disadvantages

- Large initial investment costs relative to landfill and
- The plasma flame reduces the diameter of the sampler orifice over time, necessitating occasional maintenance.

1.5 Government Initiatives (Waste to Energy)

- Project for generation of 16MW power from Municipal Solid Waste in Hyderabad city by M/s Jindal Ecopolis, Okhla, Delhi
- Project for generation of 5.7MW power from Municipal Solid Waste in Vijayawada city by M/s Shriram Energy Systems Pvt.Ltd., Hyderabad
- Project for generation of 11MW power from Municipal Solid Waste in Hyderabad city by M/s RDF Power Projects Ltd.,Hyderabad
- Project for generation of 2 MW power from Sugar Cane press mud by M/s St John Sangam Trust, Perambalur, Tamil Nadu
- Project for generation of 6 MW power from poultry waste by M/s Kakatiya Alloys Pvt. Ltd., Rangareddy Distt., A.P.
- Project for generation of 3 MW power from Poultry Waste by M/s Ramaprasad Pvt. Ltd., Tanaku, A.P.
- Project for generation of 7.5MW power from poultry wasteby M/s Rajabhaskar Power Pvt Ltd., Mundargi Vill., Billary, Dist. Karnataka.
- Project for generation of 3.6MW power from Poultry waste by M/s Raus Power Pvt. Ltd., Anaparthy Vill., East GodavariDist. A.P.

CHAPTER 2 LITERATURE REVIEW

Mufeed Sharholy et.al (2007)[17] used ArcGIS technique which included MSW sample collection and questionary survey on randomly selected houses and concluded that 45.3% of organic matter and 40% miscellaneous material (glass, paper, plastics etc.) and mentioned the qualitative and quantitative characteristics of MSW for MSWM for developing GIS maps for city of Allahabad. He also explained MSWSM collection, storage and disposal methods. Tsai et.al (2014)[33] did content and chemical analysis of MSW from year 2008 to 2012 with the use of CHP technology and compared the efficiency of plants of Taiwan with different parts of Europe, Germany and Netherlands. He also classified plants on the basis of capacity of waste handling, power generation and efficiency was done and discussed use of district heating and cooling and its use and advantage. S Rathi et.al (2014)[25] used Dulong Formulae heat energy in incineration technology to calculate and analyse potential generation of electricity in Kanpur city of 33MW from MSW of 1200 tonnes/day by considering conversion efficiency, station allowance, unaccounted heat loss and net power generated and classified solid wastes on physical and chemical composition. NIE et.al (2008)[19] explained new technology of circulating fluidized bed and emission of reduction by using equipment such as house filtration, flue gas cleaning and activated carbon in incinerator, adopted by 30 plants for development of China. Biodegradable matter shares 31-36% of total MSW in big cities and 65% in small cities having calorific value of around 5000KJ/Kg. Dioxin emission was limited to 1.0ng TEQ/Nm^3. Ojha et.al (2011)[21] explained, classified and compared cities on the basis of population, MSW composition, total waste generated; very big city, big city, medium city, small city and calculated potential of 1700 MW electricity from WTE incineration with some solutions and suggestion to problems occurring in MSWM. Siddharth Jain et.al (2011)[27] analysed and compared various methods i.e. biomethanation, incineration physically, chemically and economically using TGA/DTA method for calculating potential of 13300MWh/year from 85% biogas and rest diesel and 11083.33MWh/year from pure biogas from 190 tonnes/day of waste and calculated cost per KWh with or without subsidy in dual mode with biogas-85%, Diesel-15% and another when pure biogas was. Arena et.al (2015)[3] proposed the opinion to solve waste problem as using it as a resource. He explained WTE technology was successful and reliable because of thermal conversion, heat recovery and air pollution technique to reduce health and environmental risk, landfill substitute. Vikash Talyan et.al (2008)[35] discussed first incineration in Delhi, setup in 1989 at Timarpur to produce 3.7MW from 300 Tonnes of waste of calorific value higher 1000 Kcal/Kg but was closed in 21 days only due to falling of calorific value. First composting plant was setup in 1980 in Okhla and was shut down due to absence of market and high production cost. He explained three landfills in at Gazipur, Okhla and Bhalswa with LFG potential of energy generation $12.98*10^5$ Kwh/year. Ityona Amber et.al (2012)[10] calculated potential generation of 700KWh/tonne of electricity with calorific value of 17.23 MJ/Kg and conversion efficiency of 25% from incineration technology in Nigeria by considering methodology of analysing 5 samples of 10 Kg each of waste and evaluated that 43% of total MSW organic components are present while 8% are paper, cardboard, plastics. E. Autret et.al (2007)[7] overviewed design and operation of incineration plant on basis of composition of different type of wastes, suitable technique, avoiding environment effects and risk of human health. He described various incinerators techniques such as grate, fluidised bed and rotary kilns. He observed incineration plants replaced fossil fuel made of 50% natural gas and 50% oil in France. V G Sister (2006)[34] simulated plant model to improve the performance of waste incineration plant by considered gas turbine and steam cycle heat from outgoing fuel gases which resulted in efficiency of binary system gas incinerator of 42-45%. In addition he said Pyrolysis in incineration increases its efficiency by providing high yield of components of CO, H_2, and CH_4. Nitesh Dutt et.al (2011)[20] analysed, compared renewable source technology i.e. biomass waste including solid waste, sewage waste, and waste cooking oil in IIT Roorkee campus to calculate potential generation of total 396870 KWh annually of electricity out of which 180000 KWh from MSW, 72,000 KWh from kitchen waste, 870 KWh by Waste cooking oil and 144000 KWh from sewage treatment from 1.3 million litres per day of sewage water from MSW of 2190 Tonnes/ year and 238 tonnes per year of kitchen waste. He carried out cost assessment of cost per KWh without subsidy which was Rs 3.70 for Kitchen waste, Rs 2.80 for MSW and Rs 38.80 from Sewage treatment. Sieting Tan et.al (2014)[29] compared three WTE technologies i.e. incineration, landfill gas recovery and anaerobic digestion (AD) on environmental and economic basis which included includes transportation cost, carbon credit and sale of by-product of Taman Beringin, Malaysia landfill which can yield in 287% of increment in profit. CHG emission was checked on basis of Intergovernmental Pollution Climate Change (IPCC) guidelines. Incineration plants produced 1430 MW/day of heat and 480 MWh/day of electricity from 100 tonnes/day of waste. Hefa Cheng et.al (2007)[8] carried out methodology to study two incinerators of capacity each 250 tonnes/day having technology based on co-firing of MSW with coal in grate circulated fluidized producing 46.2 million KWh of electricity having calorific value of 3000-6700 KJ/Kg lower than developed countries of 8400-17000 KJ/Kg. In addition he calculated coal equivalent to MSW fuel ratio of 0.14, with saving of 0.2 million m^3 landfill yearly. Sudhanshu Kaushik et.al (2011)[31] studied the MSW generation during Kumb Mela 2010 at famous temples of Haridwar City; Mansa Devi & Chandi Devi located at Shiwalik Foothills on seven days of Hindu festival which includes Makar sakranti, Magh Purnima, Mahashivratri, Chaitra Amavasya and Full moon days by recording observations of individual composition of MSW according to days. 7615.0 Kg of Waste was produced at Mansa Devi Site and approximately 5000 Kg of waste was produced at Chandi Devi Site. He observed that 64.7% was biodegradable waste and 12.3% was non-biodegradable at Mansa Devi hillock and at Chandi Devi hillock 62.7% of biodegradable and 10.2% of non-biodegradable. C Liamsanguan et.al (2007) [5] compared incineration, landfill & conventional power plants using Life Cycle Assessment (LCA) methodology and declared that incineration had higher advantages for global warming & photochemical ozone formation over conventional power plants but from acidification and nutrient enrichment aspect incineration was not suitable. He described landfill with gas collection and flaring systems were much favourable than incineration technology. In addition he compared conventional plant's energy content which was much higher than of Municipal Solid Waste (MSW) and also conventional power plants had higher efficiency than incineration plants. Dioxins emissions from incineration plants cause health issues. Khaiwal Ravindra et.al (2015)[12] interestingly defined complete transfer of waste to RDF plant can save 5451 tCO_2 emission in Chandigarh and suggested new and better Municipal Solid Waste Management (MSWM) in which segregation of waste should be at source site only. Collection bin should be lifted every day irrespective of filled or partially filled. Special facilities of transportation during rainy season should be there to avoid rain water penetration. Carbon emission should be checked for storage, transportation, and disposal and processing site. Proper training of people involved in MSWM and their routine health check -up. Surindra Suthar et.al (2015)[32] carried out comparison of MSW composition along different family groups, economy and size of Dehradun city by a mass survey methodology on household waste for 3 months, collected and screened 11 different samples from 14 houses. He declared that food waste comprises major composition in household waste and biodegradable waste varied from 86.7%-96.1% of the total. In addition composting material has chemical quality product due to mixed collection of MSW. A Gallardo et.al (2015)[1] calculated door to door two wheel bin of sizes $0.06m^3$ or $0.12m^3$ and for kerb storage $1.1m^3$ sizes by using ArcGIS 10 and concluded For kerbside storage level pre collection, 95% of people had access to disposal site within 30m distance while in drop off 99.99% of citizens were having access within 150m in Spain. In addition, he determined waste fractions, the level of storage, after it location of the MSW disposal points, after the volume of MSW disposal points and bins selection. Storage level selection depends on population density and located MSW disposed sites by using Geographical Information System (GIS). Y Huang (2015)[36] compared two projects A & B of incinerator Plant being setup in China to focus on public acceptance or participation of people especially residing nearby plant to accept and promote this technology, having same technology, geographically close and variation in social and environmental impact. Structured questions and face to face questions regarding environmental impacts, social impacts of incinerators on them were asked. Four representative districts for project A and five for project B were selected for data collection from public. He discussed the result of survey that around 60% residents respond no change in road conditions in project A while in project B 83% agreed that road become well. In project A 53.6% people were not clear about whether environment was improved or not while for project B 30% believe environment slightly improved. 17% in project B while 7.4% in project A believed to support traditional method of landfill as a MSWM solution. 20% in project A and 52.8% in project B support in favour of setup of incineration plant. However project A was not successful and project B was successfully set up. Subhashish Chattopadhyay et.al (2009)[30] explained Kolkata City MSWM in three steps; collection, storage and transportation with emphasising on environmental and health issues, consisted MSW methodology as street sweeping cleaning for residential, commercial, slum and offices, collection of wastes starts from 7:30 am and 10:30 am. Wastes from large hotels, restaurants are regular transported by Kolkata Municipal Corporation (KMC) as they have their own vehicles. MSW generation was of about 3000 tonnes/day. 70-76% of expenditure of funds spent on collection of MSW while 20-25% on transportation and rest in final disposal. Dhere et.al. (2008)[6] studied the adverse impact of municipal solid waste on air and ground water due to the improper disposal of waste in Pune city. Waste material also impacts the soil quality as pointed out by Ahel et.al. (1998)[2], mainly by increasing the concentration of various hazardous elements of soil through municipal solid waste. Omofonmwan and Esiegbe (2009)[23] reported the ground water contamination due to the lechate contribution of the solid waste in metropolitan city of Nigeria. Zade and Noori (2008)[37] also described the adverse impact of solid waste in concerned areas. Mondal et.al (2010)[16] described the role of WtE to manage the solid waste problems. L A Manaf (2009)[13] studied the status of MSW generation and management practices adopted in Malaysia having MSW generation rate of 1.7 Kg/capita/day. He estimated increase in waste generation to 31,100 tonnes by 2020. In Malaysia MSW composition mainly comprises of food, paper, and moisture content. 50% of the total budget of local authorities is spent on collection and collection efficiency being 76%. He concluded that 20% of life can be extended by successful community participation for recycling technique. Management by government lacks coordination, participation, mutual interaction, understanding which results unstable waste management. L Tobiasen et.al (2014)[14] compared two types of technology of WTE i.e. anaerobic digestion and incineration for energy recovery by using life cycle assessment (LCA) methodology to determine marginal incinerator energy efficiency. He reviewed two models of incineration i.e. power production only and combined heat power (CHP) with boundary conditions i.e. power only, CHP, CHP & flue gas condensation, average efficiency if MSW, marginal efficiency of green bin waste (GBW) for incineration and efficiency of GBW for biogas plant and showed that waste heat energy can be converted to electricity in CHP plants. He also described 3 biogas production models of anaerobic digestion (AD) i.e. power only reciprocating gas engine, heat recovery and heat recovery and flue gas condensation. M Chakraborty et.al (2013)[15] explained three types of WTE technologies i.e. Refused Drive Fuel (RDF), biomethanation and incineration to deal with the landfill consequences by considering two cases i.e. first when assumed all the waste (bulk MSW) is dumped and secondly segregated MSW which consisted readily compostable and street sweeping waste. He discussed the 3 landfills of Delhi city of country India i.e. Gazipur (GL), Okhla (OL), Bhalswa (BL) and calculated their energy potential i.e. LFG generates in GL, OL & BL energy from segregated waste is 3-4, 2-3, 3-4 MW/day respectively and from bulk waste is 7-10, 5-8, 6-8 MW/day respectively. From incineration process electricity generation potential from segregated waste was 8-12, 7-11, 7-11 MW/day in GL, OL and BL respectively and from bulk MSW is 18-24, 14-19, 16-22 MW/day respectively. While using pyrolysis technique 17-32, 16-29, 11-25 MW/day can be produced respectively in GL, OL, BL landfills. From refused derived fuel (RDF) average energy potential from segregated waste and bulk MSW is 9-19, 6-15, 8-18 MW/ day respectively for different landfills and finally plasma arc gasification technique yields average energy of 17-35, 26-32, 11-28 MW/day respectively. J Rodrigues-Anon et.al (1998)[11] performed experiment on static bomb calorimeter and developed laboratory refused derived fuel (RDF-L) to compare with the calorific value of conventional residual derived fuel (RDF-C) by collecting MSW samples from three towns of Spain; Moana, A Guarda, and Ponteareas and resulted Calorific value of RDF-L and RDF-C of HHV (KJ/kg) for RDF-C was 15887 while RDF-L was 9263. And LHV (KJ/Kg) for RDF-C was 14536 while RDF-L was 9263. Two samples were made i.e. one with MSW samples as in received condition and another had different components. First sample was to calculate moisture content and was used to calculate the calorific value of individual components. S B Karajgi et.al (2012)[24] proposed a mathematical model to minimize the cost for incinerators in relation to cost liner equations of waste flow patterns by considering various costs such as wage provided to different workers for door to door collection, separation of wastes, and transportation to final site. He calculated potential of energy generation of 68390 KWh/day and concluded that composition pattern of wastes from residential should be sent to compost yard while, non-composite to incineration and paper, wood, Non-recyclable and commercial waste suitable for incineration should be directly sent to incineration facility rest was to dump. Sie Ting Tan et.al (2014)[28] analysed five modals i.e. no WTE implementation, LFG recovery only, 64% LFG recovery & 36% incineration, 36% Incineration & 64% LFG Recovery, Incineration only on basis of Electricity Potentials, Carbon Credit, Electricity Sale, operational and maintenance cost, net profit by considering methodology of collecting data of population, MSW generation, composition; moisture content to study feasibility of WTE assessment which included energy potential modal, net carbon emission modal and concluded that 64% LFG Recovery & 36% incineration modal is best suited for WTE technique in Malaysia. Narayana et.al (2009)[18] evaluated incineration on the basis of health impact, economic, medical waste and scenario in India and studied composting was unsuccessful in developing countries because of improper application and mixed waste which has non organic materials also causes toxicity to finished product and concluded an approach to segregate waste during collection time and only organic waste should be sent to compost plant and rest part should be recycled and thus compost product should be sold to farmers. Qingshi Tu et.al (2015)[22] analyzed technically, economically and environmental and calculated potential of three waste to energy (WTE) technologies for university of Cincinnati i.e. biodiesel from cooking waste oil, biogas from kitchen waste, fuel pellets by waste paper by adopting life cycle assessment methodology and resulted annual production of Biodiesel was almost 3712 L and by product glycerine of 269 L of quantity. 6000 tonnes of generation of food waste produced 6400MWh per year of electricity and further evaluated payback for the technology is 16, 155 and 74 months for biodiesel, fuel pellets and anaerobic digestion respectively. Z Shareefdeen et.al (2015)[38] compared 3 Waste to Energy technologies i.e. incineration, gasification and plasma arc in Canada and concluded gasification was suitable technology from environmental and economic point of view. In Metro Vancouver WTE facility 300000 tonnes/year of waste produced 180000MWh/year of electricity. Two flue cleaning gases systems were there using lime, ammonia and activated carbon. In Emerland Energy facility 150000 Tonnes/year was processed to produce 27000 MWh/year of energy by incineration technology. Enerkem Alberta Biofuels LP used Biogasification technology and produced Biomethnol as final product. UBC bioenergy research and demonstration facility was using 12500tonnes of dry wood waste out of which 15000 MWh of electricity was produced and 490 tonnes of steam was also produced which used biogasification process. In Plasco trail road commercial demonstration facility produced 174 MWh of electricity from 1433 tonnes in 644 hours of operation by pyrolysis technique while using same technique Duffein Eco-Energy park facility produced 24500MWh from 100000 tonnes of MSW. Samir Saini et.al (2012)[26] studied techno-economic feasibility of different types of WTE technologies of 75 Cities of India. He categorized cities in 4 groups i.e. Tier I, Tier II, Tier III, and Tier IV in his methodology according to population over 20,00,000, between 5,00,000-20,00,000, 1,00,000-

5,00,000 and less than 4,00,000 respectively. In Tier I Jaipur city generated lowest MSW of 904 Tonnes/day, calorific value 834 Kcal/Kg and moisture content 21%. While Chennai city generated highest MSW of 3036 Tonnes/day, calorific value 2594 Kcal/Kg and moisture content 47%. In Tier II city Guwahati generated lowest MSW of 166 Tonnes/day, calorific value 1519 Kcal/Kg and moisture content 61%. While Ludhiana city generated highest MSW of 735 Tonnes/day, calorific value 2559 Kcal/Kg and moisture content 65%. In Tier III Yavatmal city generated lowest MSW of 24 Tonnes/day. Ulhasnagar city generated highest MSW of 236 Tonnes/day. In Tier IV Kavaratti city generated lowest MSW of 3 Tonnes/day, calorific value 2242 Kcal/Kg and moisture content 25%. Port Blair city generated highest MSW of 76 Tonnes/day, calorific value 1474 Kcal/Kg and moisture content 63%. Further he said Maharashtra has energy potential of 470.19MW and Lakshdweep had potential of 0.08MW. Buenrostro et.al (2001)[4] classified municipal solid waste at the source that will be very useful to manage the waste especially for the developing countries.HM Zakir Hossin et.al (2014)[9] explained WTE technologies such as Biomethanation, pyrolysis and land gas recovery which can generate 186 MWh/day of electricity from 7765 Tonnes/day of waste to deal energy security problem in Bangladesh In Bangladesh 6 different corporations: Khulana City Corporation (KCC), Dhaka City Corporation (DCC), Chittagong City Corporation (CCC), Rajshahi City Corporation (RCC), Barisal City Corporation (BCC), Sylhet City Corporation (SCC) work for the collection, transportation, disposal and treatment of MSW and mentioned the composition analysis with quantity percentage of each corporation, total MSW generation in KCC, DCC, CCC, RCC, BCC, SCC was 595 Tonnes/day, 5340 Tonnes/day, 1315 Tonnes/day, 170 Tonnes/ day, 130 Tonnes/day, 215 Tonnes/day, respectively and electric power generation (KWh/day) from landfill process is 14328, 128160, 31560, 4080, 3120, 5160 respectively.

2.1 Conclusions from literature review

Population and urbanization increased rapidly in developing countries which is causing increase in waste generation and exhausting landfills. There were various advantages to use WTE technologies as a part of MSWM were to avoid landfills, generating electricity to alternative to fossil fuel and thus reducing carbon foot print. While this technology was suppressed in developing countries due to capital cost, environmental impacts, operational and maintenance cost. Energy from MSW is emerging economy in Countries as land is unavailable for dumping, disposal and unorganized disposal of MSW which is the cause of emission of greenhouse gases. Due to environmental change and disposal problem there was a need for efficient waste management and thermal treatment to produce electricity. Waste Management is a matter of concern. Since population & urbanisation is increasing, waste generation is also increasing. Uncontrollable green-house gases (GHGs) emission from landfill causes health hazard. Leachate treatment is not available which threats to ground water. Solid waste generation mainly depends on urbanization and economic development. Current MSWM includes generation, storage, collection, transfer and transport. Waste management involved the role citizens, Government, private sector. Huge investment with less return makes it unpopular in developing countries also due to low calorific value it is not popular in India but with technology up gradation and awareness this can be achieved.

2.2 Research gap identified

In spite of large studies have been performed on municipal solid waste management available in the literature so far however the following problems are state to be solved:

- Detailed analysis of conventional plants.
- Technical and economic feasibility of Indian landfills.
- Policy discussion for promoting WTE by central and state government.
- Health and environmental risk comparison from landfill with Incineration Plant.
- Community participation in India.
- Improvement in current MSWM method adopted in cities.
- Role of private sector, CSR in Solid Waste Management.
- Improvement of incineration plant by CFD simulation.

2.3 Objectives

- Study of current Municipal Solid Waste Management (MSWM).
- Comparison of different Waste to Energy technologies i.e. incineration, Biogasification , Biomethanation, Pyrolysis.
- Theoretical Calculation of Energy potential from waste on basis of Literature Review.
- Collection of sample of wastes.
- Proximity & Ultimate Analysis of sample.
- Calculation of potential of energy on basis of analysis.
- Mathematical modelling of plant.

CHAPTER 3 CASE STUDY ROORKEE CITY

3.1 GEOGRAPHIC DESCRIPTION

Roorkee is a city in Haridwar district, Uttarakhand that is located on 29^{o} 51’North latitude and 77^{o} 53’East longitude. Its municipal boundary is spread from 29^{o} 54’to 29^{o} 51’ north latitude and from 77^{o} 51’to 77^{o} 53’ east longitutde. The area of Roorkee Municipal corporation or Roorkee Nagar palika is 40 Sq Km. The municipal area is extended from the 29^{o} 54’ in the north to 29^{o} 49’ in the south and 77^{o} 50’ in the west to 77^{o} 54’in the east.

3.2 ADMINISTRATIVE SETUP OF ROORKEE CITY

Table 2: List Administrative Zones of Roorkee City

Zones	**Name**	**Zones**	**Name**
1	Cantt Area	15	Adarsh Nagar
2	Ramnagar	16	Shivalik Nagar
3	IIT Roorkee	17	Vikas Nagar
4	Civil Lines	18	Chaow Mandi
5	Main Bajar	19	Amber Talab
6	Sati Mohalla	20	Rampur Chungi
7	IRI Colony	21	Subhash Nagar
8	Purani Tehsil	22	Rajendra Nagar
9	Avas Vikas	23	Shastri Nagar
10	Maktulpuri	24	South Civil Lines
11	Azad Nagar	25	Khanjarpur
12	Chandrapuri	26	Geetanjli Bhawan
13	Krishna Nagar	27	Preet Vihar
14	Ganeshpur		

3.3 CURRENT STATUS OF MSWM OF ROORKEE

Following are the basic fundamentals of Solid Waste Management System:

Figure 9: Flow Chart of MSWM in Roorkee

So Waste collection, storage, transportation and its disposal of Roorkee City were analysed.

Following were the observations:

- Waste is not segregated at source into desirable and non- desirable waste.
- Community Bins and street sweeping is used for primary collection of waste.
- Door to door primary collection by engaging sweepers working under municipality.
- Waste treatment and processing is the most neglecting part in the system.
- Sweepers and sanitary workers engaged by the Municipality sweep the streets.
- They accumulated the collected waste into small heaps and subsequently loaded manually or mechanically onto the community containers/bins or directly loaded onto the solid waste transportation vehicles.
- After Loading these Vehicles go for disposal site.
- Roorkee Nagar Palika Parishad presently utilizes the Transport vehicles such as: TATA ACE, Tractor Trolley, Compactor and Dumper.
- Lack of Communal Bins in Khanjarpur, Purani Tehsil, Main Bazar, Sati Mohalla.
- The drains along the road and main sever lines near Amber Talab, Subhash Nagar, Rajendra Nagar are blocked because of inappropriate drainage and incorrect disposing of waste.

Table 3: Waste generation year wise

S. No.	Year	Population	Waste Generation (Kg/capita/day)	Total Waste Generation (In Tonnes)
1	1981	237294	0.30	71
2	1991	261223	0.35	91
3	2001	301268	0.42	127
4	2011	355478	0.45	160

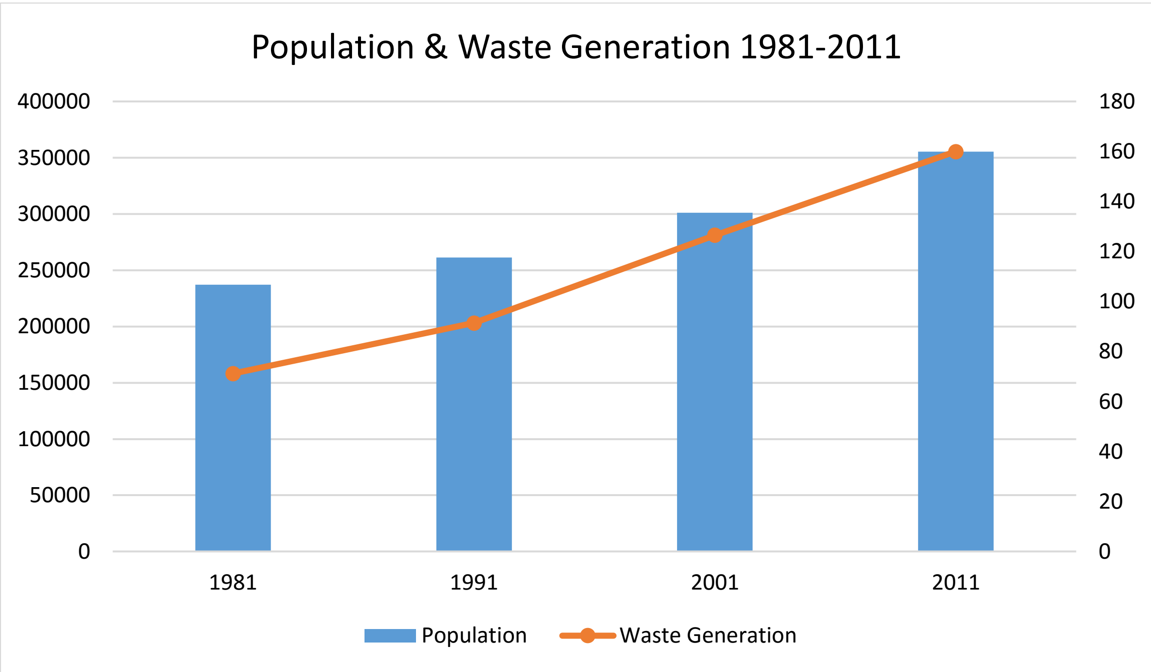

Figure 10: Year wise population and waste generation growth

3.3.1 Future Population Projection and Waste Generation Estimation

Projection and estimation of the Population and Waste generation is required to handle the management system in nearby future. Population Rise rate from year 1981-2011 is determined. Fluctuating rate of increase is observed in population growth from year 1981-2011 therefore for future projection of the population, incremental increase method is used.

Table 4: Projected Waste Generation year wise

S. No.	Year	Population	Waste Generation (Kg/capita/day)	Total Waste Generation (In Tonnes)
1	2016	430128.38	0.450	194
2	2021	524756.6236	0.455	238
3	2026	655945.7795	0.460	300
4	2031	852729.5134	0.465	396
5	2036	1125602.958	0.470	529
6	2041	1497051.934	0.475	711

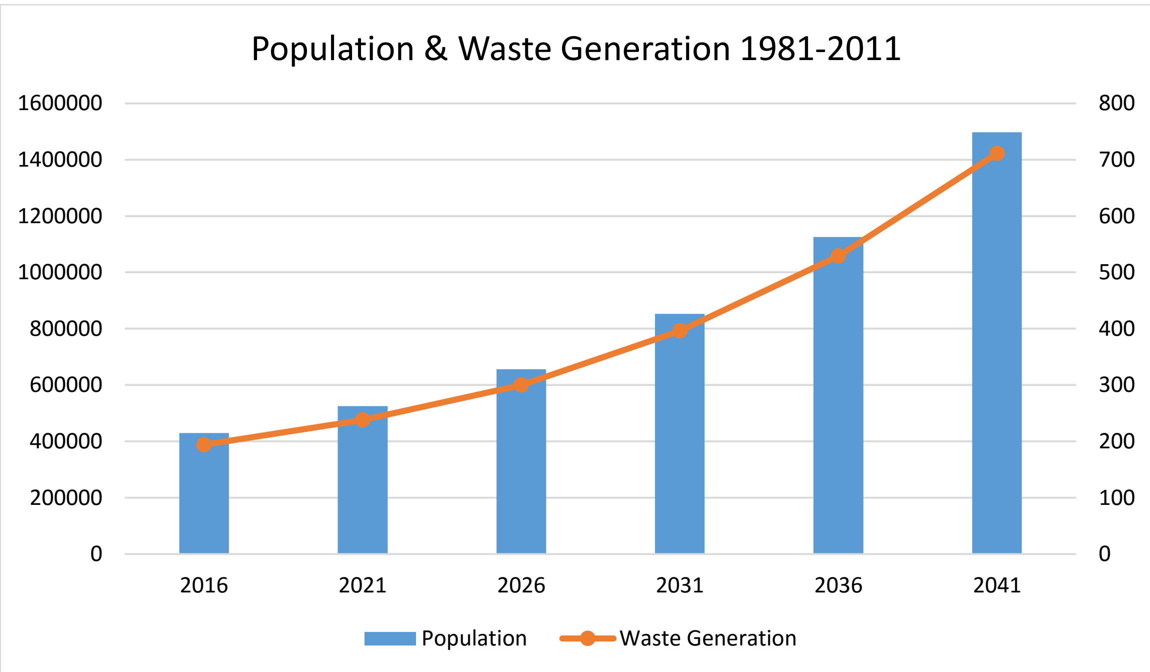

Figure 11: Projected Year wise population and waste generation growth

3.3.2 Amount of waste generated

In Roorkee City primary waste collection method involves communal bins, street sweeping and door to door collection. It is also observed that manpower is not distributed according to the area size and waste generation in some parts of Roorkee city more manpower than required is there. Street sweeping method is outdated or the tools and equipment used are less efficient. Communal Bins are not in adequate numbers to handle the waste of particular area. Collection of waste takes more time as compared to usual time as worker firstly collect the waste in a wheel barrow then transfer it to the collection point which in all increases the overall collection time. [Picture]

The city generates, on an average, about **220 MT** of MSW per day. The major sources of MSW generation of the city are domestic, shops and commercial establishments, hotels, restaurants, dharamsalas and fruit and vegetable markets. Number of registered hotels, restaurants and dharamsalas in the city are 90, 50 and 52 respectively. In addition, there are 3 fruit and vegetable markets. Out of which 1 market is excluded as it is not under Roorkee Nagar Palika Parishad [RNPP].

Collection efficiency is around 60- 70 % for Roorkee City. Generally, three types of communal bins are used by RNPP i.e. 1 cubic meter, 3 cubic meter & 7 cubic meter. In overall total no. of bins are 156.

Table 5: Renewable Energy actual installation and target Grid Interactive (Source: MNRE)

Zones	**Name**	**Types of Bins**			**Total No. of Containers**
		1 Cubic Meter	**3 Cubic Meter**	**7 Cubic Meter**	
1	Cantt Area	13	3	5	21
2	Ramnagar	7	2	1	10
3	IIT Roorkee	6		2	8
4	Civil Lines	2	3	1	6
5	Main Bajar	4		1	5
6	Sati Mohalla	4	3	1	8
7	IRI Colony	3	1	1	5
8	Purani Tehsil	3	1	1	5
9	Avas Vikas	5	-	-	5
10	Maktulpuri	5	1	-	6
11	Azad Nagar	4	1	-	5
12	Chandrapuri	7	1	-	8
13	Krishna Nagar	3	-	-	3

14	Ganeshpur	9	2	1	12
15	Adarsh Nagar	5	1	1	7
16	Shivalik Nagar	3	-	-	3
17	Vikas Nagar	2	-	-	2
18	Chaow Mandi	4	-	1	5
19	Amber Talab	3	1	1	5
20	Rampur Chungi	5	2	-	7
21	Subhash Nagar	2	-	-	2
22	Rajendra Nagar	2	-	-	2
23	Shastri Nagar	1	1	-	2
24	South Civil Lines	4	1	2	7
25	Khanjarpur	2	-	-	2
26	Geetanjli Bhawan	3	1	-	4
27	Preet Vihar	-	1	-	1
	Total	**111**	**26**	**19**	**156**

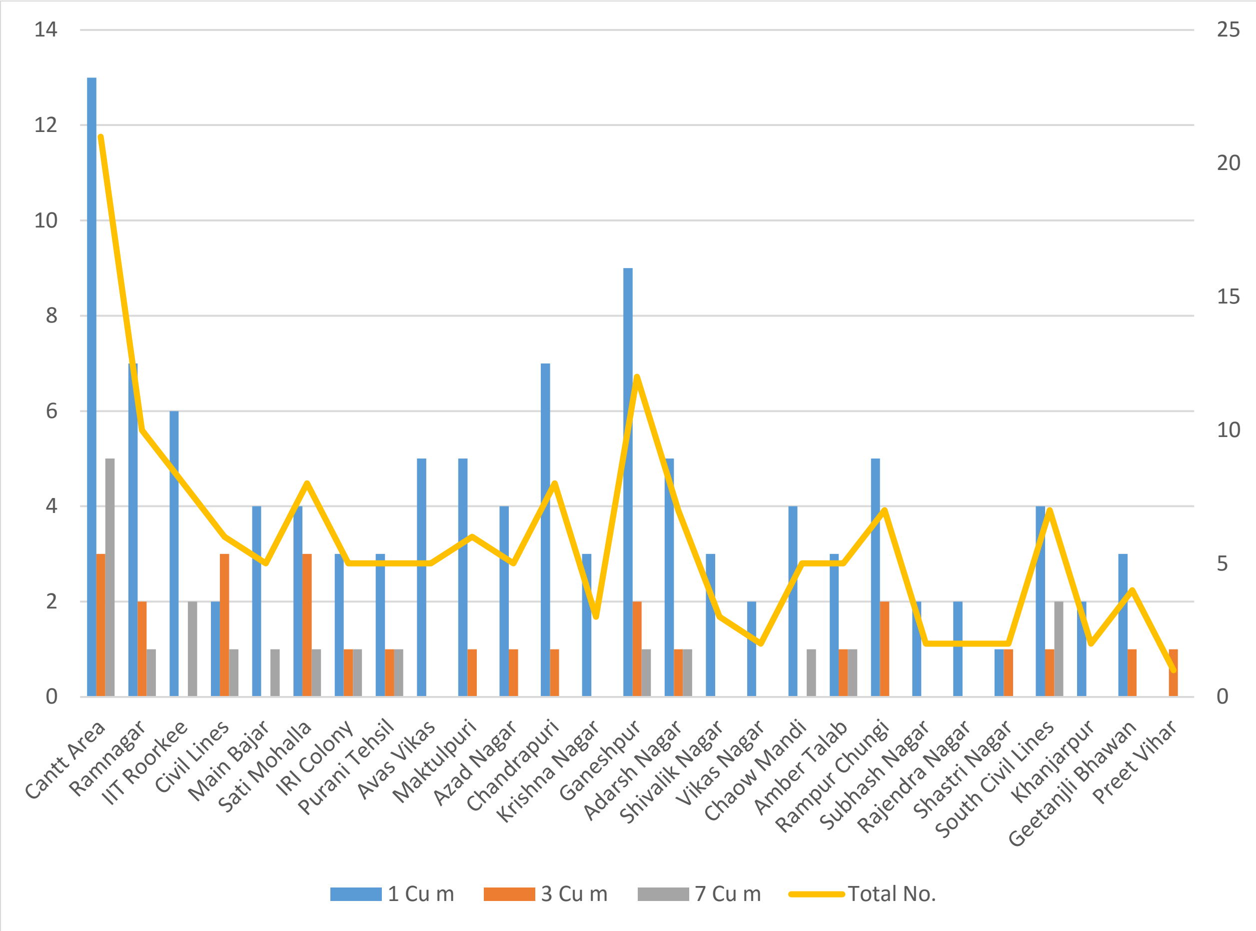

Figure 12: Zonal Wise Communal Bins Distribution

So in total 156 communal bins are there out of which 111 are of 1 cubic meter, 26 are of 3 cubic meter and 19 are of 7 cubic meter. So above table clearly shows that adequate number of bins are not there in city to handle the complete Roorkee city waste.

3.3.3 Dumping vehicles

Mostly loading or transfer of waste to vehicles is manually which increases time and use of manpower. Usually under light vehicles: Wheelbarrows & hand carts are used for door to door and street sweeping. These vehicles also load the waste in medium vehicles such as tractor trolleys and TATA ACE. Medium Vehicles transfer the waste to land fill. Heavy vehicles compactor and dumper are used as dumping vehicles. Usually vehicles trip start from early morning 7 AM to Evening 6 PM. Usually Light vehicles make 6-7 trips daily while Heavy vehicles make 4-5 trips only per day.

Figure 13: Vehicles used for dumping in Roorkee City

Figure 14: Vehicles used for dumping in Roorkee City

Table 6: Vehicle Carrying MSW

S.No.	Vehicle Type	Amount of MSW (in MT)	Quantity of vehicles	No. of Trips	Total
1.	TATA Ace	1.6	9	7	100.8
2.	Tractor Trolley	2.5	5	6	75
3.	Compactor	3.1	2	4	24.8
4.	Dumper	5	1	3	15

So total MSW generated per day averagely = **215.6 MT .**

3.3.4 Dumping Site

At present RNPP disposes the solid waste of the city to one site located at the side of the national highway-74 at a distance of about 3 km from the city. In this site waste disposal is done by uncontrolled dumping village Saliar. Near Guru Ram Rai Public School which is located 500 meters from dumping site.

Figure 15. : Landfill Site at Roorkee City

Figure 16. : Landfill Site at Roorkee City

Table 7: April Month Waste generation and No. of trips

S.No.	Date (April 2015)	Total Weight (in MT)	Number of Trips
1	6th	195	18
2	7th	183	17
3	8th	217	21
4	9th	188	17
5	10th	163	15
6	11th	195	18
7	12th	192	18
Total		1333	124

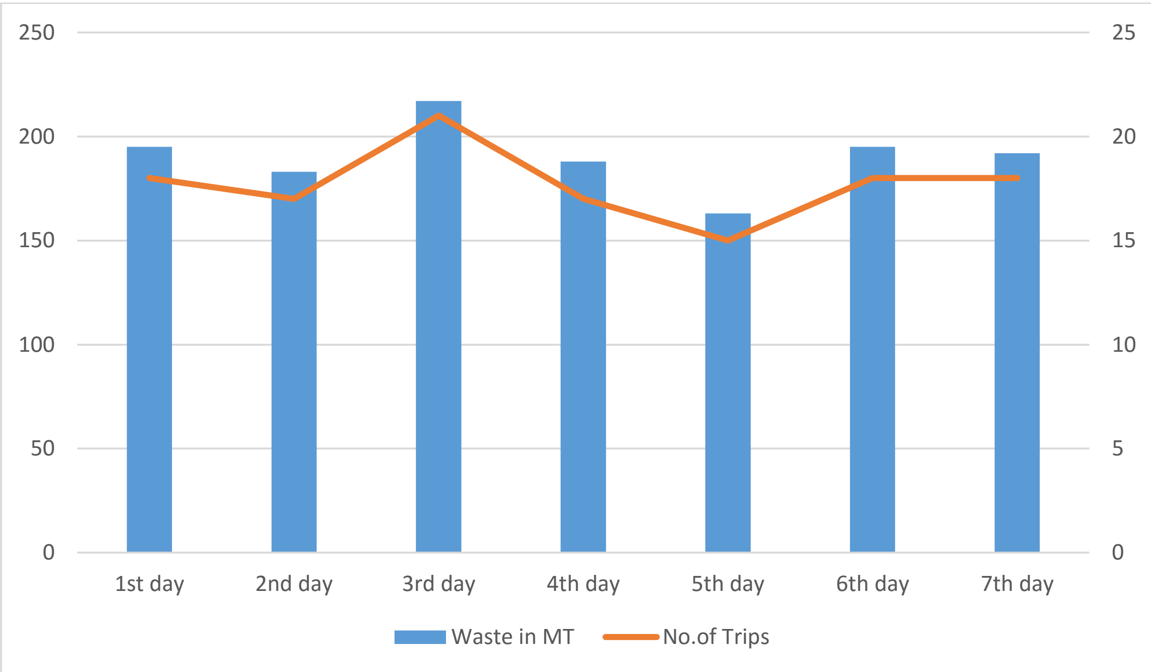

Figure 17: April Month Waste Generated and number of trips

Table 8: May Month Waste generation and No. of trips

S.No.	Date (May 2015)	Total Weight (in MT)	Number of Trips
1	4th	200	19
2	5th	195	19
3	6th	190	18
4	7th	197	19
5	8th	201	20
6	9th	185	18
7	10th	179	17
Total		1347	130

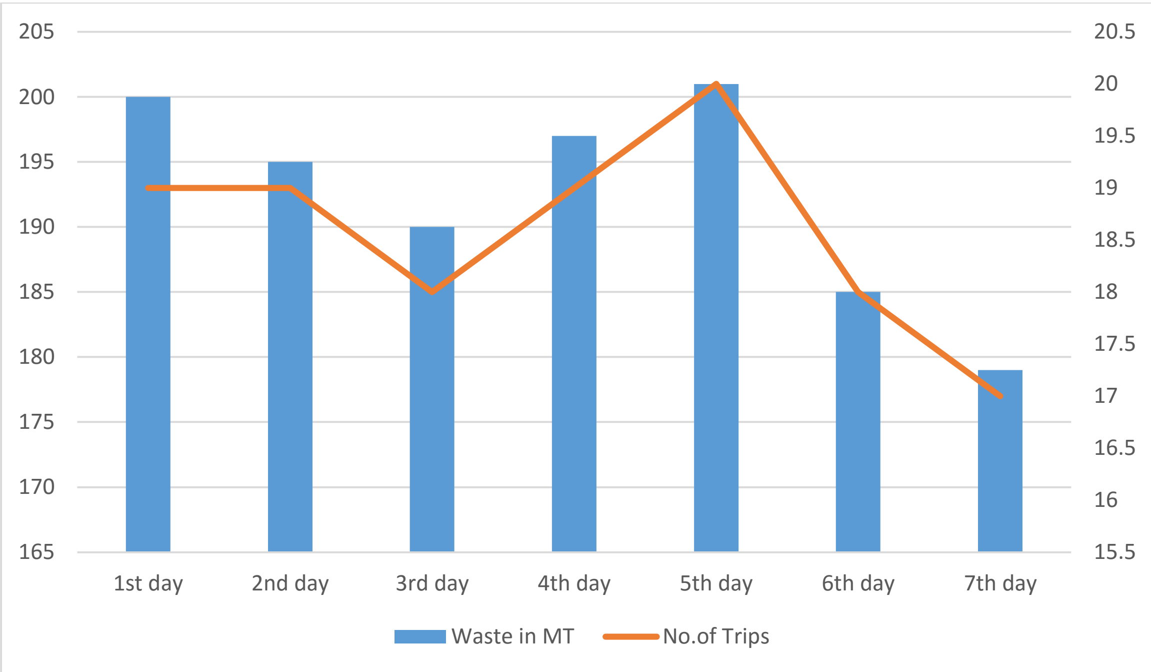

Figure 18: May Month Waste Generated and number of trips

Table 9: June Month Waste generation and No. of trips

S.No.	Date (June 2015)	Total Weight (in MT)	Number of Trips
1	1st	172	16
2	2nd	196	20
3	3rd	185	17
4	4th	188	17
5	5th	181	17
6	6th	167	16
7	7th	179	17
Total		1268	120

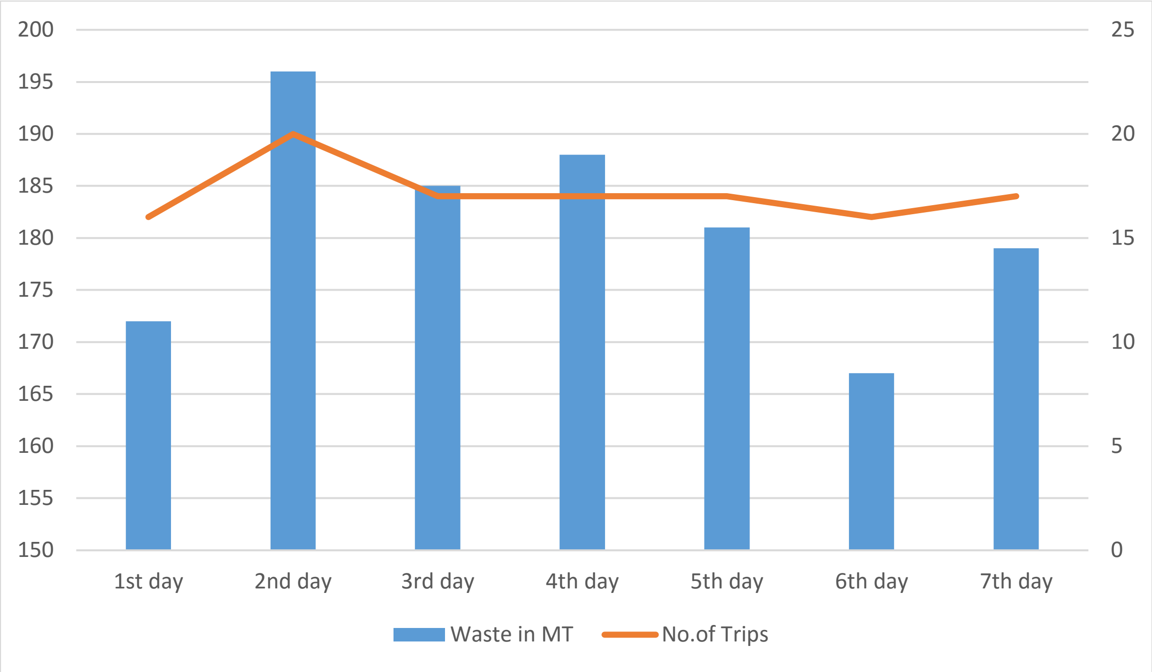

Figure 19: June Month Waste Generated and number of trips

Table 10: July Month Waste generation and No. of trips

S.No.	Date (July 2015)	Total Weight (in MT)	Number of Trips
1	1st	162	15
2	2nd	165	15
3	3rd	158	14
4	4th	152	15
5	5th	165	16
6	6th	157	15
7	7th	145	14
Total		1104	104

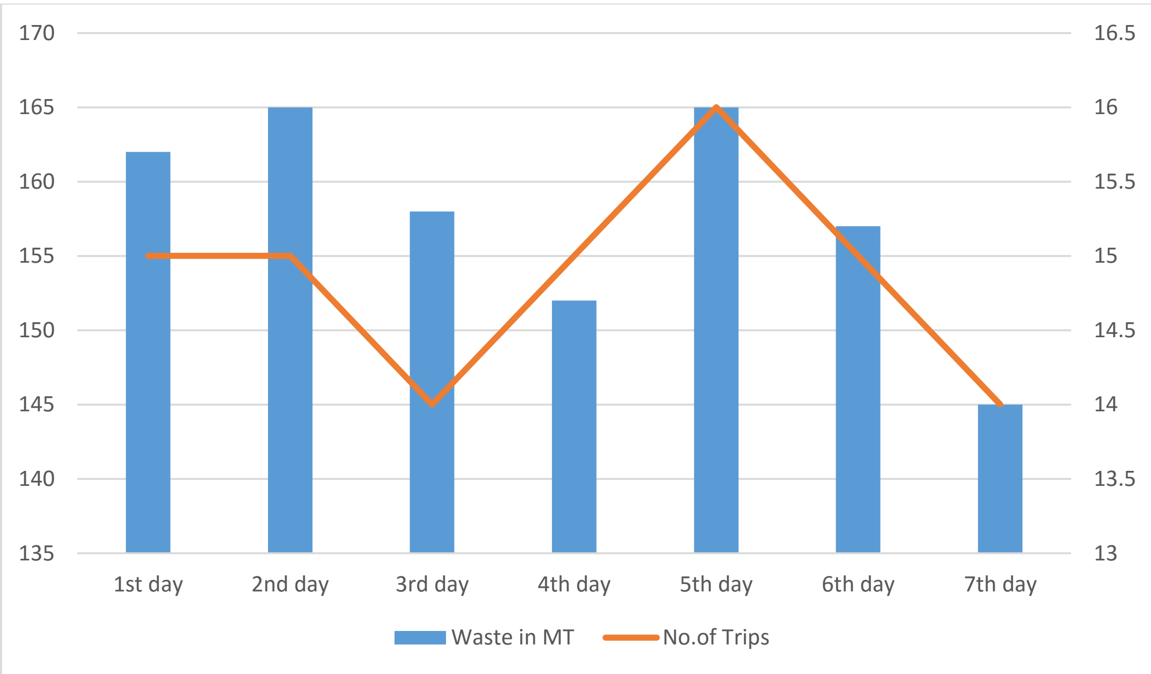

Figure 20: July Month Waste Generated and number of trips

Table 11: August Month Waste generation and No. of trips

S.No.	Date (August 2015)	Total Weight (in MT)	Number of Trips
1	3rd	172	16
2	4th	155	14
3	5th	151	14
4	6th	152	15
5	7th	147	14
6	8th	159	15
7	9th	151	15
Total		1087	103

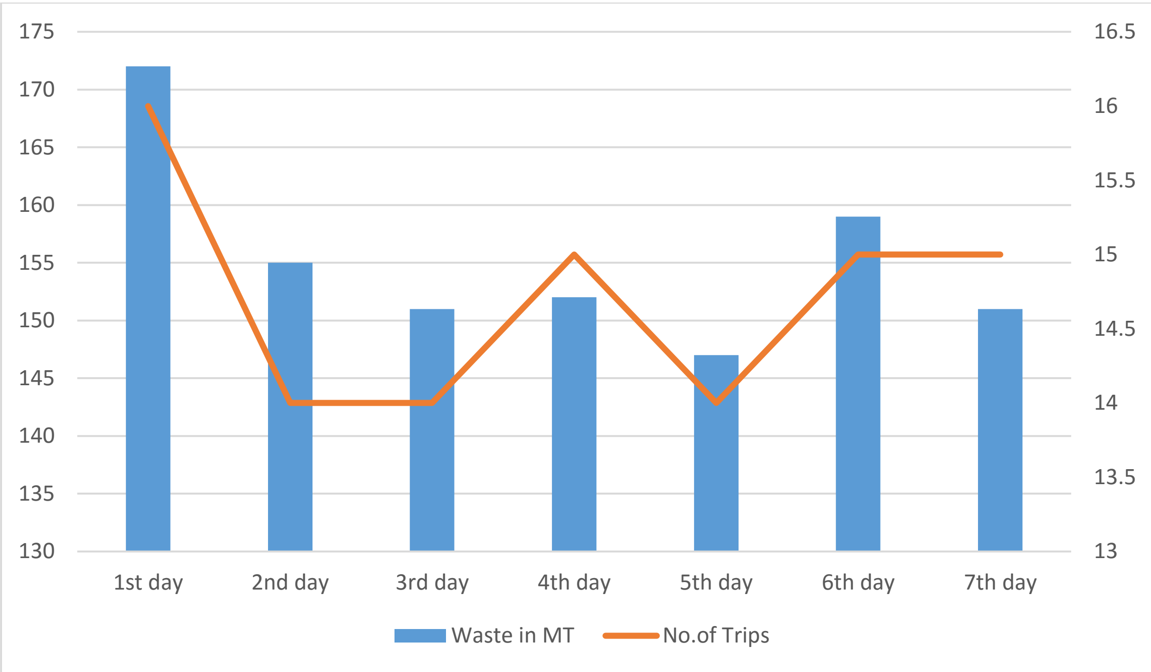

Figure 21: August Month Waste Generated and number of trips

Table 12: September Month Waste generation and No. of trips

S.No.	Date (September 2015)	Total Weight (in MT)	Number of Trips
1	7th	190	19
2	8th	193	19
3	9th	187	19
4	10th	179	18
5	11th	215	22
6	12th	187	19
7	13th	191	18
Total		1342	134

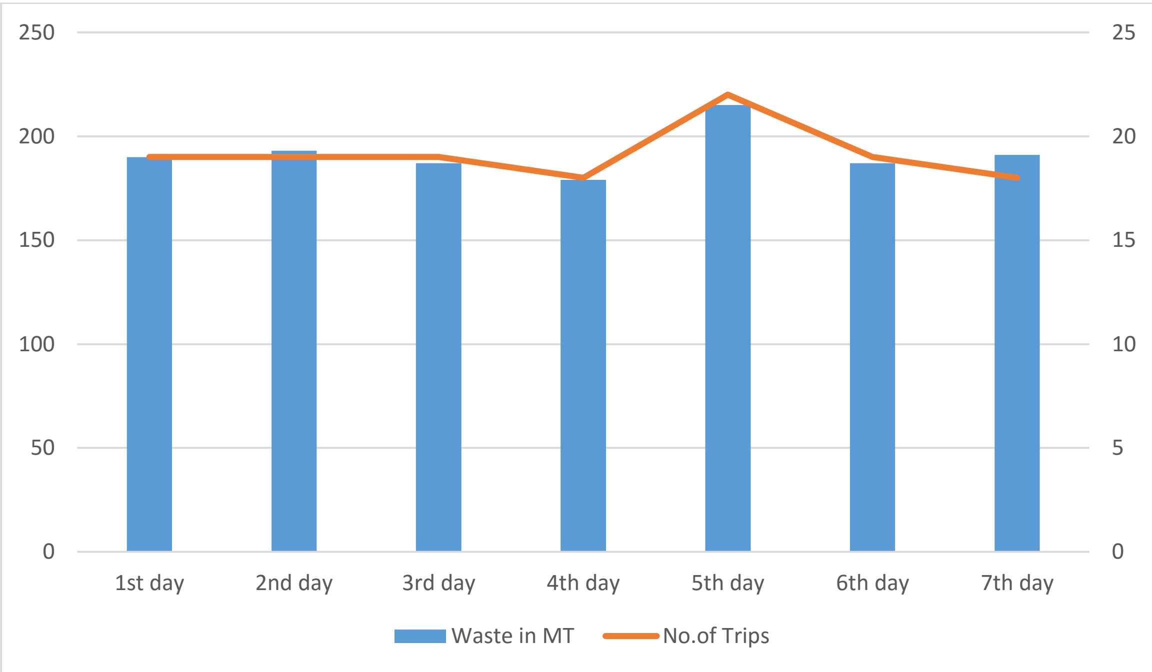

Figure 22: September Month Waste Generated and number of trips

Table 13: October Month Waste generation and No. of trips

S.No.	Date (October 2015)	Total Weight (in MT)	Number of Trips
1	5th	202	21
2	6th	211	22
3	7th	210	22
4	8th	223	22
5	9th	199	20
6	10th	201	20
7	11th	196	19
Total		1442	146

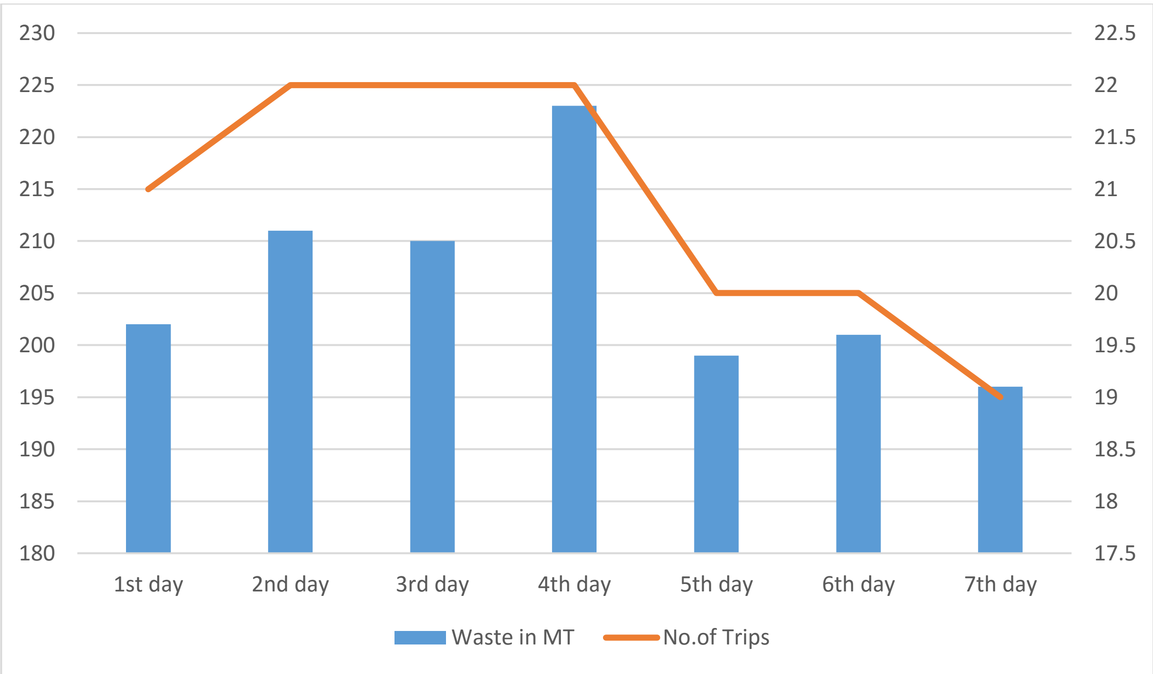

Figure 23: October Month Waste Generated and number of trips

Table 14: November Month Waste generation and No. of trips

S.No.	Date (November 2015)	Total Weight (in MT)	Number of Trips
1	2nd	175	18
2	3rd	178	18
3	4th	188	19
4	5th	202	20
5	6th	181	18
6	7th	165	17
7	8th	168	17
Total		1257	127

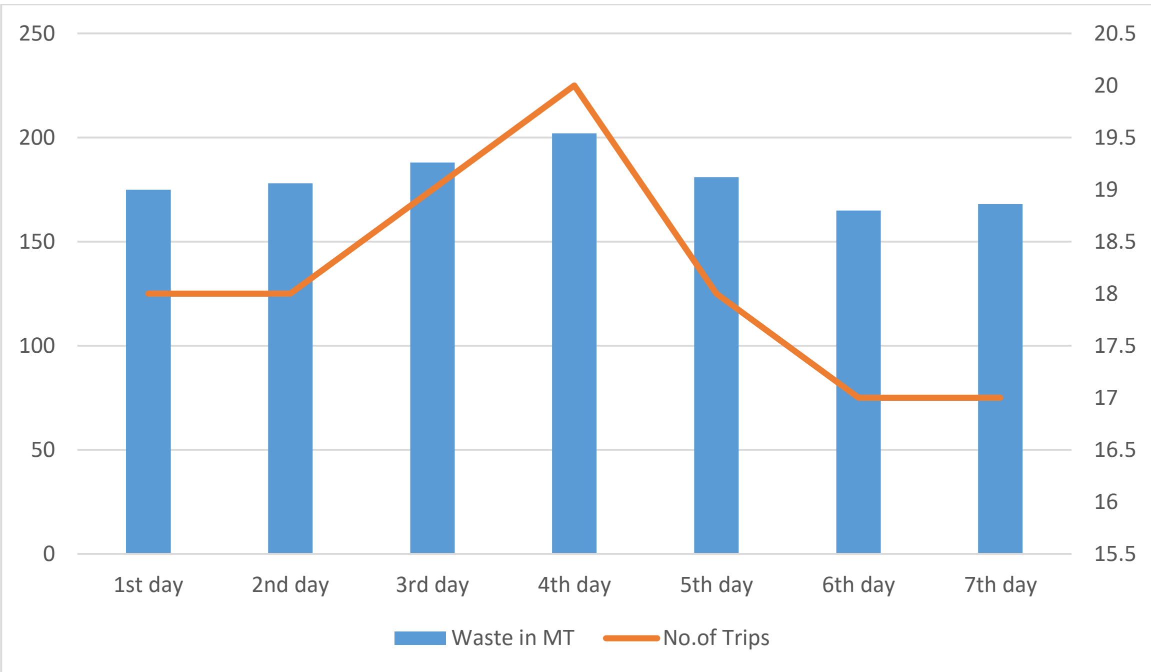

Figure 24: November Month Waste Generated and number of trips

Table 15: December Month Waste generation and No. of trips

S.No.	Date (December 2015)	Total Weight (in MT)	Number of Trips
1	2nd	211	22
2	3rd	215	23
3	4th	214	23
4	5th	235	24
5	6th	229	24
6	7th	227	24
7	8th	213	21
Total		1544	161

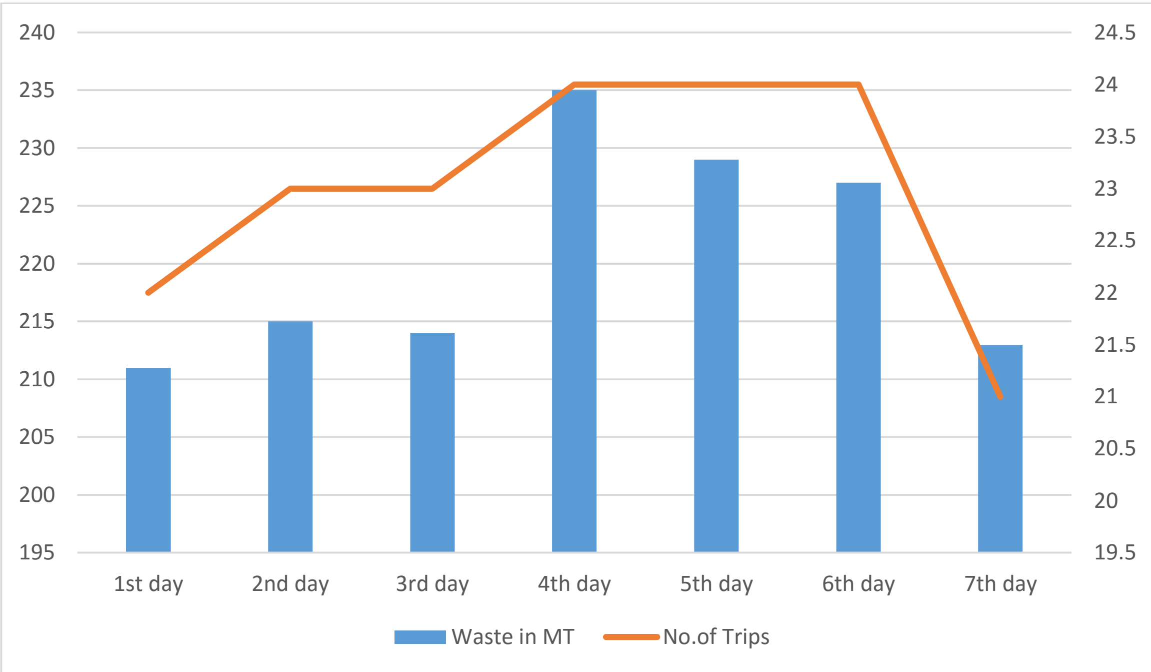

Figure 25: December Month Waste Generated and number of trips

Table 16: January Month Waste generation and No. of trips

S.No.	Date (January 2016)	Total Weight (in MT)	Number of Trips
1	2nd	125	13
2	3rd	120	13
3	4th	119	14
4	5th	117	13
5	6th	124	13
6	7th	255	22
7	8th	248	23
Total		1108	111

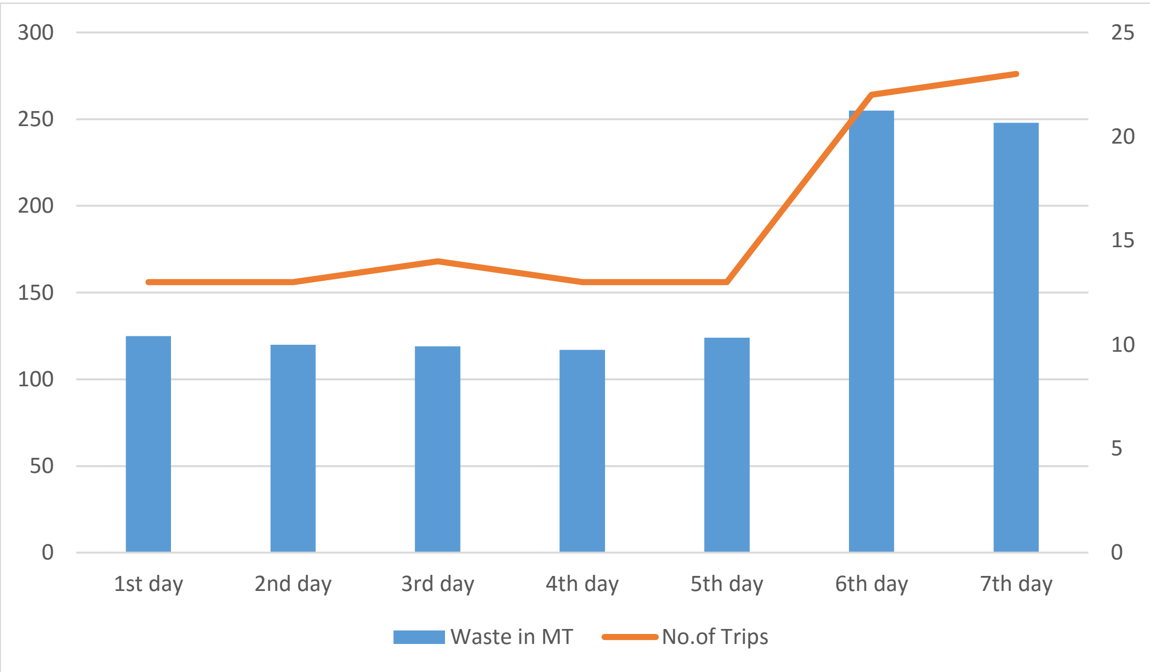

Figure 26: January Month Waste Generated and number of trips

Table 17: February Month Waste generation and No. of trips

S.No.	Date (February 2016)	Total Weight (in MT)	Number of Trips
1	1st	158	17
2	2nd	159	17
3	3rd	158	17
4	4th	162	17
5	5th	155	16
6	6th	159	16
7	7th	149	16
Total		1100	116

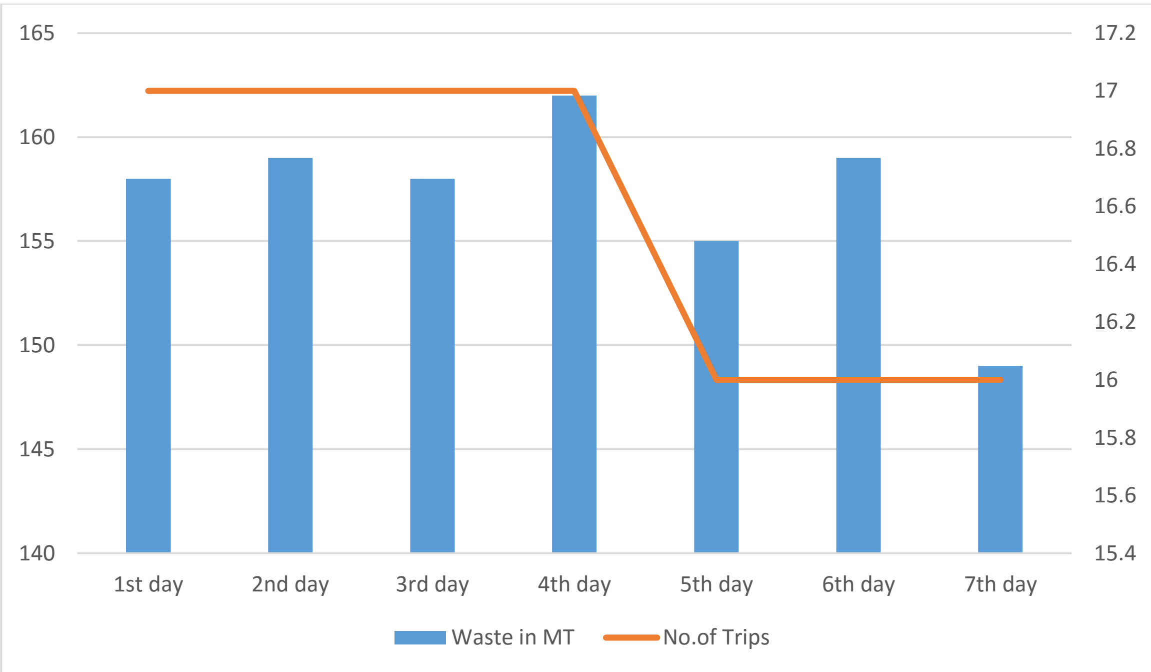

Figure 27: February Month Waste Generated and number of trips

Table 18: March Month Waste generation and No. of trips

S.No.	Date (March 2016)	Total Weight (in MT)	Number of Trips
1	14th	225	21
2	15th	198	19
3	16th	205	19
4	17th	208	19
5	18th	197	18
6	19th	196	18
7	20th	209	19
Total		1438	133

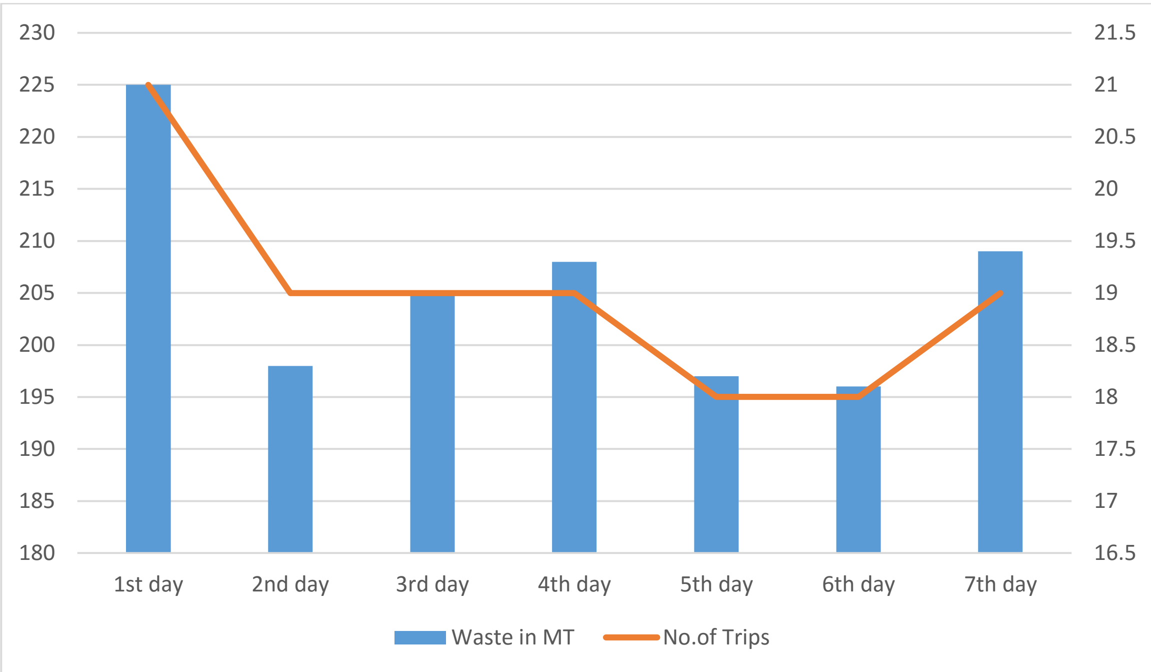

Figure 28: March Month Waste Generated and number of trips

Table 19: Month Waste generation and No. of trips

S.No.	Month	MSW (in MT)	Number of trips
1	Apr-15	5713	531
2	May-15	5965	576
3	Jun-15	5434	514
4	Jul-15	4889	461
5	Aug-15	4814	456
6	Sep-15	5751	574
7	Oct-15	6386	647
8	Nov-15	5387	544
9	Dec-15	6838	713
10	Jan-16	4907	492
11	Feb-16	4557	481
12	Mar-16	6368	589

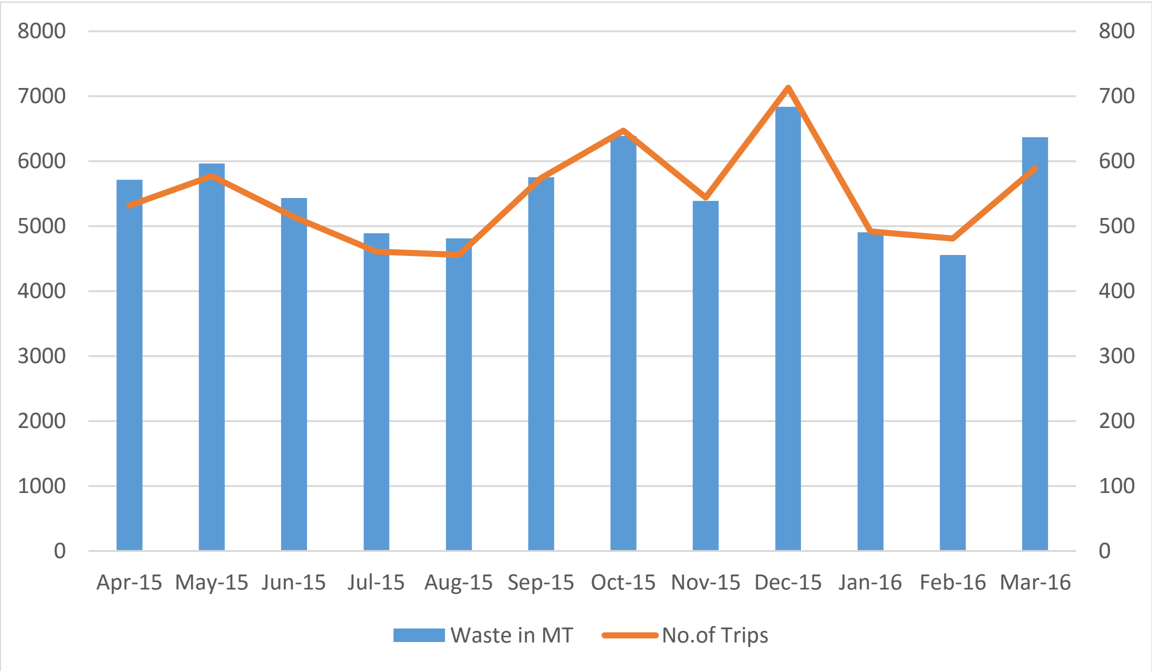

Figure 29: Monthly Waste Generated and number of trips

CHAPTER 4 RESEARCH & METHODOLOGY

Municipal Solid Waste Management is an important issue to be addressed not only this time but in coming generations also so it is important to have an adequate and proper methodology to find the solution to the problem.

4.1 Collection of Primary Data

Following methods are used for collecting the data:

4.1.1 Survey

A survey is conducted to collect the data for generation, collection, transport and disposal of the solid waste. Survey will also lead per capita waste generation, total population, number of communal bins, solid waste management method

Tool: Field Survey

4.1.2 Laboratory Tests

Density, Moisture Content, Calorific Value, Proximate Analysis and Ultimate Analysis

Tool: Laboratory tests of samples

4.1.3 Interview

Interview process is required to gather the information from personnel working in municipal corporation, workers, rag pickers, common residents. Information regarding stake holders, management, method, satisfaction content, waste handling and management.

Tool: Interview

4.1.4 Observation

Current solid waste management, handling and method will be observed by quantitative and qualitative data.

Tool: Graphs and Charts

4.1.5 Sample Collection

Municipal Solid Waste samples are collected from landfills (from top layer, middle layer and bottom layer), generation point, communal bins and dumping vehicles.

Tool: Field Study

4.2 Collection of Secondary Data

Secondary data collection is required to focus on following areas:

- Current case study area map
- Location of the city
- Population Data
- Climate
- Details of landfills
- Zonal details of the city
- Sweeping techniques
- Manpower, management in solid waste management

4.3 Landfill site assessment

Delphi sensitivity site method which considers variables like socio-economic, environmental, waste characterization.

4.4 Energy Potential Estimation

Electricity generation potential by using waste to energy incineration technology is calculated for Roorkee city by performing Proximate, Ultimate & Calorific Value analysis

Tool: Laboratory tests

4.5 Waste to Energy Incineration Technology Working

Incineration Plant working and mechanism explanation

CHAPTER 5 QUANTIFICATION OF PROBLEM IN EXISTING MSWM OF ROORKEE CITY

5.1 Problems in existing Municipal Solid Waste Management System

From the field survey it is known that RNPP ignores the importance of solid waste management and Waste treatment and processing is the most neglecting part in its system. Lack of Communal Bins in Khanjarpur, Purani Tehsil, Main Bazar, Sati Mohalla. The drains along the road and main sever lines near Amber Talab, Subhash Nagar, Rajendra Nagar are blocked because of inappropriate drainage and incorrect disposing of waste. Waste is dumped without any treatment is burnt in landfill which produces harmful gases and substances. This increases the risk of health to people living surrounding that area.

Table 20: Problems and Possible Solutions in existing MSW Management System

S. No.	Problem issues	Problem in existing system	Possible solution to problem
1.	Waste Segregation	Waste is not separated into biodegradable and non-biodegradable at the source, after that. Mix type of waste is disposed off in landfill	General awareness about waste segregation should be done At source only waste should be segregated There should be two bins one for biodegradable and another for non-biodegradable.
2.	No Sanitary Landfill	There is no provision of leachate treatment and landfill gas recovery. Open burning of waste in landfill	Proper sanitary landfill should there for dumping Leachate treatment facility should be there to save ground water

3.	Low efficient waste storage and collection	Around 60-70% of waste is collected from the roads and communal bins. Usually inadequate number of communal bins Less number of automatic loader	Proper training should done for the workers with latest technology and method. Proper distribution of bins with respect to zone size should be done.
4.	Waste Transportation	Lack of automatic loaders dumping vehicles Poor efficient vehicles Generally open body type of vehicles which emits gases in whole city during transportation. No transfer station	New technology vehicles should be used which consume less time in loading and unloading the waste. Automatic loading machine vehicles should be used to reduce man power. There should be at least one transfer station for quick and efficient disposal. Vehicles should be covered.
5.	Waste Processing	No waste treatment facility	An appropriate treatment technology facility should be there to avoid dumping in landfill.

5.2 Proposed Solid Waste Management System

For efficient and effective SWMS it is required to solve the problems of storage, collection, transport, disposal and treatment. The main focus is on:

- Efficient waste collection
- Effective and hygienic waste storage
- Proper transport of the waste from city bounds to out bounds.
- Suitable technique for treatment of the waste.

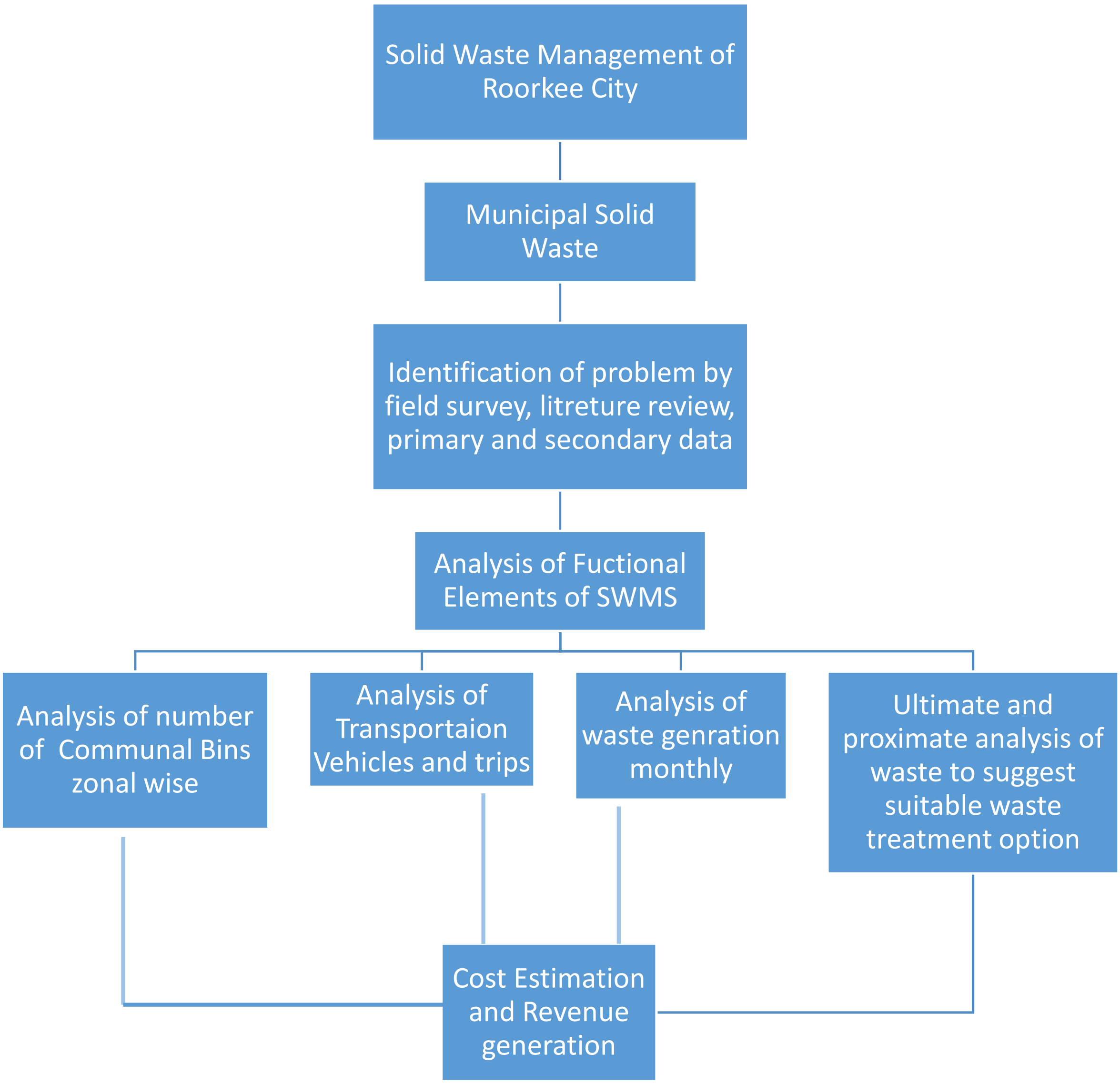

Figure 30: Problem Solving Technique of MSWM

CHAPTER 6
ANALYSIS OF PHYSICAL AND CHEMICAL CHARACTERISTICS ANALYSIS OF MSW

Process of waste should be aimed in order to diminish or lessen the final waste to great extent which is left for dumping in landfill. Calorific Value, Proximate Analysis, and Moisture content analysis is done to have a clear approach to selection of technology regarding. Total 10 samples are collected from the landfill, source of generation, transportation. Following are the locations of landfill collection point. Depth Samples are collected from 1 meter then 2 meter from top of the landfill.

6.1 Landfill Site View

Figure 31: Bird Eye View of Roorkee Land fill Area near School

Figure 32: Roorkee Landfill Identification Area

Figure 33: Sample collection

6.2 Sample Collection Data

Table 21: Sample Wise Percentage of cComposition of MSW in Roorkee City

S. No.	Sample	Biodegradable				Non-Biodegradable		
		Kitchen Waste	Paper	Textile	Wood	Glass	Plastic	Ash & Earth/Material
1	A	41.7	7.8	2.8	2.2	0.8	3.6	41.1
2	B	42.6	8.2	0	1.8	0.6	2.9	43.9
3	C	47.6	5.5	2.5	0	0	2.5	41.9
4	D	46.3	4.9	2.2	0	1.2	2.9	42.5
5	E	45.4	4.6	1.9	0.8	0.8	1.4	45.1
6	F	48.4	5.2	1.5	1.2	1.4	1.7	40.6
7	G	43.9	7.3	0	0	0.7	3.3	44.8
8	H	44.1	4.8	1.2	3	0	0	46.9
9	I	41.3	5.7	3.3	2.9	0	3.2	43.6
10	J	42.5	5.1	1.7	0.4	0.9	2.7	46.7

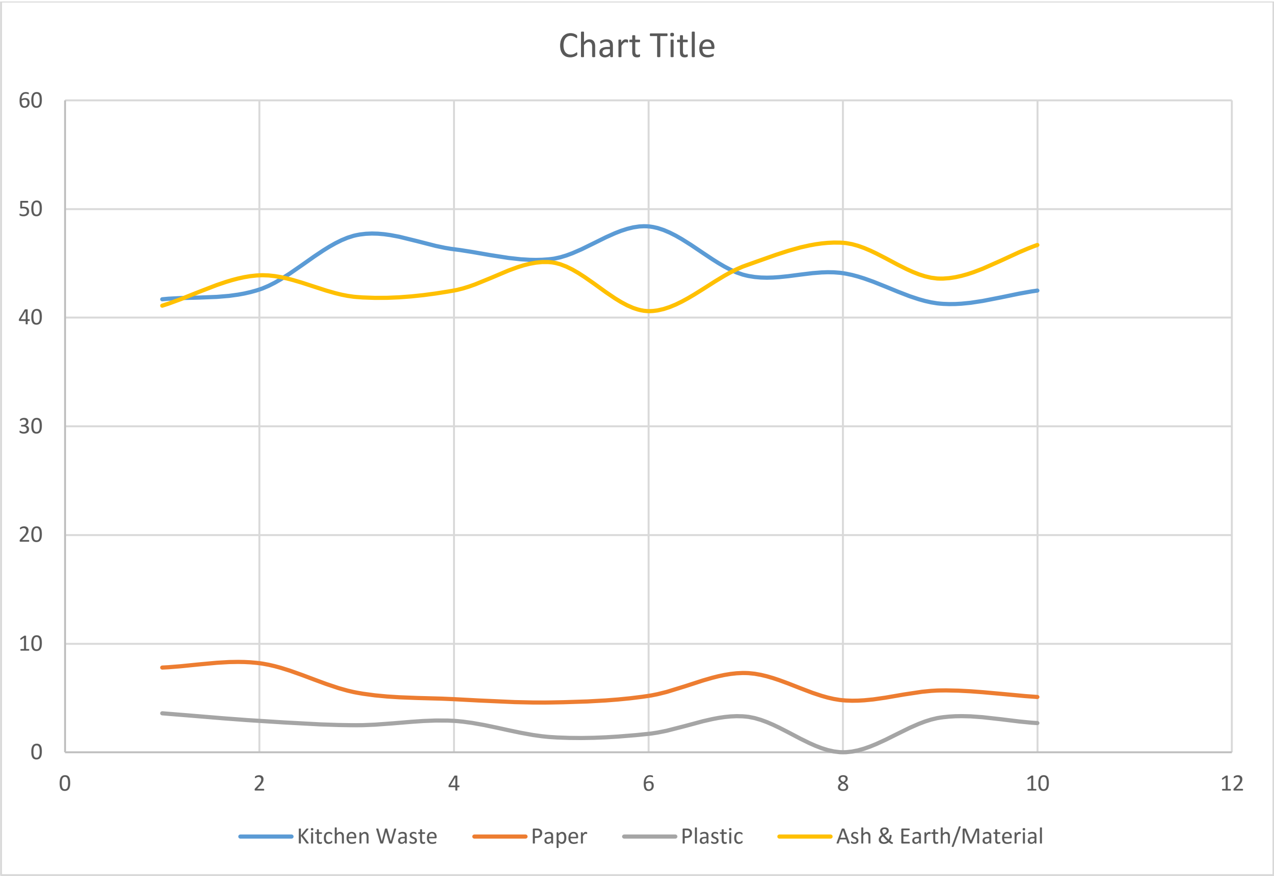

Figure 34: Sample wise composition variation

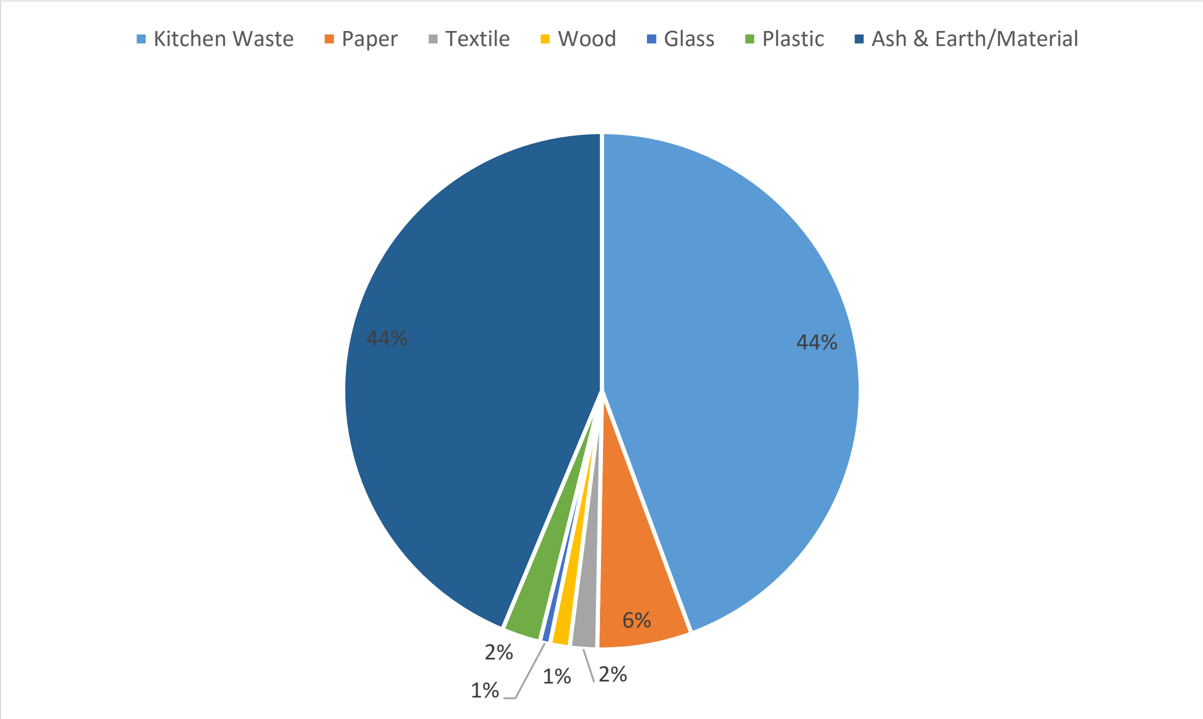

Figure 35: Composition Analysis of waste generated in Roorkee City

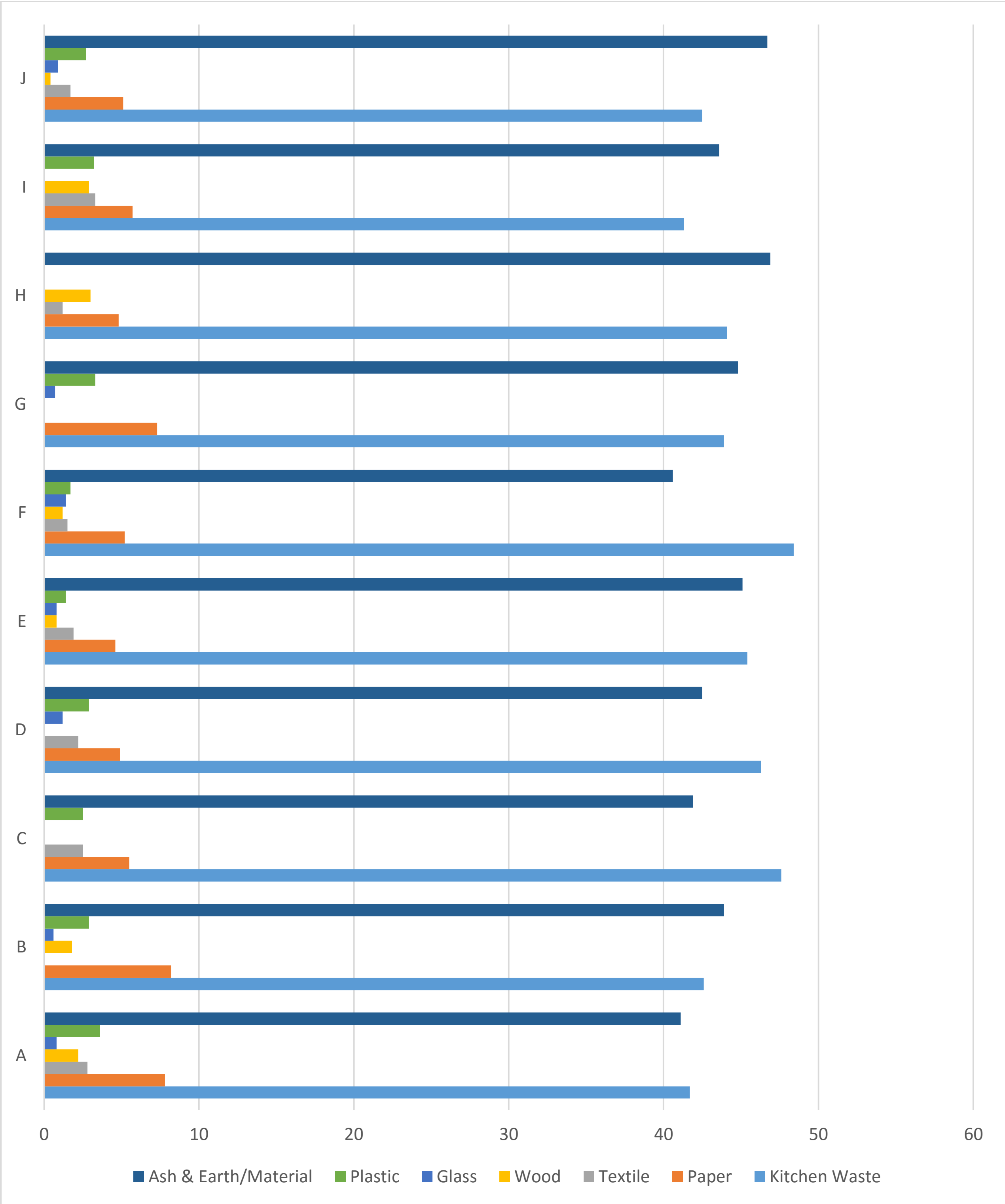

Figure 36: Sample wise composition

6.3 Moisture Content Analysis Sample Wise

Table 22: Sample A MSW Composition

Sample A	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	41.7	27.105	
Paper	7.8	6.552	
Textile	2.8	2.38	
Wood	2.2	1.54	
Glass	0.8	0.8	
Plastic	3.6	3.6	
Ash & Earth/Material	41.1	39.045	
Total	100	81.022	18.978

Table 23: Sample B MSW Composition

Sample B	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	42.6	26.838	
Paper	8.2	6.806	
Textile	0	0	
Wood	1.8	1.26	
Glass	0.6	0.6	
Plastic	2.9	2.9	
Ash & Earth/Material	43.9	41.705	
Total	100	80.109	19.891

Table 24: Sample C MSW Composition

Sample C	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	47.6	29.988	
Paper	5.5	4.675	
Textile	2.5	2.175	
Wood	0	0	
Glass	0	0	
Plastic	2.5	2.5	
Ash & Earth/Material	41.9	39.805	
Total	100	79.143	20.857

Table 25: Sample D MSW Composition

Sample D	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	46.3	29.632	
Paper	4.9	4.165	
Textile	2.2	1.584	
Wood	0	0	
Glass	1.2	1.2	
Plastic	2.9	2.9	
Ash & Earth/Material	42.5	39.95	
Total	100	79.431	20.569

Table 26: Sample E MSW Composition

Sample E	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	45.4	29.51	
Paper	4.6	3.68	
Textile	1.9	1.615	
Wood	0.8	0.6	
Glass	0.8	0.8	
Plastic	1.4	1.4	
Ash & Earth/Material	45.1	42.845	
Total	100	80.45	19.55

Table 27: Sample F MSW Composition

Sample F	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	48.4	30.976	
Paper	5.2	4.68	
Textile	1.5	1.305	
Wood	1.2	0.936	
Glass	1.4	1.4	
Plastic	1.7	1.7	
Ash & Earth/Material	40.6	38.57	
Total	100	79.567	20.433

Table 28: Sample G MSW Composition

Sample G	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	43.9	27.657	
Paper	7.3	6.059	
Textile	0	0	
Wood	0	0	
Glass	0.7	0.7	
Plastic	3.3	3.3	
Ash & Earth/Material	44.8	42.56	
Total	100	80.276	19.724

Table 29: Sample H MSW Composition

Sample H	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	44.1	26.901	
Paper	4.8	4.032	
Textile	1.2	1.044	
Wood	3	2.34	
Glass	0	0	
Plastic	0	0	
Ash & Earth/Material	46.9	44.555	
Total	100	78.872	21.128

Table 30: Sample I MSW Composition

Sample I	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	41.3	26.019	
Paper	5.7	4.845	
Textile	3.3	2.805	
Wood	2.9	1.972	
Glass	0	0	
Plastic	3.2	3.2	
Ash & Earth/Material	43.6	41.42	
Total	100	80.261	19.739

Table 31: Sample J MSW Composition

Sample J	As Received (Wet Basis)	Dry Basis	Moisture
Kitchen Waste	41.7	24.186	
Paper	7.8	6.24	
Textile	2.8	2.38	
Wood	2.2	1.716	
Glass	0.8	0.8	
Plastic	3.6	3.6	
Ash & Earth/Material	41.1	39.045	
Total	100	77.967	22.033

6.3 Calorific Value Analysis Sample Wise

Table 32: Sample Wise Calorific Value Analysis

S. No.	Sample	Calorific value (in KJ/Kg)
1	A	10785
2	B	10240
3	C	9831
4	D	9273
5	E	8904
6	F	9537
7	G	10492
8	H	9108
9	I	9748
10	J	9337
	Average	9725.5

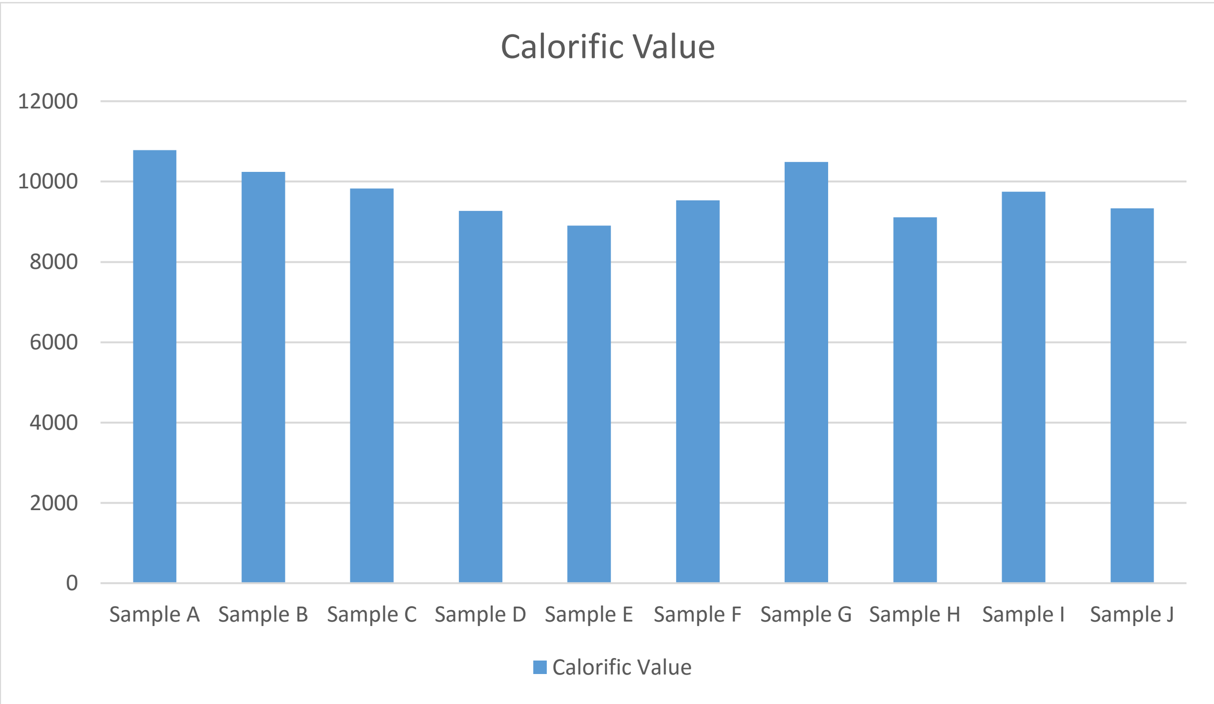

Figure 37: Sample wise distribution of Calorific Value

6.4 Proximate Analysis Sample Wise

Table 33: Sample wise Proximate Analysis

S. No.	Sample	Moisture	Volatile Matter	Ash	Fixed Carbon
1	A	19.2	25.7	32.8	22.3
2	B	20.1	28	32.4	19.5
3	C	21.3	23.2	37.2	18.3
4	D	21.6	18.8	37.8	21.8
5	E	22.4	23.6	29.3	24.7
6	F	21.6	27.8	27.4	23.2
7	G	22.9	28.5	31.2	17.4
8	H	23.4	22.4	36.1	18.1
9	I	22.5	25.8	31.1	20.6
10	J	22.7	26.9	31.7	18.7
	Average	**21.77**	**25.07**	**32.7**	**20.46**

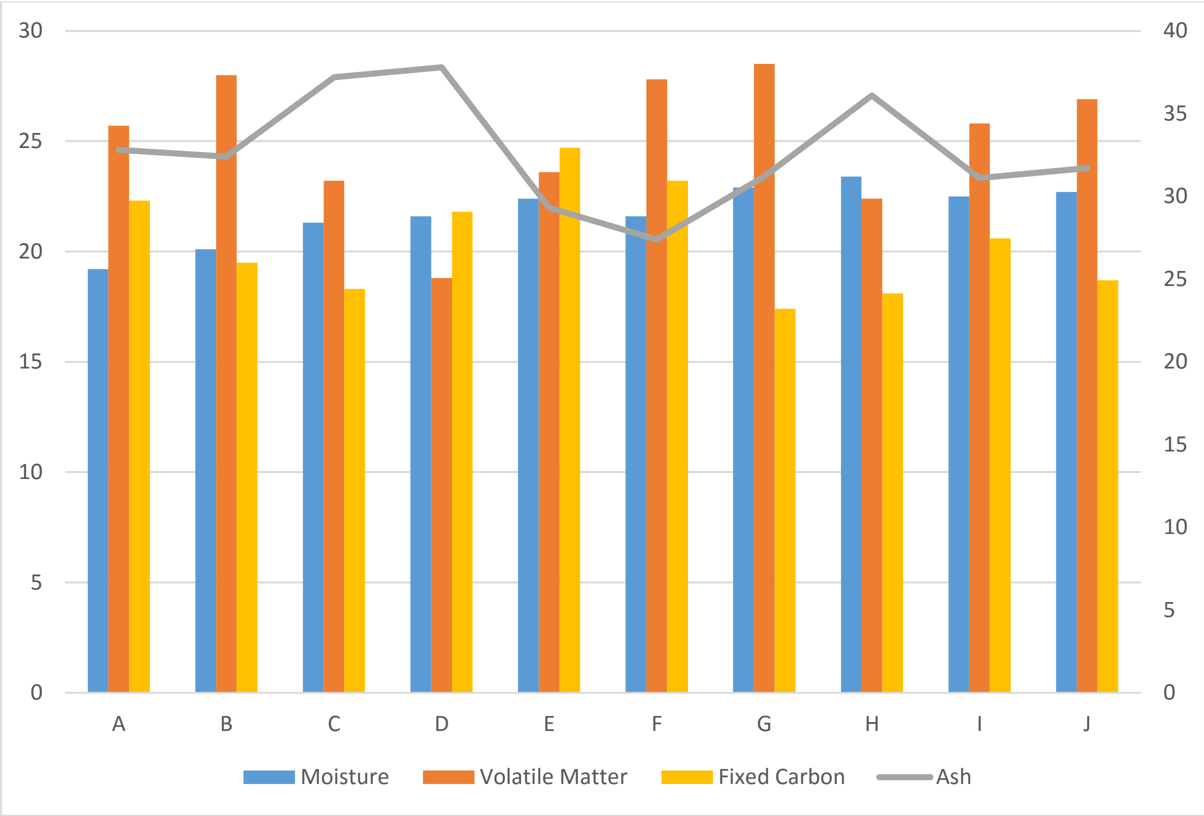

Figure 38: Sample Wise Proximate Analysis Value

CHAPTER 7 DESIGN & COMPUTATION

7.1 Energy Potential Calculation (Theoretical)

Heat Energy (Dulong's Formula) to calculated heat energy generated by whole Roorkee city's solid waste Dulong's formula needs to be applied. Dulong's formula:

Heart Energy (kJ/kg) =

where C = carbon percent

H = hydrogen percent

O = oxygen percent

S = sulfur percent

HV(KJ/Kg) = 338.2*C + 1442.8*(H-O/8) + 94.2*S

Where C, H, O and S are the % of these elements on dry ash free basis.

Considering Literature Review taking percentage by Mass theoretical calculations are as follows:

C= 26.77

H= 9.17

O= 55.68, Sulphur very small so neglected

Applying to formulae we get Heat Energy Generated = **11002.252 kJ/kg**

First, heat energy generated is used to calculate steam energy which is 70% of heat energy.

Finally after steam energy calculation, net electric power generated by solid waste is calculated after accounting station service allowance and heat losses.

Steam energy available = 70% of heat energy

Steam energy available = (0.70 ×11002.252) kJ/kg

Steam energy available = 7701.576 kJ/kg.

Above calculated steam energy is used to run the turbines, these turbines are coupled with generators which produces electricity. Heat rate is the heat input required to produce one unit of electricity (kWh).

1 kW = 3,600 kJ/h

But practically no energy conversion is 100% efficient,

considering the conversion efficiency of 31.6% in a power plant heat input of 3600 ÷ 31.6% = 11395 kJ/kWh is required.

So, to produce 1kWh electrical energy 11395 kJ of steam energy is required.

Electric power generation = Steam energy ÷ 11395kJ/kWh

Electric power generation = (7701.576÷ 11395) kWh/kg

Electric power generation = 0.67587 kWh/kg

Total weight of solid waste collected from Roorkee city =215 tons/day

Total electric power generation = (0.67587×215000) kWh/day

Total electric power generation = 145312.762 kWh/day

Station service allowance = 6% of total electric power generation

Station service allowance = (0.06 ×145312.762) kWh/day

Station service allowance = 8718.765 kWh/day

Unaccounted heat loss = 5% of electric power generation

Unaccounted heat loss = (0.05 × 145312.762) kWh/day

Unaccounted heat loss = 7265.638 kWh/day

Net electric power generation = Electric power generation – (station service allowance + unaccounted heat loss)

Net electric power generation = 145312.762 – (7265.638 + 8718.765)

Net electric power generation = 129328.359 kWh/day = 129.3 MWh/day

The above generated electricity is for one day and one day has 24 hours, so using this net electric power is calculated for per hour basis.

Net electric power generated = 129.3 MWh / 24h

Net electric power generated = **5.38 MW≈ 5.4 MW.**

7.2 Energy Potential Calculation (Practical)

Applying to formulae we get Average Calorific Value = **9725.5 kJ/kg**

First, heat energy generated is used to calculate steam energy which is 70% of heat energy.

Finally after steam energy calculation, net electric power generated by solid waste is calculated after accounting station service allowance and heat losses.

Steam energy available = 70% of heat energy

Steam energy available = (0.70 ×9725.5) kJ/kg

Steam energy available = 6807.85 kJ/kg.

Above calculated steam energy is used to run the turbines, these turbines are coupled with generators which produces electricity. Heat rate is the heat input required to produce one unit of electricity (kWh).

1 kW = 3,600 kJ/h

But practically no energy conversion is 100% efficient,

considering the conversion efficiency of 31.6% in a power plant heat input of 3600 ÷ 31.6% = 11395 kJ/kWh is required.

So, to produce 1kWh electrical energy 11395 kJ of steam energy is required.

Electric power generation = Steam energy ÷ 11395kJ/kWh

Electric power generation = (6807.85÷ 11395) kWh/kg

Electric power generation = 0.59744 kWh/kg

Total weight of solid waste collected from Roorkee city =215 tons/day

Total electric power generation = (0.0.59744×215000) kWh/day

Total electric power generation = 128450 kWh/day

Station service allowance = 6% of total electric power generation

Station service allowance = (0.06 ×145312.762) kWh/day

Station service allowance = 7707 kWh/day

Unaccounted heat loss = 5% of electric power generation

Unaccounted heat loss = (0.05 × 145312.762) kWh/day

Unaccounted heat loss = 6422.5 kWh/day

Net electric power generation = Electric power generation – (station service allowance + unaccounted heat loss)

Net electric power generation = 128450 – (7707 + 6422.5)

Net electric power generation = 114320.5 kWh/day = 114.32 MWh/day

The above generated electricity is for one day and one day has 24 hours, so using this net electric power is calculated for per hour basis.

Net electric power generated = 114.32 MWh / 24h

Net electric power generated = **4.76 MW≈ 4.8 MW.**

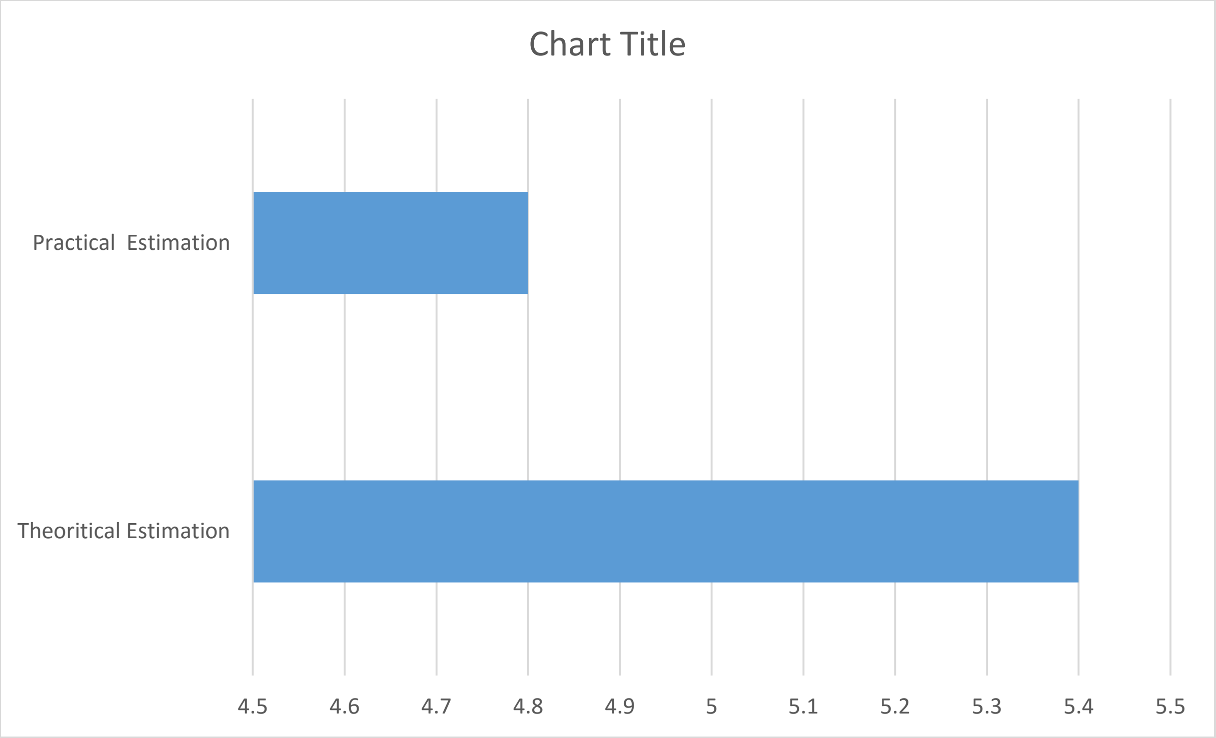

Figure 39: Comparison of Theoretical and Experimental Value of Electricity Estimation

CHAPTER 8 WTE: INCINERATION TECHNOLOGY

To understand the methodology, energy recovery process must be understood before that. Energy recovery process is shown in Fig first of all the solid waste is collected from all the collection points it is then transported to receiving station. After this solid waste is fed to shredder, here solid waste is cut down into small pieces so that can be managed easily at subsequent stages. Now this shredded solid waste is passed through dryers to remove extra moisture. After this air is blown on solid waste which blows out light materials and heavy material like ferrous metal is separated and sent for recycle as these materials can't be burned in incinerators. The light solid waste is again passed through second stage shredder to cut them into smaller pieces. Now these small solid waste pieces are burned into incinerators which reduce solid waste into ash and produce heat energy and gases. The gases are passed through air filters if needed and subsequently released into atmosphere through stacks. Heat energy is used to boil water in boilers to produce this this steam in turn runs turbine which is coupled with generators. As turbine runs it cause generator to rotate and produce electricity. This electricity is exported to the grid and some of it used for plant itself.

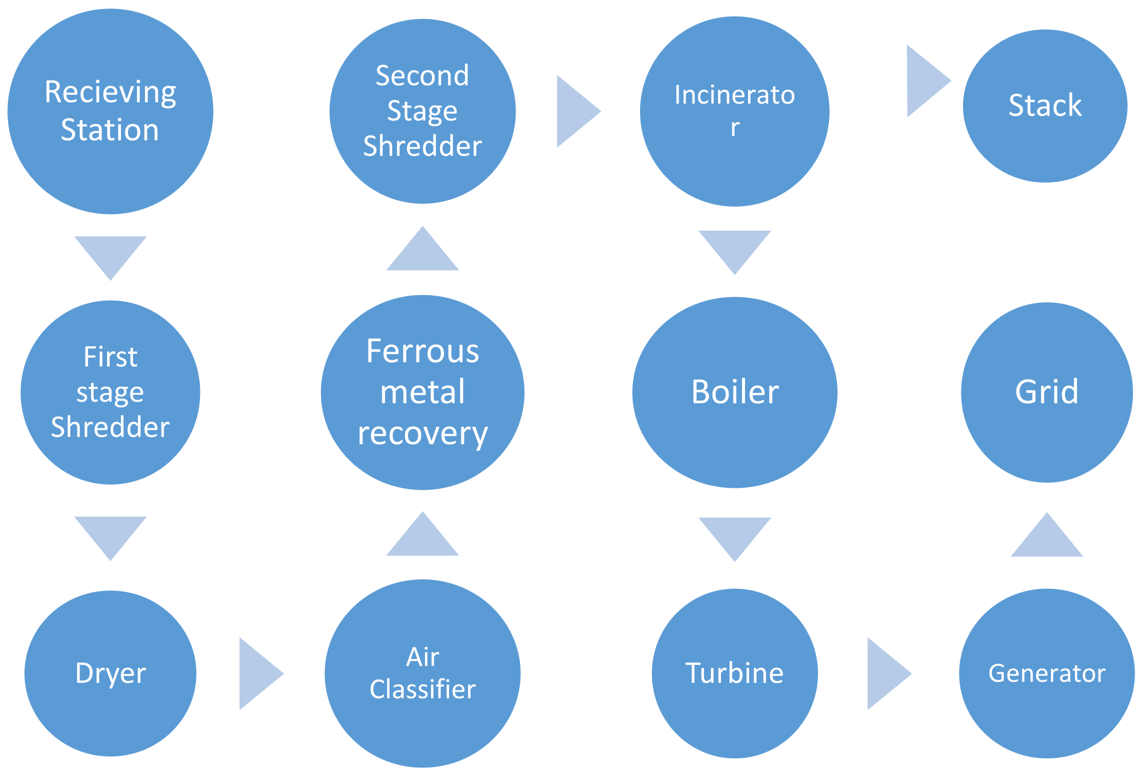

Figure 40: Schematic diagram of WTE Incineration process

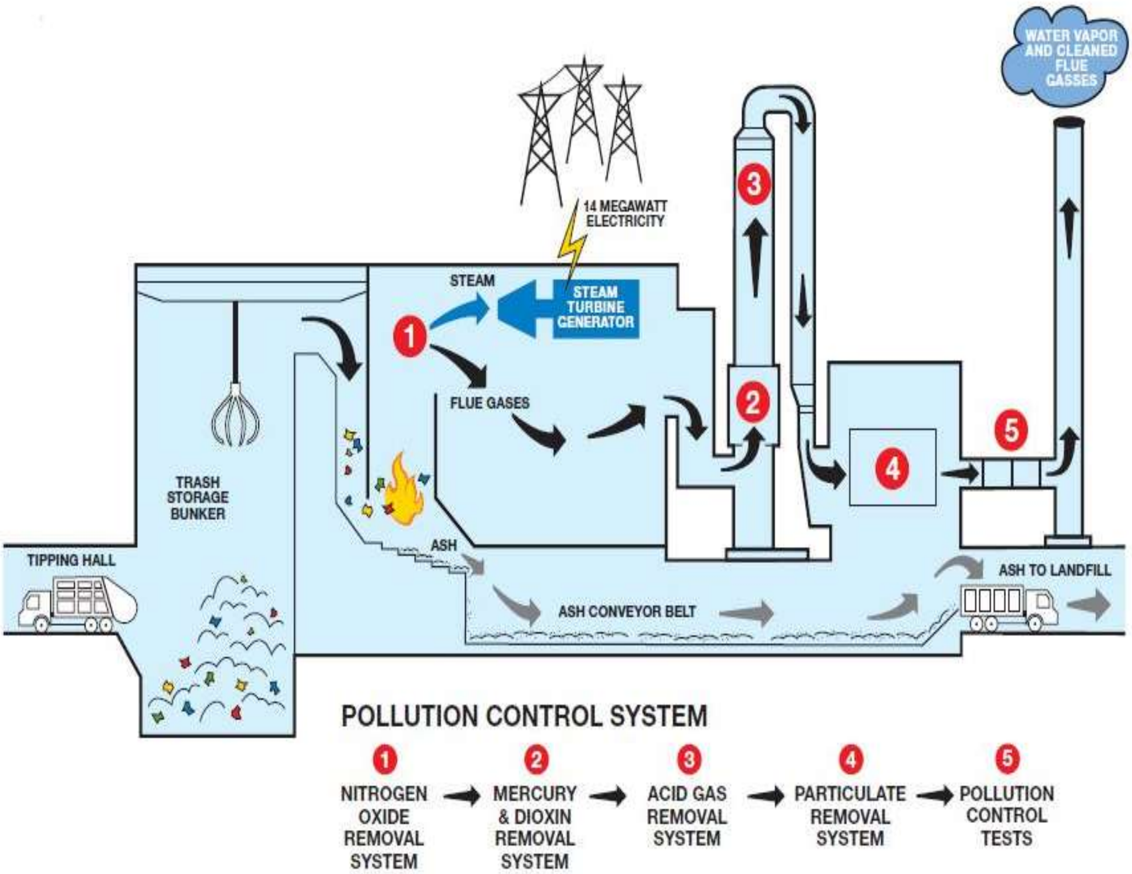

Figure 41: Process of Incineration

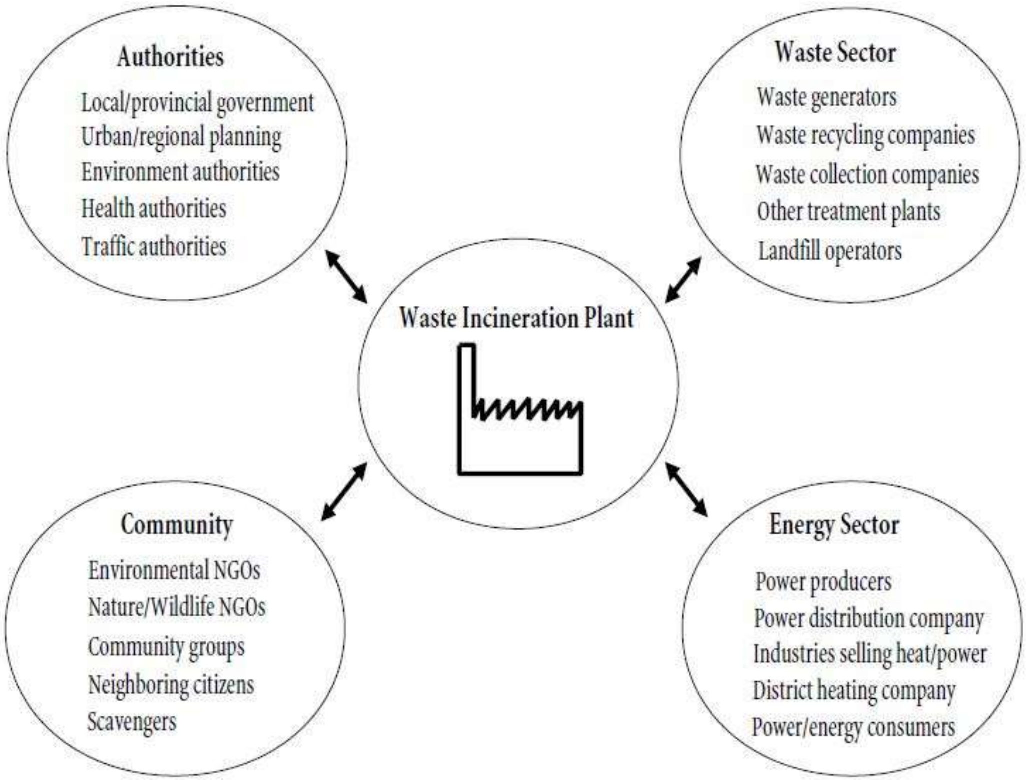

Figure 42: Pillars of WTE incineration technology

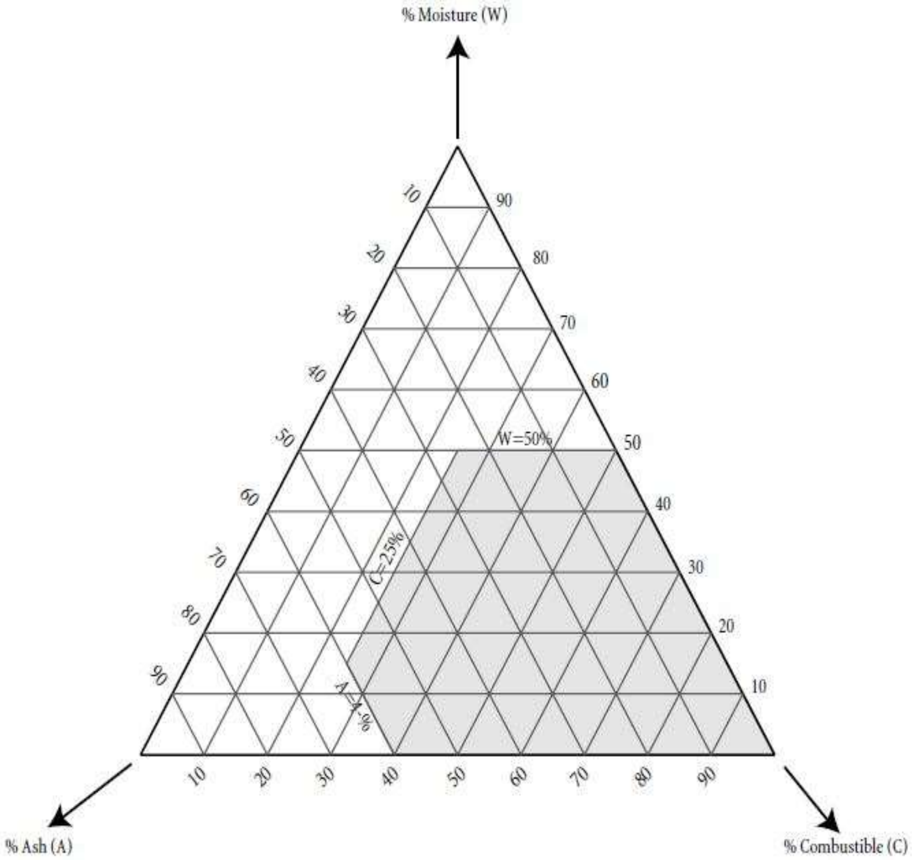

Figure 43: Tanner Diagram for assessment of combustibility of MSW

CHAPTER 9 RESULTS AND DISCUSSIONS

Objectives stated in dissertation are accomplished by applying Dulong's formula to calculate net electricity generated.

- Dulong's formula is applied on WTE incineration technique. Incineration technique is chosen because it has many advantages over other techniques like the majority of wastes will burn without giving rise to noxious products of combustion (HCI, HF, SO_2 and NOx) in significant quantities, the volume and mass occupied by the waste is greatly reduced, it produces an effectively sterile ash residue etc.
- Total theoretical energy potential comes out to be 6 MW which is around enough for nearby rural areas.
- Sample were collected from the site and proximate & ultimate analysis will done to calculate actual energy potential.
- Further all the waste to energy technologies were be compared on technical, economic and environmental aspect.
- Comparison of different Waste to Energy technologies i.e. incineration, Biogasification Biomethanation, Pyrolysis.
- Theoretical Calculation of Energy potential from waste on basis of Literature Review.
- Collection of sample of wastes.
- Proximity & Ultimate Analysis of sample.
- Calculation of potential of energy on basis of analysis.
- However, the improper fate of solid wastes and mismanagement of sanitary system create disease supportive environment.
- Therefore, it appears that WtE can play an important role to minimize and manage the solid waste during the different festival and normal days at the study site and separation of the waste as Biodegradable and non-biodegradable at the point will be very helpful to manage the wastes material.
- Population and urbanization increased rapidly in developing countries which is causing increase in waste generation and exhausting landfills.
- There were various advantages to use WTE technologies as a part of MSWM were to avoid landfills, generating electricity to alternative to fossil fuel and thus reducing carbon foot print.
- While this technology was suppressed in developing countries due to capital cost, environmental impacts, operational and maintenance cost.
- Energy from MSW is emerging economy in Countries as land is unavailable for dumping, disposal and unorganized disposal of MSW which is the cause of emission of greenhouse gases.
- Due to environmental change and disposal problem there was a need for efficient waste management and thermal treatment to produce electricity. Waste Management is a matter of concern. Since population & urbanisation is increasing, waste generation is also increasing.

- Uncontrollable green-house gases (GHGs) emission from landfill causes health hazard.
- Leachate treatment is not available which threats to ground water.

CHAPTER 10 CONCLUSIONS & RECOMMENDATIONS

Due to the strong economic growth and urbanisation in recent years, Vietnam faces many environmental challenges. In particular, solid waste management in cities has been promoted as the big issue. Solid waste generation in Roorkee is increasing dramatically, mainly generated from households, buildings, commercial activities and other sources whose activities are similar to those of households and commercial enterprises such as wastes from offices, hotels, supermarkets, shops, institutions, and from municipal services such as street cleaning, etc. The main component of MSW is food waste which is a source of a very high potential of energy.

Roorkee is a small city that produces adequate quantity of waste. Waste to energy solves the problem of MSW disposal while recovering the energy from the waste materials with the significant benefits of environmental quality, increasingly accepted as a clean source of energy. Incineration technology estimated around 5 MW of potential in Roorkee city. WTE incineration needs to be implemented to make greater contribution in supplying renewable energy in Roorkee, the challenge of MSW disposal and the demand for alternative energy resources are common in many developing countries. MSWM can also be considered as an Electricity Generation Project rather than Waste Management Plan as an as the technology can lead to a substantial reduction in the overall waste quantities (as it reduces waste volume upto 90%) requiring final disposal, which can be better managed for safe disposal in a controlled manner while meeting the pollution control standards. It is expected that the experience on the development of WTE in Roorkee can offer some helpful lessons to other developing cities of India. In addition, power produced from the WTE activity can reduce the costly natural resources fossil fuel utilization in power generation as in Roorkee most proportion of total electricity is generated by fossil fuels (coal). Fossil fuel are depleting day by day while on the other hand solid waste is increasing day by day, WTE solves both these problem by managing solid waste and producing electricity. Hence, WTE is a great step towards sustainable development as it saves coal resources which can be used by future generation while eliminating solid waste management problem which solves the land shortage problem and that extra land can be used to any fruitful work without Solid Waste Management that land is wasted as huge piles of solid waste just cover land making them useless and toxic. Also leachate problem is solved by waste management as open dump cause leachate to develop which even pollute the underground water. In this project work calculations were done on incineration technique is used to produce electricity, but incineration produces some gases which may raise some environmental issues. This study does not involve analysis of gases emitted it impact on environment, economic and social analysis of WTE process. In addition to above, future study can be done in this regard to reduce these gases. Dulong’s method is used to calculate the electricity generated but some other method can also be used. WTE incineration technique is used to generate energy but other techniques can be used with modification to get better results.

FUTURE SCOPE OF WORK

- There are many technological advancement is to be done in the field of waste to energy.
- Optimization study can be performed to develop high calorific value
- Industrial & hazardous waste management study can be performed
- Biomedical waste management system should be studied in details by collecting more sample and field survey in order to improve the results.

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