CHARACTERIZATION OF MUNICIPAL SOLID WASTE OF A CITY IN WESTERN UP, INDIA

A Thesis

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Under the supervision of

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CERTIFICATE

This is certify that work which is being presented in the thesis entitle **"CHARACTERIZATION OF MUNICIPAL SOLID WASTE OF A CITY IN WESTERN UP, INDIA"** in partial fulfilment of the requirement for the award of the degree of Master of technology in Civil Engineering with specialization in " **Environmental Engineering**" and submitted in Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Ankur Choudhary** during a period from July 2016 to May 2017 under the supervision of **Dr.Ashok Kumar Gupta**, Professor and Head of the Department of Civil Engineering , Jaypee University of Information Technology, Waknaghat, Solan.

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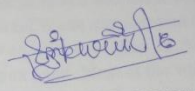

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ABSTRACT

This report consists of the Characterization of municipal solid waste and management of MSW for Muzaffarnagar City, UP, India. Characterization of Municipal Solid Waste in a city of western UP has been performed in order to determine the suitability for waste processing technologies in the city. Characterization is an important parameter in order to decide an appropriate design, cost effective and environmental friendly municipal waste management system. Physical characterization suggests about the organic and inorganic fraction in the waste. Geotechnical characteristics of waste helps in deciding the technology in design and maintenance of the landfill, whereas chemical characterization of the waste helps in deciding the technology in order to process the waste such as composting, vermicomposting, and Refused Derived Fuel . The results of characterization indicates that the approximated generation of the waste of the city is 120-125 MTD. The average per capita waste generation is 0.415 kg/person/day. A big fraction of the waste is organic in nature and has a significant calorific value too. Moreover analysis for better Municipal Solid Waste management also has been done. Around 70-80% of the city is covered by door-to-door collection method. The whole city is divided into 41 wards. Each ward has a collection point. Most of the ward's bin are overflowing throughout the year. Moreover, some of the wards doesn't have bins, so open dumping of the waste is taking place. There are not separate bins for organic and inorganic waste. There are 6 dumpers, 3 JCB, 3 tractors and 1 Ace are deployed in the city. There are inadequate labour and transportation system for the conveyance of waste. Composting and RDF are the methods to process the waste. Since last few years load on the treatment plant has increased significantly. There are not enough equipment and machines on the site that can process the waste, which has resulted into the mountains of waste in the site and around the site as well. Heaps of waste around the site cause bed odour and made unhygienic environment in the vicinity. The site has become house for many animals and insects. There is no provision of engineered landfill site, so ground water contamination from leachate has become a big problem.

Keywords: Characterization, MSW, Landfill, RDF, Composting, Leachate.

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ABBREVIATION	DESCRIPTION
MSW	Municipal Solid Waste
HIG	High income Group
LIG	Low income Group
MIG	Medium income Group
ULB	Urban Local Bodies
RDF	Refused Derived Fuel
MoEF	Ministry of Environment and Forest
UP	Uttar Pradesh
VFA	Volatile Fatty Acids
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
ASTM	American Society for Testing Materials
EC	Electronic Conductivity
TS	Total Solids
TDS	Total Dissolved Solids
APHA	American Public Health Association
MC	Municipal Corporation

CHAPTER-1

INTRODUCTION

1.1 General

This chapter will involve basic introduction about Solid waste management and Indian Scenario. This chapter will also include the brief introduction of solid waste management practice in the Muzaffarnagar city.

1.2 Solid Waste and its Management

"Waste is defined as any material that is not useful and does not represent any economic value to its owner, the owner being the waste generator". Municipal Solid Waste involves collection, segregation of waste generated by different part of our society i.e. residential, commercial, institutional, farms, gardens, slums etc., handling, transportation, processing and final disposal on engineered landfill site in a cost effective and environmental friendly manner. Amount of solid waste generated varies with place, season and income group. [Urban solid waste management in Indian cities, PEARL, 2015] There is no doubt to say that now management of municipal solid waste is an essential part of our modern society and one among the essential and obligatory services provided by local administration in the country to stablish a neat, clean and hygienic environment. Today in the era of rapidly growing economies and population mainly in developing countries generation of Solid Waste and its man agent has emerged as huge problem all over the world. The development and collection of reliable data regarding generation and characterization of the waste is one of the main issues in front of the Urban Local Bodies (ULB) all over the India in order to maintain a successful MSW management. As if now, scarcity of reliable information and data regarding generation rate, amount, and type of solid waste creates an obstacle in developing an efficient and environment friendly waste management plan. (Indris et al. 2004) has reported that problem of municipal solid waste generation has increased continuously in relation to the population and demands more land disposal. "However, waste generation increases continuously in proportion with population and challenging more land disposal." (Indris et al. 2004)

"Today worldwide scenario is such poor that whole world is producing more than 4 billion tonnes per year (Municipal, industrial, hazardous). It is reported that the generation of municipal solid waste is between 1.6 to 2.0 billion tonnes per year. Moreover, it is also reported that the global impacts of solid waste are developing very rapidly as solid waste management costs will increase significantly from today's annual $205.4 billion to about $375.5 billion in 2025."

Definition according to the Basel Convention by UNEP; "as substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". Activities involved in our day to day life results into wide variety of wastes generated from different sources. It is the fact that source reduction and prevention of waste at source is much cheaper than preventing the waste contamination in the environment. Globally, almost all of the countries are facing a great challenge in order to properly manage

their waste and minimize the final load on the landfills within provided and fund and eco-friendly manner.

"Inefficient management of waste is one of the dominant reasons behind the environmental pollution. The World Health Organization (WHO) reported that approximately one fourth of the diseases faced by mankind today happens due to exposure of human with environmental pollution for a long duration." Among all of the diseases most of them are not easily detected and result of which not appeared in childhood and manifested later in young age. It is generally noticed that waste is usually dumped near to the slums so it generally effects the poorer communities of the society. Heath implications for people who are involve in the waste management is most common because of the unsound waste management. A significant number of waste picker are directly in contact with hazardous waste as they have to do it for the survival of their family. Heavy Metals like Lead, mercury, iron, nickel, cobalt and copper are "infectious agents from healthcare facilities—as well as dioxins and other harmful emissions released during the recovery of valuable materials from e-waste—not only affect the health of waste pickers, but also contribute to air, land and water contamination."

Waste management based on the Industry is one of the most effective Waste Management practice with an annual turnover above $433 billion and unites approximately 40 million workers (including informal recyclers). This industry covers a significant variety of operations for different waste streams and different phases of the waste life-cycle. It is considered that the industry will further grow, especially in developing countries, and recycling business will be the cornerstone of it. If we talk about the employment from waste industry, Waste Recycling is one of the most important sectors in terms of development of employment. Currently 12 million people are involve in it in just three countries—Brazil, China and the United States, methane generated from landfills biggest source of GHG emissions, generated by the anaerobic decomposition of organic fraction of the waste stream. "The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China." (Factors Influencing Municipal Solid Waste Generation in China: A Multiple Statistical Analysis Study 2011)

1.3 Indian Scenario of MSW

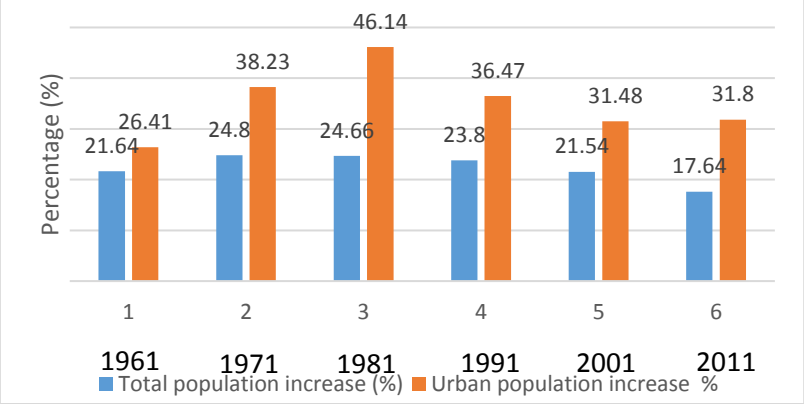


Fig.1.1 Total Population Increase vs. Urban Population Increase
Source: [Urban solid waste management in Indian cities, PEARL, 2015]

Total Municipal Solid waste generated in India is 133760 metric tonnes per day (TPD). Every day 91,152 T waste is collected and 25,884 T treated. If we assume that there may be a growth of 5% per annum in the MSW generation due to increase in the population and change in lifestyle of the people, it is expected that urban India will generate approximately 2,76,342 TPD by 2021, 4,50,132 TPD by 2031 and 1,195,000 TPD by 2050. The CPCB report also shows that there is only 68% of the MSW which is collected in the country and there is only 28% waste which is treated by the Urban Local Bodies. Thus, right now hardly 19 per cent of the total waste generated is treated. Out of the total waste it is estimated that it has a potential of generating 439 MW of power from 32,890 tonnes per day of combustible wastes including Refused Derived Fuel (RDF).

Table.1.1 Population Growth and Impact on Overall Urban Waste Generation and Future Predictions until 2041

Year	Population (Millions)	Per Capita	Total Waste generation Thousands Tons/ Year
2001	197.3	0.439	31.63
2011	260.1	0.498	47.30
2021	342.8	0.596	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

Source: Sustainable Solid waste management in India, Columbia University in the City of New York, 2012

It is also estimated that approximately 1.3 million cubic metre of biogas per day or 72 MW of electricity from biogas can be produced and 5.4 million metric tonnes of compost can be used for agricultural purpose annually (CPCP Report 2012-2013)"

More than 100000 MT of Solid waste per day is generated by urban areas in India (CPHEE0, 2000). Bangalore generates about 5000 MTPD (BBMP, 2014) Mumbai generates about 7000 MTPD (MCGM, 2014) and other metropolitan cities like Pune and Ahmadabad generate 1600-3500 MTPD (PMC, 2014). It is the duty of urban local bodies in India to collect, segregate, handle, transport and final disposal municipal solid waste (MSW).

In India, Most of the urban local bodies are struggling to provide efficient waste management services in environmental friendly manner to citizens. Still in India, a significant amount of area does not cover Door-to-Door Collection; waste is collected from local collection points and transferred into open trucks in an unsafe and unhygienic manner; very few municipalities has arranged recovery and waste to energy techniques; waste is not segregated and dumped indiscrete manner without the use of linear system and leachate collection system (HPEC, 2011). Inefficient and poor waste management system in the city has led to the bed odour, unhealthy and aesthetically poor situation in most of the cities.

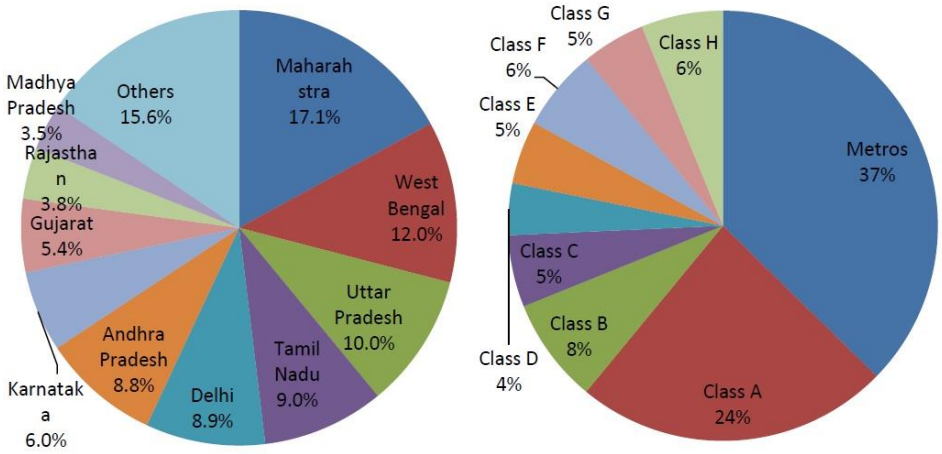


Fig.1.2 Generation Municipal Solid Waste of Different States and Union Terrorises of India Source: "Sustainable Solid Waste management in India, Columbia University in the City of New York, January 10, 2012"

"The present scenario of MSW management in India is not very encouraging. It is estimated that approximately 115,000 t of Municipal solid waste generated daily in the country (3iNetwork 2009) moreover, per capita waste generation varies from 0.2–0.6 kg per day. It is also estimated that per capita waste generation increasing by approximately 1.3% per year whereas the urban population is increasing at a growth of 3-3.5% per annum" (3iNetwork 2009). Further, it is also predicted that there is an annual 5% growth in the overall quantity of solid waste per year.

In India, most common way of disposal of waste is open dumping. Sharholy et al. 2008 reported that "about 5-6% of the total waste are disposed of by different composting methods. Due to the scarcity of technical infrastructure, political willpower and awareness among people the scope of waste reduction and eco-friendly methods of waste disposal decreases."

Social, demographic characteristics, and economic make-up are very fundamental factors on which the physical and chemical characteristics of the waste is depends on Sharholy et al. (2008). The variation of organic content varies 35-60% in different part of the country. Kumar et al. (2009) has also contributed and reported that "in selected 59 cities of India the average composition of MSW includes 30–45% organic matter, 6–10% recyclables, and the rest as inert matter". (Saha et al. 2010) has reported that all over the India, the cities which have composting and other waste to energy facility, segregation of the waste in not done efficiently which results to the poor quality of end product which definitely doesn't have any market value.

Final disposal of waste or reject in a non-engineered manner and not meeting the criteria with Municipal Solid Waste (Management and Handling) Rules (MoEF 2000) still remains the most challenging problem in front of the country and has resulted to the various health and environmental hazardous. Rapidly increase in waste generation caused by drastically increasing population, typical nature of waste caused by changing lifestyle, and scarcity of land for waste disposal have left the municipalities in difficult situation. Municipalities are faced with severe challenges in handling this situation in the absence of skilled manpower and support of community.

1.4 "Classification of waste"

"Managing waste in an environmentally sound, socially satisfactory and a techno-economically viable manner is Sustainable Waste Management. It is achieved through strategic planning, institutional capacity building, fiscal incentives, techno-economically viable technologies, public-private partnerships and community participation. Waste management approaches differ for different types of wastes and also for wastes in different geographical locations such as urban, rural and hilly areas. While there are many ways to classify waste, for the purpose of this paper we will classify waste based on its source stream. Wastes such as domestic and industrial ones can be classified under the heads of urban, industrial, biomedical and e-waste as shown in Figure 1.3"

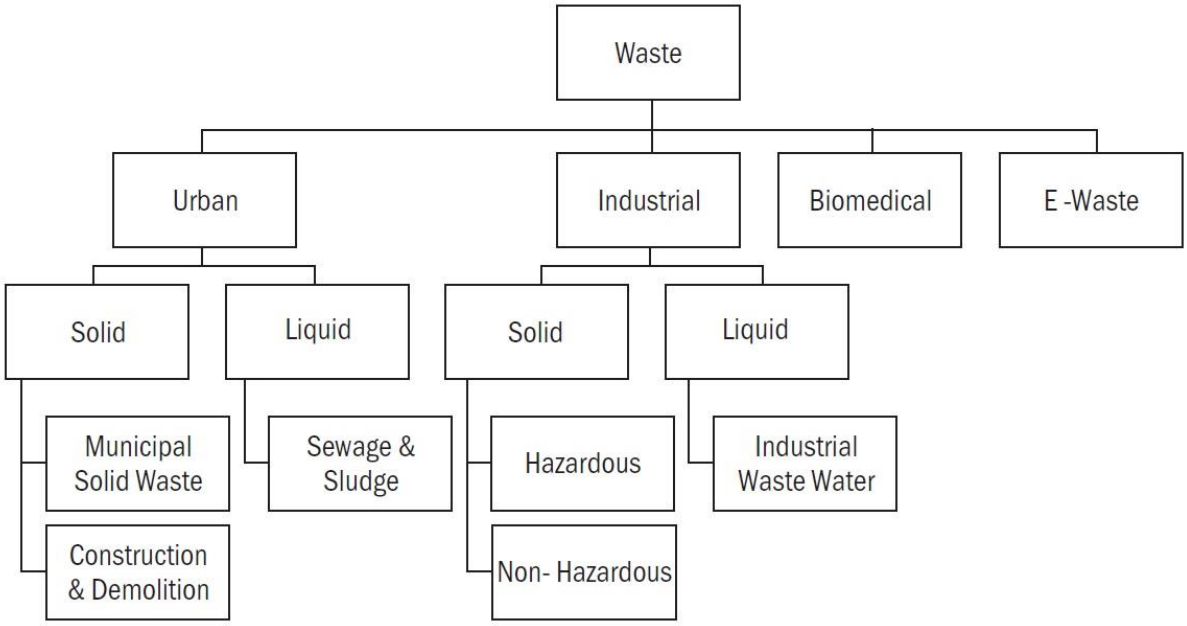


Fig.1.3 Classification of Waste

"These are generated during the extraction of raw materials, manufacturing and processing of raw materials into intermediate and final products, the consumption of final products, and other human activities."

Table 1.2: Sources and Types of Municipal Solid Waste; Source

Sources	Typical waste generators	Components of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil, tires) and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, government center, hospitals, prisons	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Municipal services	Street cleaning, landscaping, parks, beaches, recreational areas	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas

Source: "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2009"

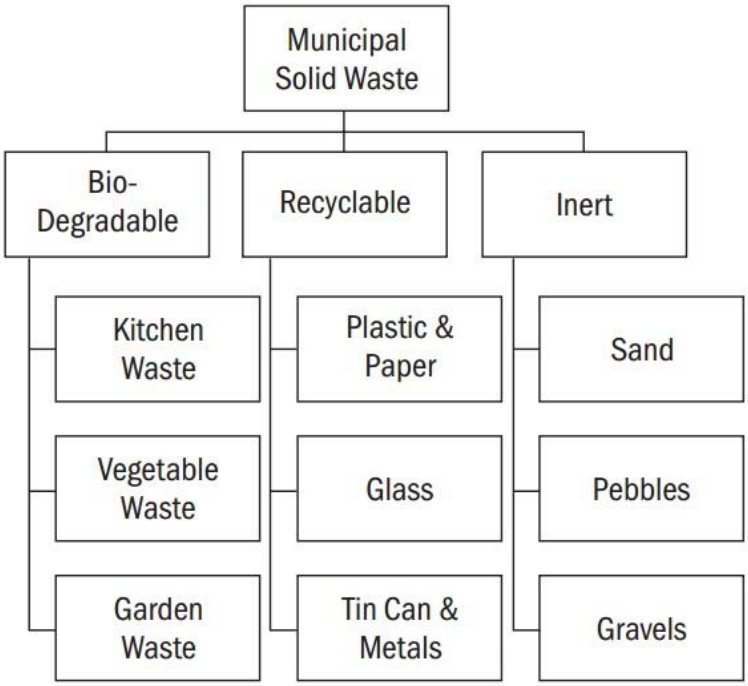


Fig. 1.4 Classification of Municipal solid waste

1.5 Legal and Regulatory Framework for SWM in India

In India, in order to standardized the management and handling of MSW [Ministry of Environment and Forests (MoEF) has published Municipal Solid Waste (Handling and Management) Rules 2000]. As per Municipal Solid waste (Handling and Management) Rules 2000, "Municipalities have been made responsible for managing MSW under the aegis of MSW rules. Rules and regulations regarding source segregation of waste and in order to process waste there are various methods such as composting, vermicomposting, biomethanation, refuse derived fuel for diverting biodegradable waste from landfills, and sending only non-recyclables, inerts, and residues to sanitary landfills are specified there."(Sethi S. et al. 2013)

Many rules and regulations have been made to make sure qualitative municipal solid waste management in the Indian cities. The list of acts and rules are shown in the Table 1.3 These Rules and regulation are applicable to every urban local body in India. It is the responsibility of every local body that collection, segregation, storage, transportation, processing and disposal of municipal waste must be done efficiently. As stated in MSWM rules, waste should be segregated before its collection is done in different waste categories such as Food waste, recyclable waste, construction and demolition and silt, household hazardous waste. Moreover, transportation, processing and final disposal should be planned in accordance with the national plan.

Table 1.3 Rules and acts for solid waste management in India

National Acts and Rules for Solid Waste Management
Municipal Solid Waste (Management and Handling) Rules, 2000
The Bio-Medical Waste (Management and Handling) Rules, 1998
The Plastic Waste (Management and Handling) Rules, 2011
E-Waste (Management and Handling) Rules, 2011
Batteries (Management and Handling) Rules, 2001
The Environment (Protection) Act, 1986
EPA - Rule and Implementation Information for Standards of Performance For Municipal Waste Landfills
EPA - Non-Hazardous Waste Regulations
EPA Municipal Solid Waste Landfill Regulations
The Water (Prevention and Control of Pollution) Act, 1974
The Water (Prevention and Control of Pollution) Rules,1975
The Water (Prevention and Control of Pollution) Cess Act, 1977
Water (Prevention and Control of Pollution) Cess Rules, 1978
The Air (Prevention and Control of Pollution) Act, 1981
The Public Liability Insurance Act, 1991
The National Environment Tribunal Act, 1995
The National Environment Appellate Authority Act, 1997

Source: Centre of Environment and Development, 2012

Compliance with the MSW Rules, 2000 it is the duty of every ULB to provide appropriate systems and infrastructure facilities to undertake scientific collection, handling, transportation management, processing and final disposal of municipal waste on engineered landfill. It is also observed that, door-to-door collection, management, handling, transportation, processing, and final disposal on engineered landfill is a very difficult task for most of the ULBs in India. Technical, managerial and financial deficiencies are the basic difficulties faced by most of the ULBs in order to provide efficient MSW management in Indian cities.

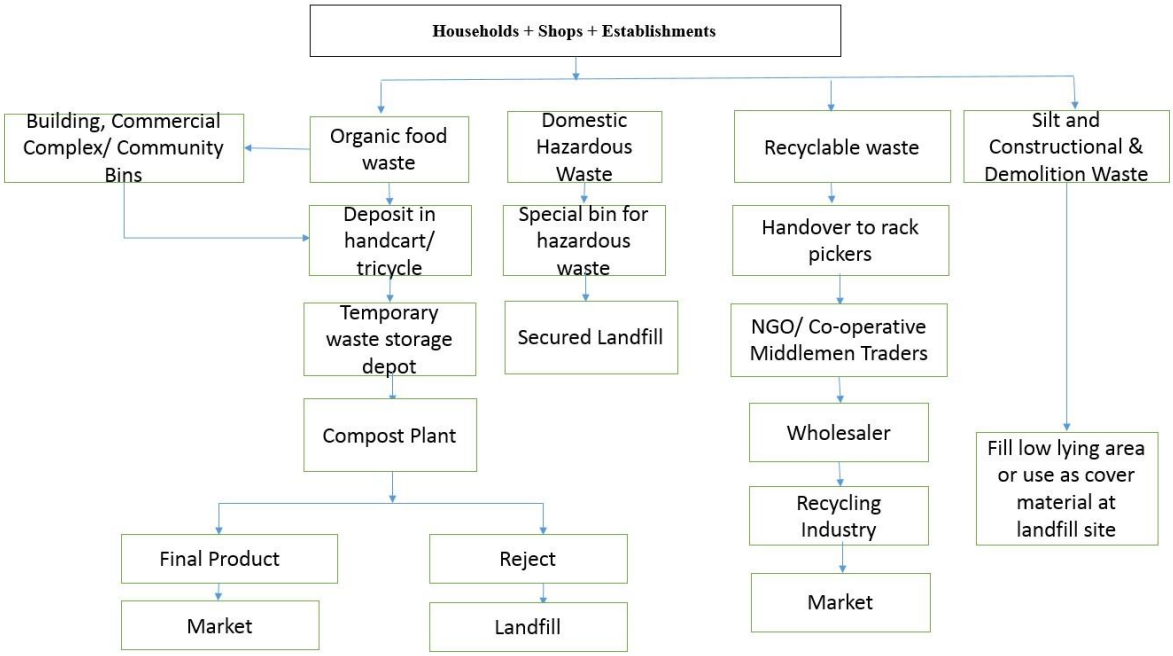


Fig.1.5 National Plan for Municipal Solid waste management

Source: Cited in (Kurien, 2000) from (Supreme court committee report, 1999)

1.6 Study Area and its MSW management

Uttar Pradesh is the biggest state in the country in terms of population. There are 5 cities in the state which population more than 1 lack, Muzaffarnagr is one of them. The Study area is Muzaffarnagar City, UP, India, Fig.1.6 shows the location of Muzaffarnagar on the map of India. Muzaffarnagr, located in the northern part of Uttar Pradesh, popularly known as Sugar bowl of India. It is roughly rectangular in shape. The economy of the district is mainly based on agriculture & sugarcane, paper and steel industry. Muzaffarnagar urban covers an area of $150Km^2$. "Recently Muzaffarnagar has been included in National Capital Region by government of India. The city is located in the middle of highly fertile upper Ganga-Yamuna Doab region and is quite near to the National capital, making it one of the most developed and prosperous cities of Uttar Pradesh" (Wikipedia).Temperature in Muzaffarnagar varies between 47℃ to -0.9℃. The average annual temperature of the city is 24.02℃.The Average rainfall of the city is 955 mm. The driest month is April, with 3 mm of rain. Highest precipitation falls in July, with an average of 294 mm. The Urban agglomeration lies between $29^0 28' 56'' N\ 77^0 42' 00^0 E$ (Wikipedia). As per 2011 census, Muzaffarnagar Municipality has a population of 392,451 and the urban agglomeration has a population of 494,792. The population of the city is increasing at a rate of 1.5% per annum. Sugar and jiggery are important industries in the city. Sine soil and environment is very favourable for the farming Muzaffarnagar has become hub of jiggery trading business. Muzaffarnagr has 8 Sugar mills and many steel industries. More than 40% population is involve in farming. According to Economic Research firm *Indicus Analytics*, "Muzaffarnagar has the highest agricultural GDP in Uttar Pradesh. Muzaffarnagr has major paper, sugar and steel industries." Daily generation rate varies between 120-130 MTPD. The Average generation rate of MSW is 0.315 kg/person/day. Whereas per capita waste generation for LIG, MIG and HIG are 0.1388, 0.1666, 0.6441 kg/day respectively. The city

has ample number of institutes, hospitals, shops, hotels and restaurants and approximately 64000 households. The organic matter in solid waste in developing countries is much higher than that in the waste in developed countries (Bhide and Sundaresan 1983). By 2010, waste used to dump near the Kali Nadi and Near Saharanpur Bus stand in outskirts of Muzaffarnagar, as still there is not any engineered landfill in city. Though there is an integrated SWM in the city, but due lack of interest of local bodies and funds the management is not taking place efficiently. In present study review of MSW management in the city has been done moreover physical Characterization, characterization based on income level i.e. High income group, Low Income Group, Medium Income Group, Chemical properties, geotechnical properties and physiochemical properties of the MWS has been done.

In the city, there are approximately 22 no. of hospitals and 27 no. of clinics are there, biomedical waste generated from those hospitals and clinics does not under go to separate processing of waste. Waste from hospitals and clinics is collected and directly send to the same MSW dumping site. Moreover, there are total 76 no. of mills in the Muzaffarnagar, sugar mills (6), paper mills (24), and Steel Rolling mills (36) present in the city, hazardous and toxic waste produced by them also don't under go to any special treatment. All of them discharge there waste into local stream (Kali Nadi) or directly dump in the open.

In 2010 MSW management has been implemented as per Municipal Solid Waste (Management and handling) rules (MoEF 2000), still open dumping is the predominating for a big fraction of MSW.

This thesis presents the characterization of MSW of Muzaffarnagar city which includes Physical, chemical and geotechnical characteristics of the MSW to decide the suitability of various waste management technologies. Moreover, this paper also review and analysis the current MSW practices in the city.

Fig1.6 Study Area

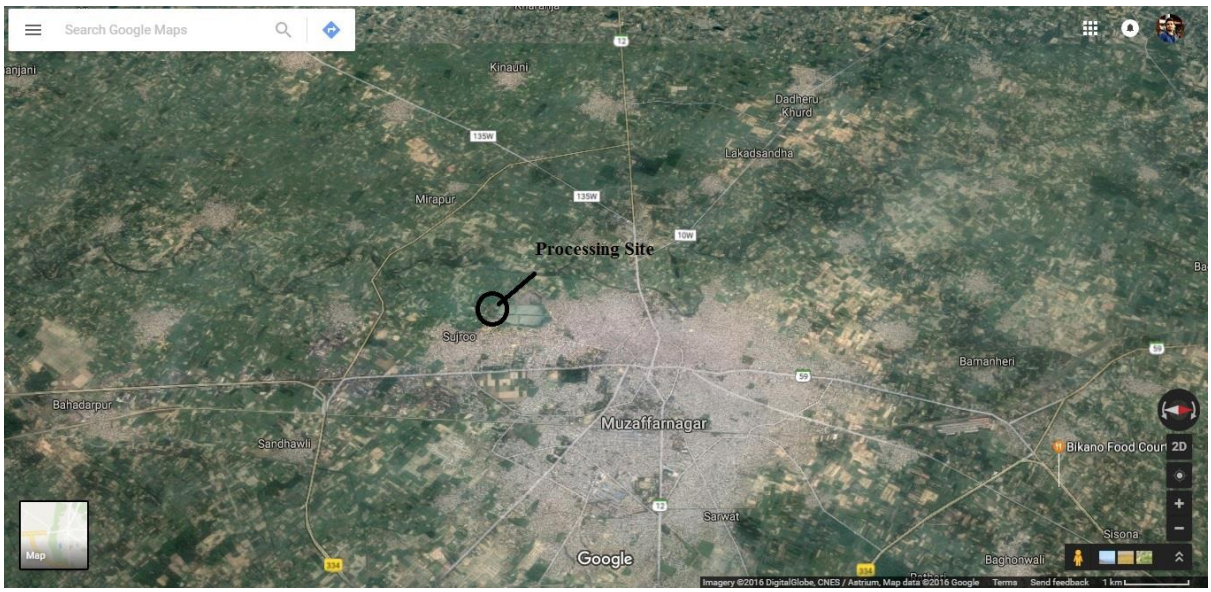


Fig.1.7 Project Site

CHAPTER-2
LITERATURE REVIEW

2.1 General

This chapter involves the review of literature in context to the characterization of solid waste. A review of Physical, chemical and geotechnical properties of waste is discussed.

2.2 Physical, physicochemical ,chemical and based on income group characterization of MWS

A review of past study states that a lots of work on characterization of solid waste has been done in India and outside the country as well. Some work is as shown below:

"Ramakrishna V. (2016) has reported that in order to effectively manage the MSW management of the city appropriate quantification of generation rate and characterization of the waste are essential. Recovery of the methane from the landfills is rare in India. There is a Solid waste management in Rajam, a municipality in Srikakulam district, AP ,is considered in the study where there is a significant generation of solid waste but not functioning of appropriate sloid waste management in the city. The per capita waste generation for the city is 0.214 kg/person/day. Food waste is approximately 74%. Average density of the waste is 320 kg/m^3. Average methane production is 180 m^3/tonne of waste."

"Mgimba C. et al. (2016) the results show that, it is found that waste has a big fraction as organic waste which is about 57%. The results also correspond to the findings obtained by Senzige, et al., (2014) from which it is found that characteristics of the waste is varying with socioeconomic categories of the household. In low income group it was 52.9%, middles income group category 57.7% and 70.1% in high income group category. Based on the survey done in the city it is found that waste has plastic (9%), paper (12%), textile (6%), metal (6.8%), wood (4%), e-waste (2%) and glass (4%) and inert (3%)."

"Joshi R. et al. (2016) stated that urbanization is being the main cause in significant enhancement of MWS generation rate and unscientific handling, processing and final disposal of the MSW which has degraded the urban environment and caused health hazards."

"Selvan S. et al. (2015) reported that has done a comprehensive study on Dharamapur municipality, Tirupur District in Tamilnadu. This research has shown that city is suffering from poor management of the Municipal solid waste management in the city. This research has discussed the population growth and its impact on solid waste generation and its management. Data has been collected in summer and winters. The bulk density of the waste varies between 184-196 kg/m^3 in summer and winter season seasons. The organic fraction has been reported significant and varies between 59-75 % in winters and 60-76% in summer season. The fraction of Plastic (5-12%), paper (3-12%), rubber (1-3%), glass (1.5-2.5%), silt (11-13%), metal (0.9-2.5%) and cloth (2-7%)."

"Srivastava R. et al. (2014) has reported that in Varanasi city, the biggest fraction is food waste (31.9 %) followed by plastic (22%), textile (10.6%), paper (9.6%), glass (6.7%), cardboard (6.2%), ash (5.3%), leather (5.7%) and minimum metals waste (2.8). It is found that per capita MSW waste generation rate for the city approximately 800 MT per day and per capita demand is found about 0.217kg/person/day. The calorific values for the Sample collected from Ordali bazar was found to be the highest energy content according to Modified Dulong Formula with a value of 254524.46 KJ/Kg followed by Daphi 167545.84 KJ/Kg, Nakhighat 96455.80 KJ,/Kg Puranapull 16147.11 KJ/Kg."

"Mohammedbirhan M.et al. (2014) reported that generation rate was 0.54 and 0.49 kg/capital/day and 362.5 kg/m^3 and 355 kg/m^3 for Aksum and Shire Endaslassie town respectively. Based on the characterization done in Axum city is it is found that waste has food wastes, grasses and leaf characterized as 'decomposable' (36%) followed by plastic (21%), Ashes (17%) and Paper and cardboard contributed 8%. Similarly, the composition of the waste generated in Shire Endaslassie is predominantly food wastes, grasses and leaf characterized as 'decomposable' (43%) followed by Ashes and dusts (21%), plastics (8%), and Paper and cardboard contributed 7%. The remaining waste, including metals, glass, rubber/leather, textiles, and others accounted for less than 18% and 21% for both Axum and Shire Endaslassie towns respectively."

"Rajani et al. (2014) Sample from Ordalibazar showed the highest amount of energy content according to Modified Dulong Formula with a value of 254524.46 KJ/Kg followed by Daphi 167545.84 KJ/Kg, Nakhighat 96455.80 KJ,/Kg Puranapull 16147.11 KJ/Kg."

"Sethi S. et al. (2013) has reported that mainly MSW were biodegradables and inerts. Physical characterization of the waste indicated that there is an approximately 24–41% of organics are there which mainly involves fruits and vegetables generated by the different socioeconomic groups in the city. It is observed that maximum organic fraction is produced by slum and low income group area. There is approximately 21-33% inert fraction in the MSW. The reason behind the high percentage of organic fraction is that the sand, silt, dust, grit, and ash was found from cleaning and sweeping of street and mixing of some amount of construction debris in MSW. Low income group and slums has contributed the most in inert.

Moisture content of MSW was reported 27–35%. C/N ratio was also determined, it vary from 22–26 for the organic fraction of MSW. Calorific value for the waste was also determined and found to be low (3956–4521 kJ/kg), reason being the lesser amount of paper and plastic and significant quantity of inert, the fraction of ash is found significantly high because of the presence of a huge amount of inert in the waste. The bulk density of MSW was also determined and found to be 389 kg/m^3. The bulk density was found significantly high because of a higher fraction of compostable and inert fractions in the city waste.

This research paper has also found the concentration of heavy metal Iron 1064 mg/kg, Copper 20.26 mg/kg, Lead 9.38 mg/kg, Nickel 5.06 mg/kg, manganese 13.06 mg/kg, Zinc 31.08 mg/kg. The concentrations of Copper (Cu), Zinc (Zn), Nickel (Ni), Chromium (Cr), Lead

(Pb), and Manganese (Mn) for MSW were within the range of the Indian compost standard of Municipal Solid Waste (Management and Handling) Rules (MoEF 2000)."

Katiyar et al. (2013) reported that the density of solid waste generated is ranging from 300 to 400 kg/m^3 which implies that compaction of waste is unnecessary during transportation. The percentage of food waste is varies between 40-45% which involves approximately 50% of waste is from residential areas and 45% from vegetable and fruit Markets. If the organic fraction is near about 50%, it is a big fraction which directly impels that concentration of biodegradables is high hence composting will be the best method to process the waste. High percentage of recyclable matter has also been reported. Approximately 10% of inert waste, bio-resistant and high inert contents and high ash contents (15-20%). It can be used as cover material. The fraction of metals are very less (approximately1%). In the residential area the density of solid waste has been found about 300 kg/m^3 from hotels and nearly 285 kg/m^3 from vegetable and fruit market (This density is at the source of generation)

"The average values of different parameters has been determined; Density (314.9 kg/m^3), low and higher calorific values 2244.2 and 2411.7 kcal/kg respectively, moisture content (28.1%) , ash (15.6%), fixed carbon (9.5%), volatile matter (46.6%), Carbon (26.6%), Hydrogen (5.9%), Oxygen (47.7%) , Nitrogen (1.1%), Sulphur (0.98%), Phosphorus (0.84%), Potash (0.93 %), C/N Ratio (26.6)."

Dasgupta B. et al. (2013) has reported that MWS in the Varansi city is heterogeneous in nature and characteristics of the waste vary with seasons. Generation, collection and handling, transportation, processing and final disposal on dump site is a versatile problem in front of the municipality. Organic fraction was always the biggest fraction throughout of the year with minimum percentage (48.25%) in the rainy season. Since waste has such fraction of organic waste it is suggestable to adopt composting and biometanation as waste processing techniques. The average per capita waste generation was found to be about 0.460 kg/person/day. Generation and collection of the waste is rapidly increasing every year which may be due to dramatic rise in the population.

Rawat M. et al. (2013) has stated that changing life style pattern mainly in urban areas has led to the significant increment in MSW generation. Indian Cities approximately produces 40-60% organic matter which can be easily converted into compost. The most appropriate method to convert organic fraction of waste into compost is aerobic composting using windrow method. Samples from thickly populated cities (Delhi, Ahmedabad, and Banglore) has been collected and heavy metals has been determined. Few samples had heavy metals above the permissible limits.

Annepu K. R. (2012) has done a study on India and reported that there is a huge scope of improvement in the MSW management in India. They have estimated that India is producing 68.8 million tonnes per year (TPY) and 188500 tonnes per day (TPD). Based on the data collected he has stated that there is a 50% growth in the MSW generation within a decade (2001-2011). It is expected that in a "business as usual scenario", urban India will generate approximately 160.5 million TPY (440,000 TPD) by 2041; in the next coming ten years, urban

India will generate approximately a total of 920 million tons of MSW so it essential to be properly managed in order to avoid further degradation of public health, air, water and land resources. In todays "In today's business scenario India may not be able to manage the waste in a efficient and proper way a "business as usual" scenario, India will not be able to dispose these wastes properly.

Late A. et al. (2012) has done the composition and characterization study of MSW for Aurangabad City. They have stated that with rapidly increasing population and urbanization; problem such like generation of MSW has taken place. Characterization and composition of MSW varies with income level, population, social behaviour, social behaviour, industrial production and markets. The research has been taken place for three years (2007-2009). Based on the research done it can be stated that biodegradable fraction in the MSW stream is approximately 83.50% whereas inorganic fraction in the MWS stream is approximately is 16.50%. However the physic-chemical parameters of the solid waste collected from disposal sites were found in moderate range.

"Bhalla B. et al. (2012) has done a survey in Ludhiyana at Jamalpur, Jainpur and Noorpur sites and concentrations of leachate contaminants has been determined. Concentration of leachate contaminants at Jamalpur and Noorpur belt landfilling site were comparative greater than that of Jainpur landfilling site which is older than both. Based on the characterization of landfill leachate, Jamalpur and Noorpur landfilling site demonstrated low bio-degradability i.e. BOD5/COD (0.19) and BOD5/ COD (0.20) compared with Jainpur landfilling site i.e. BOD5/COD (0.24)."

Bundela P.S. et al. (2012) has reported that Leachate generated from the working municipal solid waste landfills can be a major source of contamination to surface water and ground water. So the investigation has been done and different parameters of the leachate sample collected form the site has been quantified. Total 10 no of leachate samples were collected from various locations and significant value of COD and BOD 1213 mg/L and 542 mg/L have found in the samples respectively.

Vyas P. B. (2011) has reported that a study of Delhi, Malad, Bhopal, Nasik, Ahamdabad, and Gwalior has been done by Central Pollution control board. Municipal solid was is processed and converted into compost and various physicochemical characteristics and heavy metals has been determined and compared with Municipal Solid waste (Management and handling) rules, 2000 (MSW rules). In Ahmadabad and Nasik heavy metals in MSW compost was found in limits except Pb, whereas in other cites concentration of heavy metals has found above the permissible limit.

Yu et al. (2011) has reported that the unit weight also affects the carrying capacity of the waste within a landfill. Field capacity has also been calculated and found to be 0.42. In order to design

an engineered landfill field capacity is a very important parameter because field capacity is the important key parameter which governs the amount of moisture in the landfill.

Thitame N. S. et al. (2010) done the characterization of the MSW for Sangamner city, District Ahmednagar, Maharashtra, India. They have segregated the waste into different components i. e. paper, kitchen waste, earth and fine material, slaughter house, metals, leaves etc. whole waste stream was divided into organic and inorganic waste. Based on the work done they have concluded that MSW has good nutrients which can be used for agricultural purposes where the inorganic fraction can be used as landfill.

Kumar. N.K. et al. (2009) has conducted a study in Kharagpur, a city in West Bengal, India. In the study it was found that total waste generated is 95 MTPD but only 50 MTPD waste is being collected. Most of the waste is directly dumped on the road sides, open lands, and in natural and engineered drains which results into clogging of the drains and overflowing of the storm water from the drains and ground water contamination. Unappropriated bin location, undersigned bins, poor condition of the vehicles involve in transportation of waste and poor waste treatment has led to the poor management of the MSW in the city. "The average values of various parameters were moisture content = 42.05 (±10.25) percent, total solids = 58.36 (±11.57) percent, volatile solids = 19.63 (±9.53) percent of total solids, fixed solids = 80.35 (±9.54) percent of total solids, organic carbon = 8.91 (±5.79) percent, COD= 0.158 (±0.08) mg oxygen/mg of SW and calorific value = 2391.16 (±264.58) cal/g (10,008.24 kJ/kg)."

Ramesh N. et al. (2009) worked on a Erode (I- class city), Tamilnadu, India; they have reported that there is necessity for the improvement and based on the work done they have suggested a appropriate technology to improve the system in order to minimize the damages on Environment. They have also collected some ground water sample in the vicinity of the dumping site and determined the physicochemical properties. Results has shown that most of the critical parameter like BOD, COD, most of the heavy metals was found above the permissible limits obviously which require the improvement in on going municipal solid waste management in the city. They have also reported that vermicomposting is not only inefficient but also not enough to manage huge amount of waste generated.

"Kumar et al. 2009 has done a research for the cities having population 1-2 million, various constituents of MSW, such as compostable matter (39–54%), recyclables (9–25%), C/N ratio (18–52), calorific value (714 kJ/kg), and moisture content were in the range of (25-65%). However, the compostable fraction of MSW was observed to be lower than that of Kumar et al."

T. Ch. Ogwuelekac (2009) has reported that the density of solid waste in Nigeria ranged from 250 kg/m^3 to 370 kg/m^3. These values are very much higher than the solid waste densities found in developed countries. The percentage of plastic (8.4), paper (13.8), textile (3.1), metal (6.8), glass (2.5) and others (9.4).

Sharholy M. et al. (2007) has reported that MSW contains 45.3% organic fraction and 40% collectively bricks, fine dust, rubber, wood, leather, wastewater, etc. The fraction of recyclable materials (glass, paper, plastic, and metals) has been found to be very low reason being the rag pickers, who collect and segregate recyclable materials from collection points and disposal sites.

Gupta S. et al. (1998) has reported that in India collection, transportation, handling, processing and final disposal of waste is unscientific. Outskirts of almost every cities and town have overflowing with the wastes. Uncontrolled dumping have become a very serious issue not only for the people living in the vicinity but also for the environment in terms of ground water, surface water contamination and global warming. Burning of the waste in the open is leading to air pollution by increasing the concentration of pollutants in the atmosphere.

2.3 Summary of Literature Review

1. Rapidly increasing rate of solid waste generation has not been only local issue but also a global issue. Developing countries like India; in order to become one of the fastest economy in the world setting up new industries, which are one of the main solid waste generators.
2. With rapidly increasing population, urbanization, industrialization and changing life style; problem such like generation of MSW has taken place.
3. Due to lack of resources people living in rural are migrating to the urban area which is resulting into significant increase in the urban population hence in the increase in the solid waste generation and load on the landfills.
4. Today collection, transportation, disposal, processing and final disposal of Municipal waste in a scientific and efficient manner is a big problem in front of the Urban Local Bodies in different cities of India.
5. Waste stream can be divided into different components i.e. Food, paper, plastic, metals, rubber, construction debris, street sweeping, agricultural Waste etc.
6. Mainly constituents of MSW can be divided in two categories: Organic and Inorganic.
7. Organic can further be divided into food waste, agriculture waste, tree leaf, grass etc.
8. Different properties (physical, chemical) can help in design criteria's.
9. If Organic content is high; Composting is best way to process the waste.
10. Thorough understanding of different characteristics of waste helps in deciding which process (composting, incineration etc.) has to be adopted for any particular city.
11. Uncontrolled dumping of waste on the roadsides, outskirts of the cities in a non-engineered manner has cause huge problem for the people living in the vicinity and for the environment as well.
12. In most of the places in India, there is a trend of open dumping; after the rainy season; contamination of ground water and surface water has always been a very serious issue throughout the country.

2.4 Objectives

1. To review the present MSW generation, composition, handling, transport and final disposal methods applicable in the area for management of MSW under Integrated MSW management plan in the city.
2. Characteristics of municipal solid waste will be reviewed and different physical and engineering properties of municipal solid waste will be determined.

CHAPTER-3
METHODOLOGY

3.1 Materials and Methods

This chapter includes the methodology adopted in conducting the Laboratory tests to find out the physical, Chemical and geotechnical properties of MSW and Refuse. The following geotechnical tests were conducted on refuse samples to determine their geotechnical engineering characteristics. Laboratory tests were performed according to the Indian Standards (IS-2720) methods of testing soil for engineering purposes. The geotechnical laboratory tests were conducted at Jaypee University, Waknaghat, Solan. Figure 3.1 shows the flow diagram of research methodology adopted in this report in order to accomplish the project.

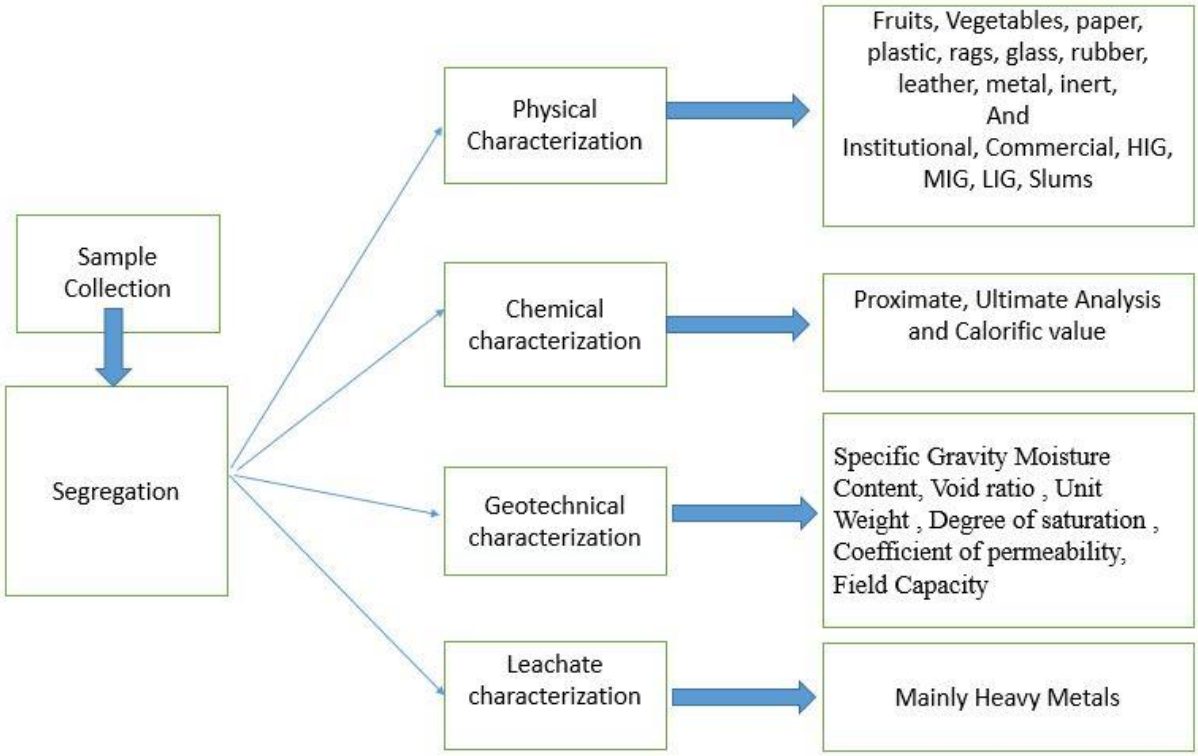


Fig.3.1 Methodology for the Solid waste Characterization

3.1.1 Physical Characterization of MSW

Sample collection was done in accordance with ASTM D5231-92 (ASTM 2008) in the very first week of January, 2017. Sampling has been done for 7 consecutive working days from dumping site, each day 150 kg sample collected while trucks used to unload. Each day samples were collected from at least 7 no. of wards in order to cover all the wards of the city, since city is divided into total 41 wards. By the end of 6^{th} day total 1050 kg sample has been segregated.

This sampling method involves sampling of MSW from vehicles deployed for collection and transportation of MSW. According to this method, collection crew coming from the desired zone reaching to the dump site; each day randomly samples were collected in order to make the waste stream representative. MWS was further classified based on the income class i.e. Low Income Group (LIG), High Income Group (HIG), Medium Income Group (MIG) of different areas. The conventional and fundamental method of gravimetric profiling was adopted by emptying out the entire MWS on a plastic sheet to prohibit the mixing of waste/soil. The 100 kg of fresh waste samples has been collected for 7 times during first months of the year 2017 from the Muzaffarnagar dumping site by using the previously mentioned methodology. The waste samples has been segregated manually onsite with the help of rag pickers present the dump site of Muzaffarnagar. Thereafter, Segregation of MSW samples has been done into various physical components, such as food waste (fruit, vegetables etc.), paper, plastic, rubber, metals, inerts, construction and demolition material etc. After segregation, all components has been weighed separately. The mean waste composition was calculated by using the results of the composition of each of the sorting samples. Each time, approximately 5 kg of waste sample has been collected in a polythene bag and send to the laboratory for chemical characterization. Moisture content has been analysed immediately, and rest of the samples has been refrigerated and used for chemical analysis. The gradation of MSW samples also has been performed using the sieves of diameter 200, 150, 100, 50, and 20 mm.

3.1.2 Chemical Characterization of MSW

"In order to perform characterization of the Chemical characterization of waste has been done to understand its potential for various waste processing techniques, like vermicomposting, composting, refused derived fuel (RDF) and incineration. Proximate analysis involves the determination of, Volatile content (%), % ash content, and the calculation of % fixed carbon. The proximate analysis will be conducted according to ASTM standards E790 (ASTM 2004a), E830 (ASTM 2004b), and E897 (ASTM 2004c). Bomb Calorimeter will be used in order to determine the calorific values."

The ultimate analysis included determination of carbon, hydrogen, nitrogen, sulphur, and oxygen content in dry samples. The test will be carried out by a CHNS analyser [(Model Vario EL-III) according to the ASTM D3176-09 (ASTM 2002) standard test procedures]. The oxygen content will be determined by difference, knowing the mineral content. Heavy metals will be analysed by using an atomic absorption spectrometer (model 4141, ECI). Prior to the analysis, each sample will be digested with concentrated HNO3 according to the ASTM standard method D5198-09 (ASTM 2003) (Method A)."

3.1.3 Geotechnical Characterization of MSW

The geotechnical properties are also the one most important properties in order to determine the design and maintenance of the landfills. The specific gravity of the samples was determined in accordance with ASTM D854 (ASTM 2006a). Average specific gravity and Average moisture content were used to calculate unit weight, degree of saturation, void ration and unit weight, (Venkatramaiah 1993). Constant head permeability will be used in order to calculate the coefficient of permeability of MSW samples [ASTM D 2434-68 (ASTM 2006b)]. It will be reported in cm at 27°C. Field capacity is defined as water holding capacity of the waste against the action of the gravity; is one of the most important geotechnical property of the MSW; determination—undisturbed samples (7.0 kg) of 17 cm in diameter and 40 cm in height in a cylinder were first saturated with water and then left to drain until the drainage ceased.

3.1.4 Leachate Characterization

The leachate samples has been collected at various locations of the dump site. And randomly mixed before its analysis. Leachate sample has been analysed for different physicochemical properties like electrical conductivity, pH, Total Dissolved Solid (TDS), Total Solid (TS), Biochemical Oxygen Demand BOD, Chemical Oxygen Demand (COD), $NH4 - N$, and heavy metals (Fe, Pb, Cr, Cd, Cu, and Ni) using standard methods [American Public Health Association (APHA) 2005].

3.2 Data and Information Related present Solid Waste Management exercise in the City

The data and information regarding present solid waste management exercise in the city were collected initially by carrying out a primary survey of different waste management practices, starting from the household collection, segregation, transportation, handling, processing and final disposal. Further, the information from the preliminary survey was supplemented with that obtained from Municipal Corporation Muzaffarnagar and A2Z Infrastructure Limited.

CHAPTER-4
RESULT AND DISCUSSION

4.1 Assessment of SWM in the City

A2Z Pvt. Ltd has taken the responsibility of collection. Approximately 70% of the city's waste is collected by Door-to-Door method. There are 41 collection points are there in the city, person from A2Z comes for street sweeping and to collect the waste to each door and dump it those collection point (transfer station), and houses those don't come under door-to-door collection dump their waste on these collection points. Most of the collection points either doesn't carry metallic containers or with insufficient capacity, moreover there are open spaces to dump the waste, no boundaries are defined resulting to spreading the waste on the roads also.

At some places it is also found that waste is dumped in middle of road, City's vegetable market is one of the cases where waste dumped in the middle of road, though collection crew comes daily to collect the waste except Sundays and national holidays but in case if collection crew doesn't come on time due to any reason like national holiday or heavy rain it becomes the epidemic. Loading is done manually, there is only one garage in the city from where the vehicle vehicles are operated and maintenance is also done with the help of private contractors.

After the collection waste is sent to the processing site, at the site there are to processing methods are adopted to process the waste one is composting and other is RDF but due to the very poor condition of plant including machines, equipment, scarcity of technical manpower the processing of waste coming each day can't be processed. Though from the data provided by the plant manager it is observed that compost and RDF made after the processing of the waste is very efficient has very well C, N, P and calorific values respectively. Since waste generation rate is very high and machines capacity to processes the waste is very low, waste stream coming to the plant is turning in to mountains of waste with in and around the site.

There is no provision of engineered landfill, approximately 120-130 MTPD waste is collected and disposed off at the site without segregation and applying soil covers. There is no provision for leachate collection on the site so it can easily percolate into the ground. The physiochemical properties of the landfill leachate samples has shown in the Table.3. These values clearly shows that there is presence of higher concentration of organic and inorganic

chemicals including heavy metals. The concentration of these chemicals in the surrounding water resources is further a scope of the study. By the time effect of leachate on the water resources has been a matter of ignorance only.

Analysis of City's MSW management system can be performed with the flow diagram shown in the Fig. 4.1 and Fig. 4.2. Both the figures describes the complete process of Management of solid waste in the city with formal and informal sector.

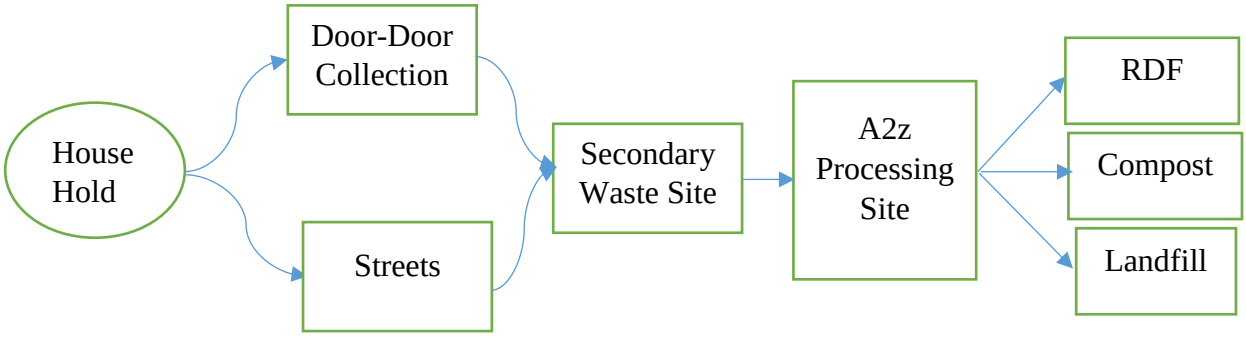
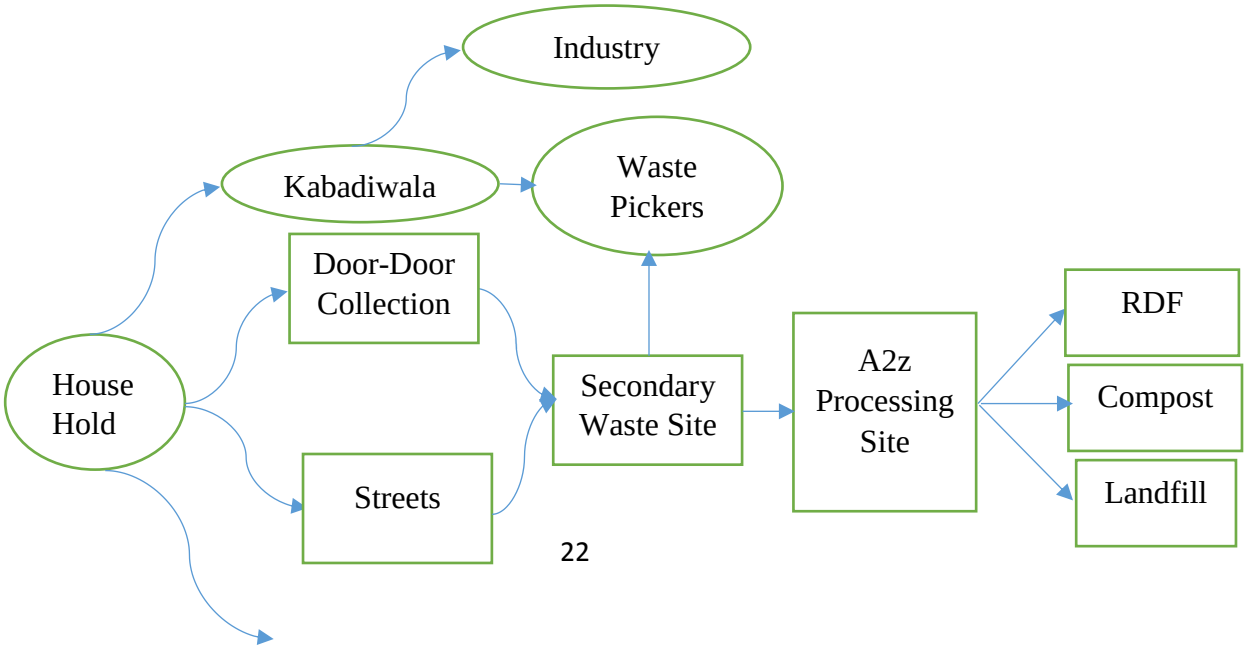


Fig.4.1 Muzaffarnagar MSWM system design with A2Z

As shown in the above figure, whether the waste is collected from the houses by door-to-door collection method or the households through it on the road side, from both the places waste is collected by the people of A2Z Infrastructure Limited. Once waste is collected, it is send to the secondary waste site or kind of small transfer site. From the secondary waste site itself waste is send to the A2z processing centre with the help of transportation system provided by A2z Infrastructure Limited, though Municipality of Muzaffarnagar also provides transportation system if needed. At the site waste is segregated by mechanical means.



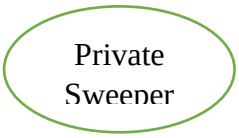


Fig.4.2 Muzaffarnagar MSWM system design with informal sector

Once the segregation is done, organic fraction segregated from the waste stream is converted into compost, which is further used for the agriculture purposes and the fraction of the waste which can be bur or incinerate easily is used to make RDF, reject from both the process is send to the landfill.

The flow chart shown in **Fig 4.2**, the analysis of MSW management system with informal sector. As shown in the diagram above, at the household level itself, kabadiwala collects the recyclable waste as paper, plastic, metals, glass etc. and sell it to the small scale industries or large scale industries. Waste from the households is collected by door-to-door method or households through it on the roadsides, in both the cases waste is collected by A2Z infrastructure Limited and further send to the transfer site. From the transfer site, waste picker collects recyclables as paper, plastic, glass, metals etc. and sells it to the industries. Thereafter, waste is send to the processing site and treated. Reject from the processing send to the landfill site for the final disposal.

4.1.1 Population

The current population of the city is 392451. City's population has grown dramatically over past 20 years. Between years 2001-2011 the population has grown by 1.7% annually. The census count shows that between years 1991-2001, the urban population almost get doubled. Outside the municipal boundary population is growing steadily. Since, 1991 four to 5 urban areas have been growing on the edge of Muzaffarnagar with annual population growth rate between 5-7%. With those 4-5 urban area's population Muzaffarnagar Metropolitan population becomes closer to 500000.

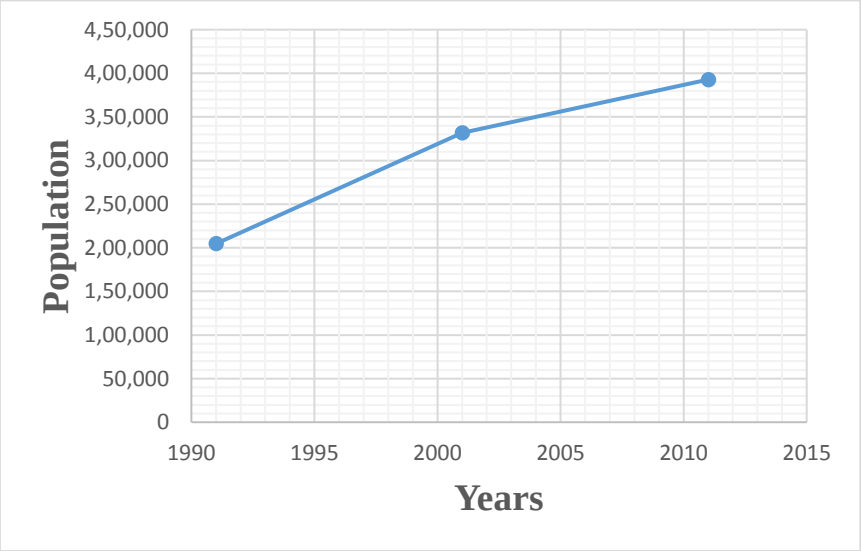


Fig.4.3 Population vs. Years

4.1.2 Household waste generation in the Muzaffarnagar

The first and one of the largest challenge in trying to understand any waste system is to find out how much waste is produced. A survey was conducted (70 households; 132.3 kg waste collected) and the waste generation rate is found to be 0.315 kilograms per person per day. Using the rate, an average family of 6 people would produce around 1.89 kg of waste per day. At the municipal level with 64,000 households, this translate to 123.5 metric tons of household waste generated daily. On a daily basis A2Z collects around 120 MT of waste, which include the household and business waste too.

Waste Collected from 70 households = 132.4 kg

Person in each household = 6 (assumed)

Per Capita Waste Generation = $$\frac{\text{Totale Wasre Generated}}{\text{No. of House Holds X No of person in each House Hold}}$$

$$= \frac{132.4}{70 \text{ X } 6} = 0.315 \frac{\text{kg}}{\text{person}}/\text{day}$$

4.1.3. Waste collection

The collection method is **Door-to-Door**. Around 70-80% of household is covered under door to door collection. This was the first Door-to-Door Collection system implemented in the city. The new MSW management system in Muzaffarnagar was designed to offer household two means for disposal:

1. Either daily Door-to-Door Collection
2. Disposal through Convenient dumpsters placed throughout the city.

Waste collected from the households is expected to separate by the household itself in organic, inorganic and recyclables. Moreover, households are expected to separate dry and wet waste at household level only. But there no such practice done by the households of the city. Waste is collected 6 days in a week.

Fig.4.4 After door to door collection

Moreover, every ward has its own dumping point and it is observed that in a every ward almost all households belong to same socioeconomic group, every day or once in two days when dumper used to come to collect the waste from each ward, it is weighted for 7 day for each of the socioeconomic group randomly from different wards in order to make a representative sample. From the data collected for seven days per house hold (6 member/ house hold assumed) and per capita generation was calculated which is shown in table no. 1. It can be clearly understand from the table that LIG has the lowest waste generation whereas HIG has the highest generation rate. If mean of all of the generation rates for socioeconomic groups is calculated, comes 0.316 kg/person/day.

Table 4.1. Per House Hold MSW generation in Low, Middle and High income group

Income Group	**Average Waste generation (kg/day)**		**Range (kg/day)**	
	Per House Hold	**Per Capita**	**Per House Hold**	**Per Capita**
Low Income Group	0.8328	0.1388	(0.555-1.1106)	(0.0925-0.186)
Medium Income Group	0.999	0.1666	(0.641-1.357)	(0.106-0.226)
High Income Group	3.8065	0.6441	(1.357-6.256)	(0.226-1.0426)

4.1.4. Handling, Transport and incentives

Before 2010, Municipal Corporation Muzaffarnagar was taking care of the solid waste management in the city. Street sweeping and waste dumping were only two activities done by the Municipal Corporation of the city. City currently spends 35% of its budget on waste management. 2010 onwards, A2Z Infrastructure Limited has come into the picture.

Table4.2: Dump Points and Vehicle Summary

Item	**No**
Total Dump points in City	41
Cover Dump Points same day	41
Total JCB	3
Total Dumper	6
Total Tractors	3
Tata Ace	1

Whole city is divided into 45 wards. Each ward has a dumping point. Once the waste is collected from the houses, will be transferred to dumping point (which are also transfer stations). From the dumping points further waste is collected by collection vehicles (generally

Dumper and JCB involved) and send to the dumping site. The site is at the outskirt of the city, Kidwayi Nagar. Here on the site, first of all dumper with waste is weighted and the further send to the segregators. The function of segregators is to segregate the organic and inorganic fraction. Once the segregation is done. Further the organic and the inorganic part is divided into two parts, first which can be converted into compost and the other which can be used as RDF (refused derived fuel) and remaining part would be landfilled.

4.1.4.1 Street Sweeping and Collection Points

"The sanitary workers of A2Z collect waste during street sweeping and dump it to the nearest collection point. Approximately 45 collection points or temporary waste storage depots exist in the city. Collection points are either open spaces without any boundaries or metallic containers/bins (open and closed). Containers are not placed on the paved surface, resulting in generation of additional quantity of inert material along with the collection of spillages. At a number of places, these bins are found overflowing or underutilized. The location of these bins is not properly sited. Garden and park waste is collected separately by MC Muzaffarnagar and A2Z for composting in the city."

4.1.4.2 Secondary Collection/Transportation

"In the city, bins are emptied by collection vehicles daily, except on Sundays and national holidays. The MSW transportation is done intermittently, by mechanized systems using auto tippers, tipper trucks, dual dumper placers, and tractors. Most of the waste loading is done manually. In congested areas, three wheelers are used for waste collection. Survey on the total waste collected in the city reveals approximately 120 T-130T of waste is collected by the municipality in a day. Regular servicing and maintenance of vehicles is done with the help of private contractors."

Household are expected to pay a monthly service fee of INR30 per month. Unfortunately, scenario in the city is such poor that people are not willing to pay even such small amount i.e. 1 INR/ day. Though Urban local body claims that they invest 35% of the budget in the MSW management for the city, but it is a bitter truth that it is not so.

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Fig.4.5: Jila Aspatal dumping point

At the processing site, Composting and RDF unit is there, but the capacity of the unit is not sufficient that they can handle whole waste generated every day, which is resulting into mountains of waste around the processing site.

Table 4.3: Dump Points name and ward information

List of Dump Point Muzaffarnagar City			
Sr. No.	**Name of Dumping Point**	**Zone**	**Ward**
1	Kabristan	**1**	43
2	Divider Khalapar	**1**	41
3	Gehra Bagh (Walmiki Basti)	**1**	26
4	Police Chowki (Khalapar)	**1**	41
5	Income Tax (Meerut Road)	**1**	26
6	Gudri Bazar (Bhagat Singh Road)	**1**	36
7	Daal Mandi (Bhagat Singh Road)	**1**	36
8	Sabji Mandi (Bhagat Singh Road)	**1**	36
9	Azad Band (Bhagar Singh Road)	**1**	38
10	Puja Sweets House (Krishna Puri)	**1**	23
11	Eid Gah	**1**	32
12	Kali Nadi	**1**	11
13	Ramlila Tilla	**1**	15
14	Bharat Steel	**1**	31
15	District Hospital	**1**	5
16	Rampuri Gate	**1**	25
17	City Cetre	**2**	14
18	Keshaw Puri	**2**	14

19	Tempo Stand (Meerut Road)	**2**	14
20	Company Bagh	**2**	16
21	Sharden School	**2**	16
22	D.M. Aawas	**2**	13
23	Arya Samaj Road (Neharwai)	**2**	14
24	Arya Samaj Road (Opp. State Bank of India)	**2**	14
25	Government Inter College	**2**	16
26	Chhotu Ram Inter College (Circular Road)	**2**	13
27	Gupta Nursing Home (Circular Road)	**2**	16
28	Ganna Farm (Opp. Shakuntalam Colony)	**2**	16
29	SSP Aawas (Near Railway Station Road)	**2**	6
30	Omega Hotel (Near Railway Station)	**2**	6
31	Collectrate	**2**	6
32	Sai Dham (Station Road)	**2**	13
33	Manu Sweets (Near Post office)	**2**	6
34	Bachha Jail (Arya Puri)	**2**	6
35	Bhopa Pull (Near Masjid)	**3**	34
36	Kamla Farm House (Gandhi Colony)	**3**	21
37	Babu Ram Gate (Near Gud Madni)	**3**	10
38	Apache D.J. (Rajawaha Road)	**3**	7
39	Jansat Road	**3**	22
40	Almaspur Chauraha	**3**	22
41	Moon Star School	**3**	7

4.1.5 Waste Segregation

Waste stream consist of food waste, agricultural waste, garden trimming, paper, plastic, glass, rubber, metals, sand, silt, constructions and demolition waste, which can be further divided into organic, inorganic and combustible fraction from the composting and waste to energy point of view. Success of any of the above technology depends upon the segregation at source. In order to successfully perform the waste processing it is very important to educate and make ware the people to segregate the waste at source in biodegradables, non-biodegradables and recyclables.

Moreover, it is very important avoid mixing of waste because of the various size of particles are involved in the waste streams. More care should be taken about the inerts i.e. sand, silt, and dust, girt etc. because there presence spoils processing of biodegradables and recyclables. Mixing of street sweeping, construction and demolition material should be prohibited in the MSW. Separate containers must be kept at the transfer station so that organic, recyclable and inerts collected from household or street sweeping to ensure the segregation of waste before the processing site for the better efficiency of the waste processing. Inerts must be used for daily cover material.

4.1.6 Waste Composition

The waste composition is on average 45% organic and 55% inorganic fraction. Organic fraction involves food waste, agriculture waste, garden trimming, leaves etc. whereas inorganic waste involves sand, silt, construction and demolition waste etc. Waste stream also comprises of recyclables such as paper, plastic, glass and metals etc., most likely recyclables are sold to the kabaddiwalas or collected by the waste picker from the transfer site. One MT waste converts to approximate 19% compost, 14% RDF and 2% inert that is disposed to landfill.

4.1.7 Final Disposal of MSW

Muzaffarnagar city does not have any sanitary landfill for final disposal of the waste. In the Muzaffarnagar Municipal limit, the collected MSW is disposed off Near Kali Nadi and Saharanpur Bus stand (earlier).

Presently, because of insufficient equipment's, Mixed MSW is dumped in heaps without proper spreading and compaction, which causes a foul smell and unhygienic conditions. The waste which is processed (after composting and RDF) is dumped without soil cover in a non-engineered way. The MSW is dumped at the site without following any segregation and applying daily soil covers. There is no provision for leachate collection by A2Z at the site, so it may easily ooze into pervious soil and underground water.

Fig.4.6: Disposal on the Site

A. Waste Processing Techniques in the City

(i) Composting

The compost plant is not functioning completely. The compost plant is partly operational. At present, this plant utilizes only 20% of the total quantity of garbage that it treats and produces compost. Open windrow method is used for the composting as there is high ambient temperature is available in the city. The composting process comprises of aerobic degradation

of organic fraction of the MSW. Standards for composting mentioned under Schedule IV in the Municipal Solid Wastes (Management and Handling) Rules (MoEF 2000) consider waste segregation as a prerequisite for effective composting but complied in very few municipalities (Saha et al. 2010).

Fig.4.7: Compost bags

(ii) Waste Burning

Before the A2Z, MC Muzaffarnagr used to burn the waste, but now it is not in practice. The burning of waste resulted in very unhealthy conditions. Since initially dumping sites were just adjacent to city, so it caused many breathing problems for people in the vicinity. Waste burning has been observed at the household level, particularly by the people residing in slum areas and at the secondary collection points also.

4.2 Compliance with Municipal Solid Waste (Management and Handling) Rules (MoEF 2000)

This report analyse the current MSW management in the city, which implies that management of waste is in very preliminary stage, manual handling of the waste is exercised from collection to the final disposal of the waste. Non-engineered, unscientific and inefficient practice of MSW in the city has resulted to unhygienic situation, littering of waste, transportation in open vehicle, no proper segregation. Many times, when collection crew don't reach at time to collect the waste for a long duration (1-2 days), people living in the surrounding burn the waste. Right now machinery, tools, equipment, manpower involve in management of MSW are not enough. The present practices of MSW management in Muzaffarnagar city does not comply with Municipal Solid Waste (Management and Handling) Rules (MoEF 2000) in any aspect from collection to final disposal of waste. Participation of public in MSW management is necessary in the city.

4.3 Community Participation

Spreading awareness among the residents regarding the waste management is the biggest challenge in front of the developing countries.

A. Awareness programs should be conducted by the Urban Local Bodies of the city in order to make people aware of waste minimization at source, reuse, recycling and segregation of the waste; Mixing of different type of waste should be prohibited.

B. Time to time awareness among the people, campaigns based on information, education and communication strategy may be important step to motivate and inspire the people regarding the waste management issues. The awareness programs involves advertisements, local ward meetings, rallies and distribution of pamphlets.

C. There must be hoardings in the public places and it should be advertise in public transports. Moreover, there should be training or sessions on waste management problem for corporation worker, revenue officers, zonal officers, technical staffs, school children and college students.

D. The Urban Local Bodies must take the responsibility to conduct programmes in order to ensure public participation in waste segregation, for this purpose, regular meetings at certain intervals must be arranged by the Urban Local Bodies with and nongovernmental organizations. The NGOs and women associations can play a vital role in communicating and guiding the public on waste management issues.

4.4 Municipal Solid Waste generation and its characteristics

For seven days consecutively segregation and weighing of the segregated wastes has been done. Percentage of each type of waste for all seven day has shown in the table 2.

From Fig. 1 it can be clearly seen that that Biodegradable fraction is approximately 45% which mainly include food, vegetable, fruit, leaves tissue paper, flowers from temples etc. Inert fraction is reported approximately 35%, which mainly include sand, silt, ash, human hair, stone, concrete, batteries etc. The reason behind the big fraction of inert is construction work going on in the city and pathetic condition of city's unpaved roads. It should also be noticed that more the inert fraction will be lesser will be the calorific value. The combustible material, which involve paper, pouches, cardboards, polyester fibres, rubber, leather, egg tray, jute bags etc., was found to be approximately 19%. Recyclables, which involve glass, metal, plastic, carton packs, synthetic fibres (nylon ropes), toys etc. , was found to be approximately 1%, which is very less, reason being rack pickers, who travel almost every street of the residential areas moreover all markets, institutes, industrial areas and pick up the plastic, glass and metals and then sell it to the kabaddis. The kabadi directly sell the inert materl to the industries or the material which is not picked up by rack pickers will be segregated on the processing site and sell to the industry.

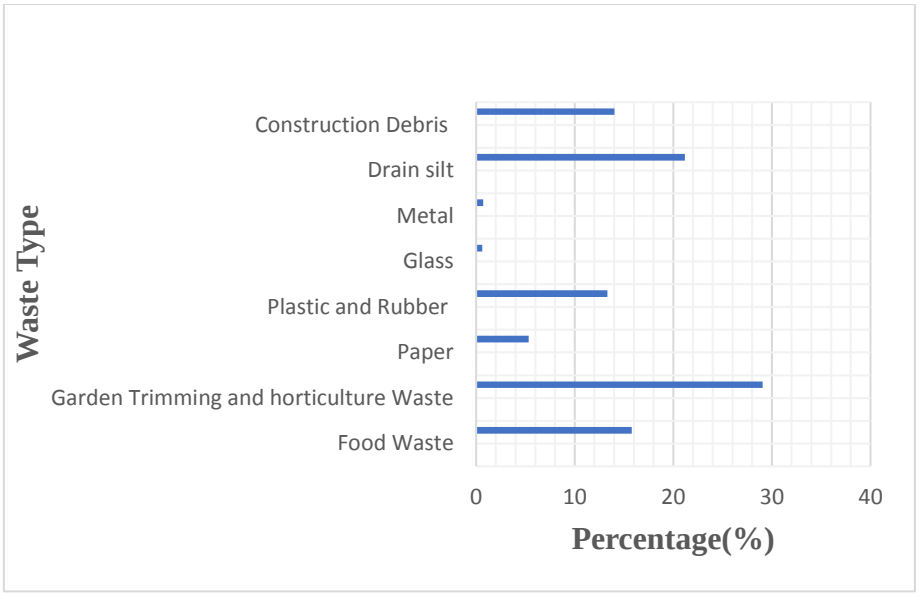

Fig.4.8 Physical Compositon of the MSW

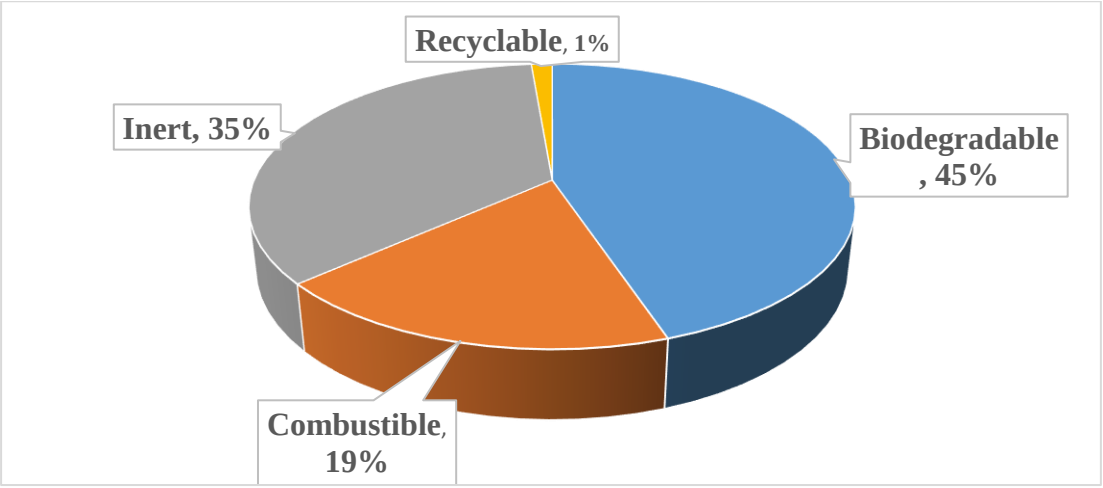

Fig.4.9 Physical characterization based on Biodegradables, recyclables, inserts and combustibles

Table 4.4. Physical Characterization of MSW of Muzaffarnagar in percentage

Waste Type	S1 (%)	S2 (%)	S3 (%)	S4 (%)	S5 (%)	S6 (%)	S7 (%)	Average (%)
Food Waste	15	14.8	13.9	17.15	18.33	15.78	15.45	**(±1.50)15.772**
Garden Trimming	30	31.8	32.3	25.3	23	28.56	31.5	**(±3.30)29.051**
Paper	4	4.9	5.13	7.7	4.6	5.1	5.87	**(±1.18)5.328**
Plastic and Rubber	15	13.9	12.3	9.4	12.5	16.8	13.31	**(±2.32)13.314**
Glass	0.5	0.2	0.6	2	0.4	0.54	0.1	**(±0.63)0.62**
Metals	0.25	0.56	0.52	1.8	0.88	0.76	00.2	**(±0.54)0.71**
Drain Silt	19.25	20.12	21.37	25.2	23.4	19.57	19.34	**(±2.30)21.178**
Construction Debris	16	13.72	13.88	11.55	15.89	12.89	14.24	**(±1.57)14.024**

Particle size distribution of the particles is shown in the table no. 4. Which clearly interprets that paper and cardboard has the maximum where as food varies between 20-100 mm. The importance of the particle size distribution in context of MSW is that the rate at which MWS will be decomposed will be directly related to its particle size. Lesser will be the particle size more will be the surface provided for the bacteria hence faster the degradation. Moreover, if size of the particle of MSW will be small, lesser will be the pore size between two adjacent particle and limiting the movement of oxygen, which is beneficial for anaerobic decomposition but not for aerobic decomposition. For any composting system, the optimum range of particle size usually varies between 12-50 mm diameters.

Table 4.5 Particle size distribution of MSW

Component	Size Range (mm)
Food	20-100
Paper and Cardboard	above 200
Plastic	50-150
Glass	50-200
Rubber	below 20
Ash and Dust	below 20
Rags	100-20

Table 4.6 Characterization of MSW based on Income

Waste Type	HIG	MIG	LIG
Food Waste	24.72	17.26	14.82

Garden Trimming	31.45	29.12	28.56
Paper	7.98	5.12	5.23
Plastic and Rubber	17.23	13.76	12.86
Glass	0.7	0.45	0.32
Metals	0.45	0.35	0.28
Drain Silt	11.24	25.34	28.56
Construction Debris	6.23	8.66	9.37

4.5 Physicochemical Characterization of Leachate from Muzaffarnagar dump site

In the **physicochemical analysis of leachate** collected from dumpsite, it is observed that the concentrations of Copper (Cu), Iron (Fe), Chromium (Cr), Lead (Pb) and Cd, as shown in Table 3, were not within the range of the as per Municipal Solid Waste (Management and Handling) Rules (MoEF 2000). Moreover, pH, TDS and BOD5 were not also within the range of the as per Municipal Solid Waste (Management and Handling) Rules (MoEF 2000). Since concentration of all the heavy metals is above the permissible limits, there should be proper landfilling of waste with appropriate liner system so that not even a single drop of leachate can percolates into ground and meet to the ground water. Otherwise in Muzaffarnagar, almost every household has such system in which they directly extract water from the ground. If ground water is contaminated, it may affect the people of city adversely.

Table 4.6 Physicochemical Characterization of Leachate from Muzaffarnagar dump site

Parameter	**S1**	**S2**	**S3**	**S4**	**Average**	**Permissible limits**
pH	10.7	10.9	9.8	9.8	10.3	5-9
TS (mg/l)	24,148	23,980	23,117	24,986	24057.75	-
TDS (mg/l)	20,056	19,347	18,967	16,786	18789	2100
Electrical Conductivity(m Moh/com)	20.01	19.83	19.44	21.1	20.12	-
BOD_5 (17°C)	14180.50	14375	13989.5	14876	14355.25	100
COD (mg/l)	22547.64	23000	22242.51	22956	22686.53	-
Cu (mg/l)	0.040	0.089	0.076	0.067	0.272	0.05
Ni (mg/l)	0.020	0.045	0.034	0.022	0.030	3.0
Fe (mg/l)	0.320	0.567	0.043	0.045	0.243	0.3
Pb (mg/l)	0.400	0.487	0.003	0.002	0.223	0.05
Cr (mg/l)	0.060	0.089	0.075	0.068	0.073	0.05

Cd (mg/l)	0	0.001	0.890	0.003	0.2235	0.01

Fig.4.10 Leachate Collection from the site and sieving of Reject

Table 4.7 Chemical Characterization

Parameter	**Unit**	**Value**
Moisture Content	% by Weight	20.2
Volatile Matter	% by Weight	21.3
Ash Content	% by Weight	47.2
Fixed Carbon	% by Weight	11.3
Calorific Value	KJ/ Kg	4,387
Carbon	% by Weight	25.2
Hydrogen	% by Weight	3.87
Nitrogen	% by Weight	1.34
Oxygen	% by Weight	20.9
Mineral Content	% by Weight	48.69

The analysis of chemical characteristics of Municipal Solid Waste plays a very important factor in deciding and fixing up the best waste processing and disposal facility in the city and in finding out the efficiency of a waste treatment process. The Results of Chemical Characterization has shown in table no. 4.7. Moisture content of the waste was determined about 20%. The results shows that there is a good amount of minerals are present in the waste. The Calorific value was determined to be low (about 4387 KJ/kg) due to the lesser amount of paper and plastic and significant amount of inert material which makes the waste lesser incompatible for incineration. The ash content was also determined and found significantly high due to the large amount of inert matter present in the waste sample.

4.6 Geotechnical Properties of the MSW

In order to analyse Geotechnical properties of the MSW moisture content, degree of saturation, specific gravity, unit weight and coefficient of permeability has been determined, results of the geotechnical properties has been shown in the table 4.7.

Table 4.7 Geotechnical Properties of the MSW

Parameter	**Values**
Moisture Content (v/v)	0.19
Degree of Saturation (%)	76
Specific gravity	2.15
Wet Unit Weight KN/m^3	11.34
Coefficient of Permeability	1.5 x 10^{-3} - 4.5 x 10^{-3}

The wet unit weight for the MSW of the city was reported approximately 11.34 KN/m^3. The Degree of Saturation was also found 76%. Wet unit weight, Moisture content, degree of saturation and coefficient of permeability play a very important role in strength and stability of the MSW when it is finally dumped in the landfill.

CHAPTER-5
CONCLUSION

This Study helps in deciding important strategies for waste handling and disposal, which will ultimately improve the MSW management practice in the city. Due to the explosive rise in the population, growing demands of modern society and poor management of solid waste by the municipality, waste generation rate is increasing every year. Segregation of the waste at source is not taking place and people are still throwing the waste on the roadsides leads to the pathetic condition of environment. Not unlike maximum cities of India, waste is dumped on the ground without engineered landfilling leads to the various pollutions as ground water contamination and air pollution. Approximately 1050 kg of waste were analysed and physical characterization of the waste showed the high organic and combustible fraction. Unpaved roads, street sweeping and ample no. of construction activities has led to the high inert fraction in the city, so it discourages waste to energy method like incarnation. Moreover, mixing of inerts with MSW needs to be avoided because it is very difficult of separate because of their

very small particle size. As if now composing RDF, biomethanation and disposal of rejects and inerts seems to be suitable waste processing technology for the city. Organic fraction has been significant so composting should be appropriate method to process the waste.

Explosive increment in the waste generation and scarcity of land to manage the waste in the city will require best strategies for the waste management in the coming time. Although public participation is also very important, and will remain a great challenge in front of the local administration. There is a need of efficient planning by the collaboration of local administration and private sector which will improve the aesthetic and hygiene level in the city and also spread awareness among the people not to spread trash on the roadsides and to cooperate in this mission in mission in their best interest. There is a great scope of improvement in the MSW management in the city, therefore significant amount of efforts are required by the Municipal Corporation Muzaffarnagar and public. Waste reduction, waste segregation at source, reuse, recycling, composting at household could provide long-term solutions to reduce the amount of waste and load on the landfill sites.

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