A Framework for Assessment of Existing Solid Waste Management Practices and Characterization of Municipal Solid Waste in Muzzafarnagar City, India

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Chapter 1
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ABSTRACT

This chapter reports the details of the existing system of MSW management and characterization of Muzaffarnagar City located in Western Uttar Pradesh (UP) state in India. The overall waste generated in the city is about 120-125 tons per day (TPD) with a per capita generation rate of 0.415 kg/person/day with a collection efficiency of 70-80%. Physico-chemical and geotechnical properties of the MSW were carried out to determine its overall characteristics. The characterization results showed about 46% of the waste generated in the city is organic nature (from HIG and MIG) and 52% for (LIG) with chemical characterization showing that the elemental carbon was in the highest proportion. Further, the chapter also recommends suitable remedial measures for proper management of the existing MSW management system and suitable treatment alternatives.

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INTRODUCTION

Rapid rise in India's economy due to increased urbanisation and globalization and thereby changing lifestyle coupled with increasing population (births, migration etc.) has led to production of eight fold increase in MSW generation in comparison to 1947 (Sharholy et al, 2008; Talyan et al, 2008) leading to severe degradation of existing environmental conditions (Hazra et al, 2009). With the passage of time it is expected that Indian population will increase further with the annual rate of growth of urban population in India being predicted at 5% ("Census of India", 2011). Further, rapid influx of population from rural areas in urban cities lead to unwanted population growth leading to development of unplanned rural areas in the outskirts of the Indian cities leading to additional generation of MSW which are often unaccounted. In general, waste is defined as a material of unuseful nature and of no economic value to its owner, the owner being the generator of the waste (Mor et al, 2006b). Effective management of MSW is a global problem with developing countries facing the biggest obstacles (Ramachandra et al, 2003; Tchobaanpoglous et al, 1993). It has been inferred that increasing population is directly related to rapid increase in MSW generation in developing countries with India being no exception and might be reaching critical levels particularly due to unavailability of barren land for disposal (Indris et al, 2004; Talyan et al, 2008).The per capita waste generation of India rate varies between 0.15 kg in rural areas to 0.45 kg in urban areas (Akhtar, 2014; Katiyar et al, 2013) and it has been observed that increased economic success leads to increased per capita consumption and generation of MSW (Taylan et al, 2007; Tricys, 2002). The average per capita waste generation in India is 370 g/day as compared to 2200 g/day in Denmark, 2000 g/day in US and 700 g/day in China (Liu et al, 2011).

In an Indian context, the MSW can be classified primarily as the solid waste generated from domestic, commercial, institutional sources and to a lesser extent biomedical and industrial (toxic waste). The most prevalent method for disposal of such wastes in India are open dumping (90%) which over the period of time leads to choking of sewer pipes, breeding grounds for vectors and other serious heath hazardous and environmental problems. Such status of MSW disposal is regularly observed for Tier-II and Tier-III cities. In Tier-I and metropolitan cities some of which have implemented management strategies for tackling such huge voluminous quantities the procedures implemented have been outdated and inefficient due to lack of characterization studies which would have enabled these municipalities in implementing an effective treatment and disposal system. For example, it is estimated that about 1.3 million cubic metre of biogas per day or 72 MW of electricity from biogas can be produced for agricultural purposes along with about 5.4 million metric tonnes of compost annually ("Central Pollution Control Board", 2015). However, due to improper MSW management practices including no segregation of wastes being followed the end products of several waste to energy (WTE) systems implemented are poor in nature with no economic value (Rana et al, 2015).

In the above context, it is an essential duty of concerned urban local body (ULB) for effective management of the MSW generated within their city limits ("The Gazette of India" 2000). However, implementation of an effective MSW management system requires suitable data including quantity, quality and characterization results which are further dependent on geographical locations, food habits and other socio-economic conditions and also adequate budgetary provisions (Goswami et al, 2007). A detailed characterization study can help in determining the drawbacks in the existing treatment processes; identify the most appropriate treatment technology for effective management of the MSW

The main objectives of the study were to assess the existing MSW management and determine the characteristics of the waste generated in Muzaffarnagar city to determine deficiencies in the existing management system and propose remedial methods for improving the existing system.

MUZAFFARNAGAR CITY AND EXISTING MSW MANAGEMENT

Muzaffarnagar Municipality has a population of 392,451 and the urban agglomeration has a population of 4, 95,543 as per census 2011 with a growth rate of about 17% in a decade (2001-2010) covering an area of 150 Km^2 ("Census of India" 2011). The population of the city is increasing at a rate of 1.5% per annum. Presently, the city is divided into 41wards. The overall municipal solid waste generation in the city is about 120-125 Tonnes/day (TPD) [Personal communication with an employee of A2Z Infrastructure Limited, 2017] with an average generation rate of 0.32 kg/(capita-day). The per capita generation can be further subdivided for different socio-economic groups with average per capita generation of 0.14, 0.17 and 0.65 kg/day respectively for Low Income Group (LIG), Middle Income Group (MIG) and High Income Group (HIG) respectively.

The city has ample number of institutes, hospitals, shops, hotels and restaurants and approximately 64000 households [Personal communication with an employee of A2Z Infrastructure Limited, 2017]. Further, biomedical waste generated from hospitals and clinics (particularly syringes) do not undergo separate processing. These biomedical wastes are mixed with the MSW and are dumped at the non-engineered landfill site. Moreover, manufacturing wastes generated from different industries including sugar mills, paper mills and Steel Rolling mills don't under go to any special treatment and are disposed with the MSW making the overall nature of the waste highly hazardous.

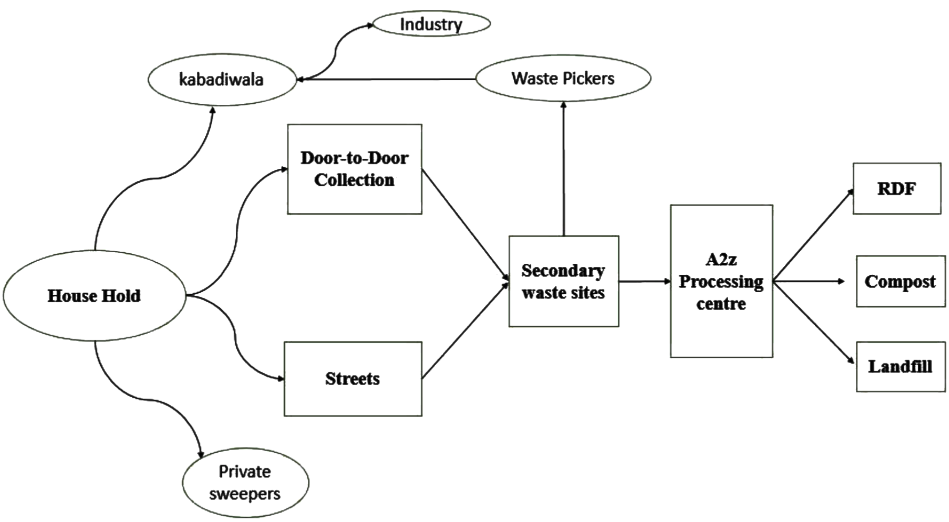
Collection efficiency of domestic MSW generated is about 70-80% of the city is covered by door-to-door collection method using handcarts of volume 2-5 m^3. As mentioned earlier, the city is divided into 41 wards and if certain wards are not covered by door-to-door collection these wards have a designated collection point for waste. Insufficient bin capacity, use of open bins and location of these bins in inaccessible stations in some wards lead to overflowing of such bins almost through the entire year. Further, some wards have no designated bins leading to open dumping of generated MSW in these wards. No source segregation is followed and hence no separate bins exist for organic and inorganic wastes. Further, it has been observed that waste is open dumped in middle of road particularly in the vegetable market areas and even though collection is done on a daily basis if there is a lapse in collection of one day could lead to epidemic like conditions.

Loading of MSW is done manually and there exists only one garage in the city from where the transportation vehicles are operated and maintained with the help of private contractors. Transportation of the collected MSW is done using a total of 13 collection vehicles (6 dumpers, 3 J.C. Bamford Excavators limited, popularly designated as JCB, 3 tractors and 1 Tata Ace). Assuming the density of waste to be around 300 kg/m^3, the collection capacity per capita was determined to be only 0.001 m^3 which is extremely low and almost negligible highlighting the need for procurement of additional transportation vehicles. Further, lack and too much dependency of labourers, unplanned routing, non-covering of waste on top during transportation process highly reduces the efficiency of the transportation system. There are no intermediate transfer stations and no equipment or machinery is present at the open landfill site for segregation of wastes due to which mountains of waste exist in and around the landfill site and since last few years the load on the dumpsite has increased significantly. This leads to production of highly obnoxious odours, breeding ground of infectious vectors and propagate unhygienic environment in the vicinity of the dumpsite. Since, it is a non-engineered landfill contamination of groundwater and soil due to leachate percolation could lead to severe environmental hazard.

Though Ministry of Environment and Forests (MoEF) has specified detailed guidelines for management of MSW but majority of the cities in India generally follow only comprises only four activities (waste generation, collection, transportation and disposal) for management of MSW which is inadequate (Sharholy et al, 2008). The same was observed for our study location. Figure 1 shows the study location and Figure 2 summarizes the existing MSW management practice at the study location. Though there is an integrated SWM facility in the city, very poor condition of plant including machinery, equipment, scarcity of technical manpower, lack of interest of local bodies, lack of detailed characterization results, limited funds and inadequate management procedures not being thereby reducing the efficiency of the process. In

Figure 1. Location map of Muzaffarnagar, Uttar Pradesh

Figure 2. Schematic diagram of Solid Waste Management Practice in Muzaffarnagar city



practice, since waste generation rate is very high and capacity of machines installed to processes the waste is very low, the waste stream coming to the plant is being underutilized leading to waste being accumulated.

MATERIAL AND METHODS

Sample Collection

Sampling was done as per the guidelines laid out in ASTM D5231-92 (ASTM, 2004a, ASTM, 2004b; ASTM 2004c; ASTM 2006a; ASTM, 2008. To summarize, sampling was carried out consecutively for a week at the dump site, with each day 150 kg sample collected while trucks used to unload. From the total waste collected over the week, about (n =7 (denoting sampling days); collection =1050 kg) about 100 kg of the final homogenised mixed waste was processed. Further, the physical characterization was carried out for LIG, MIG and HIG, to determine the characteristics of the MSW generated from the three different socio-economic groups.

Physical Characterization of MSW

Physical characterization is one of the most important components for designing an effective MSW management system. The samples (collected using the procedure described above) was segregated manually into food waste, garden trimming, paper, plastic, rubber, glass, metals, drain silt and construction debris and weighted to express as percentage of total weight. The fundamental aim of following this process was to identify the organic and the inorganic components. One of the major sub-classification of inorganic waste type is inert waste the major characteristics of which are non-reactive and non-biodegradable. For our present study, the inert fraction was primarily due to stones, sand and gravel. Such high quantities of inert wastes are generally accumulated due to road sweeping of construction dust which is collected and dumped at the open landfill site. Moisture content of the waste was determined immediately after collection of the samples and then the samples were processed for chemical characterization.

Chemical Characterization of MSW

Chemical characterization was carried out using both proximate and ultimate analysis to determine the elemental composition of the MSW and also its ash content. Collected samples were processed as per the procedure laid out in BIS-IS: 9234 and ASTM-D5231-92 (ASTM, 2004a; ASTM, 2004c; ASTM, 2006a; ASTM, 2008). While the proximate analysis method was adopted to determine ash content, fixed carbon and volatile matter the ultimate analysis was used to determine the proportions of carbon, hydrogen, nitrogen, sulphur and oxygen content in dry sample. The calorific value of the MSW waste sample was determined by bomb calorimeter (Model 6200 Spectronics).

Geotechnical Characterization of MSW

Different sieves with diameter 200, 150, 100, 50 and 20 mm was used to perform the gradation of MSW. Generally, geotechnical properties (moisture content, specific gravity, unit weight, field capacity, coefficient of permeability, and degree of saturation) helps in design and maintenance of the landfill. Constant head method has been used to evaluate the coefficient of permeability at 25^0C in the laboratory.

RESULTS AND DISCUSSION

The characteristics of a MSW generated at a location are significantly influenced by geographical demographics, lifestyles, cultural traditions, economic prosperity, literacy rates, dietary habits and climatic conditions (Jin et al, 2006). Accurate characterization of MSW generated is the foremost step in designing an effective management system (Lin et al, 2011; Rana et al, 2014).

Physical Characterization

Physical characterization is helpful in determining the organic and inorganic fraction present in the waste stream and forms the basis for determining the treatment alternative. The results of physical characterization of MSW from Muzaffarnagar have been summarized in Table 1.

Density of MSW helps in deciding the appropriate handling processes including collection and transportation of the MSW generated. A higher inert fraction as observed from Table 1 significantly increases the bulk density and was found to 475 kg/m^3. Further, it is observed that the organic fraction accounts for the highest proportion from the entire socio-economic group (about 46% from HIG and MIG) and about 52% from LIG followed by inert constituents (27%, 34% and 32% for HIG, LIG and MIG respectively).

As observed from Table 1, the organic fraction comprises mainly of food wastes and garden trimmings for the different socio-economical conditions. Further, the maximum organic fraction is generated from the LIG community and is similar to other reported studies. This is primarily because with decrease in economic status

Table 1. Physical Characterization of Municipal Solid Waste in Muzaffarnagar city

Waste Type	HIG (%)	MIG (%)	LIG (%)	Mean± SD (%)
Food Waste	14.82	17.26	24.72	18.93±5.16
Garden Trimming	31.45	29.12	27.56	29.38±1.96
Paper	7.88	5.12	5.23	6.08±1.56
Plastic and Rubber	17.23	13.76	9.09	13.36±4.08
Glass	0.7	0.45	0.32	0.49±0.19
Metals	0.45	0.35	0.28	0.36±0.09
Drain Silt	21.24	25.34	26.43	24.34±2.74
Construction Debris	6.23	8.6	6.37	7.07±1.33

of the location there is an increase in the organic content of the waste generated (Goel, 2008; Sharholy, 2008). Further, it has been reported that MSW generated in developing countries have high proportion of organic waste (40-70%) making them unsuitable for disposal by incineration (Khajuria et al, 2010).

It has been further reported that proportion of paper increases with increase in population and generally varies between 1 to 6 (Garg et al, 2012). For our study location, the fraction of paper constituent was determined to be 5.3%, and lies within the range as reported by literature. In addition, the combustible fractions of the waste including paper, pouches, cardboards, polyester fibres, rubber, leather, egg tray, jute bags etc. was determined to be about 19%. Such other studies carried out in Indian context, reported similar values for Varanasi with combustible fraction being 14% (Dasgupta et al, 2013). High proportion of plastic and rubber was also observed as plastics are used on daily basis by the local residents. In particular, plastic, rubber and paper waste were significantly higher in HIG in comparison to LIG and MIG areas, similar to other reported literature. Glass and metal fraction was higher in HIG as compared to the other socio-economic groups.

Inert fraction was determined to be approximately 35%, which mainly include sand, silt, ash, and was on the higher side. This is primarily due to the street sweeping of construction wastes which end up being finally disposed off at the landfill site. The inert fraction determine for Muzaffarnagar was similar to other reported studies in Indian cities, for example Pune reported about 26% of inert wastes (Mane et al, 2012); Jalandhar reported about 21-33% of inert (Sethi et al, 2013) and the tricity regions of Chandigarh, Mohali and Panchkula as about 25-30% (Rana et al, 2017). Further, increased inert fraction decreases the calorific value and increases the density of the waste (Sethi et al, 2013). Drain silt fraction was found to be maximum in LIG areas because unpaved roads are more in the LIG locations in comparison to HIG areas which conditions are roads which have more paved roads reducing the percentage of drain silt.

Recyclable components include glass, metal, plastic, cartons packs, synthetic fibres (nylon ropes), were determined to be approximately 1%, which is very less, primarily due to rag pickers and waste collectors who cover all of residential areas, markets institutes, industrial areas collecting all recyclables and then selling it to the *kabaddis*. They directly sell these to the industries to be recycled.

Chemical Characterization

Physical Characterization of the MSW provides information of the components of the waste stream but is not sufficient enough for deciding the overall processing technique of the waste, hence chemical characterization is performed in order to determine crustal element present in the MSW. Ultimate and Proximate analysis were carried out to determine the chemical characterization and the results have been summarized in Table 2.

Moisture content in Asian countries vary from 17-65% (Kolekar et al, 2016; Kumar et al, 2009) and the moisture content of our study location was determined to be about 22.6% lying within the prescribed limits. High value of moisture content indicates higher fraction of biodegradables.

Table 2. Chemical Characterization of Municipal Solid Waste in Muzaffarnagar city

Parameter	Mean± SD
Moisture Content	22.60±1.16
Volatile Matter	22.30± 2.63
Ash Content	44.90± 2.30
Fixed Carbon	10.10 ±1.57
Calorific Value	4236.15 ±119.78
Carbon	31.21±2.35
Hydrogen	3.87±0.52
Nitrogen	1.34±0.29
Oxygen	20.91±0.63
Mineral Content	42.68±2.29
C/N	23.75 ±4.78

*All values in percentage except calorific value (kcal/kg) and C/N

Ash Content was determined to be 44.9% primarily due to the high fraction of inert present in the waste stream. Such high percentage of ash content has also been reported for earlier studies in Jalandhar (42%) (Rawat et al, 2013) was reported.

The C/N ratio for Muzaffarnagar was determined to be 23.75 which were well within the C/N ratio reported for Asian countries which vary from 17-50 (Kolekar et al, 2016; Rawat et al, 2013; Sharholy et al, 2008). Elemental composition shows a high fraction of C (31.21%) followed by O (20.9%), H (3.87%), N (1.34%). Analysis of elemental components are particularly useful in determination of stoichiometric reactions and thereby estimation of gaseous by products of the waste (Khajuria et al, 2010).

Determination of Calorific Value provides information regarding energy recovery from the waste. Due to a high proportion of combustibles (19%), the calorific value of the waste generated from Muzaffarnagar area has been determined to be 4236 kcal/kg. In practice, calorific value generally varies between 800 to 1000 kcal/kg (Saha et al, 2010). However, studies conducted at Indian cities show higher reported calorific values.

Geotechnical Characterization

Particle size distribution of the different components has been summarized in Table 3.

It is observed from Table 3 that paper and cardboard has the maximum size range whereas ash and dust have particle size less than 20 mm and the food component varies between 20-100 mm. Particle size distribution of different waste stream characteristics are important as decomposition rate is directly proportional to the size distribution. Further, lesser the size of the particle lesser will be the pore size between two adjacent particles which limits the passage of oxygen, thereby facilitating the process of anaerobic degradation. The optimum particle size should vary between 12 to 50 mm for design of a successful composting system (Thakur et al, 2015).

Table 3. Particle Size distribution of Municipal Solid Waste in Muzaffarnagar city

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

Geotechnical properties of the waste affect waste degradation, leachate distribution, and the overall stability of landfills (Yu et al, 2011). The geotechnical characterization of the MSW has been summarized in Table 4.

The moisture content was determined to be 0.19, which is very less in comparison to other reported literature (Sethi et al, 2013; Rana et al, 2017). This was primarily due to the climatic conditions existing at the study location which is exceedingly hot and had experienced very less rainfall. The unit weight was determined to be 11.34 kN/m^3. This parameter is primarily significant in determining the strength of the landfill as it depends upon the effective over burden pressure and effective overburden pressure is directly related to the unit weight. Further, it has been reported that unit weight also effects the capacity of the landfill (Yu et al, 2011). The degree of saturation of the waste was determined to be 76% and the coefficient of permeability was determined to be 3.0 x 10^{-3} cm/s.

RECOMMENDATIONS FOR IMPROVEMENT OF EXISTING MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES BASED ON CHARACTERIZATION ANALYSIS

The characterization study carried out for Muzaffarnagar reveals that an integrated MSW management system is of immediate need. Though there exists waste processing system, it is severely lacking and needs a severe upgradation or a complete overhaul. The following remedial measures are suggested for better management of the MSW generated in Muzaffarnagar.

Table 4. Geotechnical Properties of Municipal Solid Waste in Muzaffarnagar city

Parameter	Mean± SD (%)
Moisture Content (v/v)	0.19±0.03
Degree of Saturation (%)	76.1±9.6
Specific gravity	2.15±0.11
Wet Unit Weight (kN/ m^3)	11.34±1.82
Coefficient of Permeability(cm/s)	3 x 10^{-3}

Source Segregation

Physical characterization of the MSW carried out has revealed that about 48% of waste stream are biodegradables and about 32% of inert materials. In this context, source segregation of the waste should be carried out to effectively reduce the burden on the landfill site and for implementation of adequate treatment procedures. Further, unsegregated wastes significantly reduce the calorific value of the waste thereby diminishing the potential energy content. The process of source segregation can be easily implemented with provisions of two bins (or colour coded containers) one for collection food waste and other organic materials and the second bin for other waste types. Further, education and importance of source segregation should be imparted to the local residents to apprise them of the potential benefits of the process. It had also been observed from our study that the combustible fraction is about 19% and it would be highly beneficial if source segregation of combustible methods were performed to yield better quality of Refuse Derived Fuel (RDF). In particular, it should be ensured that inert waste should not be mixed with domestic generated solid waste. The density of the MSW was determined to be 475 kg/m^3 and an effective strategy would be implement adequate size and number of bins depending upon the population, waste generation rates and density of wastes at the different wards of the city. The number of transportation vehicles should be increased and proper maintenance along with planned route layouts should be followed to improve the efficiency of the disposal system.

Recycling and Recovery

Our study show that about less than 1% of recyclables enter the waste stream with informal recycling process being most predominant carried out by rag pickers and waste collectors which are passed onto the industries. Though to a certain extent, such informal recycling practices reduce the burden on the landfills, the absence of formal recycling units significantly lower the economic potential of the recyclables with no benefits being passed onto the government. In this context a formal recycling unit should be set up with proper management to derive all potential benefits of the recycling process.

Installation of Biomethanation Plant

Since, the municipal solid waste consists of a high fraction of biodegradables in the waste stream it will be highly appropriate to install a biomethanation plant. Further, organic wastes from other sources should also be utilized (like kitchen and restaurant wastes) for proper functioning of the biomethanation plant.

Composting

The climatic conditions of the study location are highly suitable for composting process. Composting process is one of the finest methods for disposal of organic waste as it stabilizes the waste and the end product of the composting process can be used as a natural fertilizer. It is an environmental friendly aerobic process carried out through microbial action. The efficiency of the composting process depends upon the efficiency of segregation of organic wastes from other types. Further, composting process can be carried out at household levels and as such proper training and education should be provided to the residents to start their own household composting systems. At the governmental levels, community composting pits should be set up to utilize the voluminous quantity of organic waste generated.

Installation of RDF Plant

It is observed from our characterization study that a RDF could be utilized effectively as a part of an integrated MSW management system. In practice, a working RDF plant already exists in Chandigarh city and can be similarly implemented for Muzaffarnagar. For the existing plant in Chandigarh it has the capacity to treat about 500 tonnes per day (TPD) with the RDF produced having a calorific value of 3100 kcal/kg and moisture content less than 15%. Implementation of RDF unit will significantly reduce the volume of waste thereby increasing the lifespan of the landfill.

Engineered Landfill and Other Recommendations

Municipal Solid waste is openly dumped at the landfill site leading to possible contamination of soil and groundwater. In this context, it is proposed a proper engineered landfill site with leachate collection and extraction system should be installed to avoid such contamination. Skilled manpower should be employed and periodical trainings should be provided to such personals for operation of such systems. Further, the personals should be educated on occupational health hazard and medical checkup of ragpickers and waste collectors to be done.

CONCLUSION

The book chapter reports the existing solid waste management practices in Muzaffarnagar city along with characterization analysis studies which are then utilized in recommendations as important strategies for the municipal solid waste management. With an increased population and excessive consumption rates the city is nearing a critical point with no implementation of an integrated MSW management facility. Existing status for management of MSW is deficient in almost all aspects with less collection efficiency due to inappropriate bin size, inaccessible locations of bins, inadequate number of transportation vehicles per and non-functioning of the integrated MSW management system. Physical Characterization of the waste stream generated from the Muzaffarnagar denotes high fraction of organics followed by inert. Waste streams from LIG were determined to have the highest organic fraction. Chemical characterization showed a high proportion of ash content primarily due to presence of inert. In this context, source segregation should be carried out to obtain maximum benefits of using WTE technology with biomethanation and composting for organic fraction and RDF for the inorganic fraction of the waste. Further, a formal recycling unit should be setup to to derive the economical benefits of the recycling system. In particular, local administration will need full support of the local public to implement any potential schemes for integrated MSW management system. This can be done by educating the general public on the drawbacks of the existing waste management practices. There is a great scope for improvement in the existing practices of MSW management in the city, however significant efforts are required by the Urban Local body of Muzaffarnagar and support of the public. Waste reduction, waste segregation at source, reuse, recycling, and WTE schemes like composting, biomethanation and RDF could provide long-term solutions to reduce the burden of waste disposal on the landfill site. Finally, the open dumpsite should be converted to an engineering landfill site with immediate effect.

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