MUNICIPAL SOLID WASTE PROCESSING TECHNIQUES AND SELECTION OF THE MOST SUITABLE TECHNOLOGY

Dr. Ramji Lal Meena[1], Dr. Susheela Meena[2], Dr. Rajesh Kr. Yadav[3]

[1]CMJ University.

[2]Swami Keshvanand Rajasthan Agriculture University (SKRAU), Bikaner.

[3]Subodh College, UOR.

Abstract

Apart from other factors such as resource recovery and environmental soundness, one of the most important considerations for the success of a waste management system for a specific town/city is the selection of appropriate technology, financial support, stakeholder/public involvement, and institutional capability. Many waste processing technologies are available and in use around the world. The efficiency of a particular technology, on the other hand, is determined by the criteria for which it is designed and planned. The primary criteria for selecting technologies are waste quantity, waste characteristics, physical properties and composition of wastes, land availability, social factors, capital investment, duration of treatment, product market, and so on. A poor choice of waste processing technology can lead to the failure of the entire waste management system, resulting in poor economics and environmental consequences.

Keywords: Municipal Solid Waste, Refused Derived Fuel, Pyrolysis, Thermal Processing Technologies

There are several MSW processing technologies, which are being followed in various parts of the world. Besides source reduction, reuse and recycling, broad categories of available technologies for processing MSW are mentioned below:

- Physical Processing Technologies
- Thermal Processing Technologies
- Biological Processing Technologies

Table 3.19 shows the technologies expressed in terms of the three major groups (thermal, biological & physical) that have been considered for evaluation purpose for processing MSW of GMADA cluster.

Table 3.19

List of Identified MSW Processing Technologies

Waste Processing Technology Group	Waste Processing Technology
Physical Processing Technologies	Refuse-Derived Fuel (RDF)
	Densification / Pelletisation
	Mechanical Separation
	Size reduction
Thermal Processing Technologies	Incineration (Mass burn)
	Pyrolysis
	Pyrolysis / Gasification
	Plasma Arc Gasification
Biological Processing Technologies	Aerobic Digestion (Composting)
	Anaerobic Digestion (Biomethanation)
	Landfill as Bioreactor (Bioreactor Landfill)

3.9.1.1 Physical Processing Technologies

Physical technologies involve altering the physical characteristics of the MSW feedstock. The MSW is subjected to various physical processes that reduce the quantity of total feedstock, increase its heating value, and provide a feedstock. It may be densified or palletized into homogeneous fuel pellets and transported and combusted as a supplementary fuel in utility boilers. These technologies are briefly described below.

A. Refused Derived Fuel

The RDF process typically includes thorough pre-separation of recyclables, shredding, drying, and densification to make a product that is easily handled. Glass and plastics are removed through manual picking and by commercially available separation devices. This is followed by shredding to reduce the size of the remaining feedstock to about eight inches or less, for further processing and handling. Magnetic separators are used to remove ferrous metals. Eddy-current separators are used for aluminum and other non-ferrous metals. The resulting material contains mostly food waste, non-separated paper, some plastics (recyclable and non-recyclable), green waste, wood, and other materials. Drying to less than 12% moisture is typically accomplished through the use of forced-draft air. Additional sieving and classification equipment may be utilized to increase the removal of contaminants. After drying, the material often undergoes densification processing such as pelletizing to produce a pellet that can be handled with typical conveying equipment and fed through bunkers and feeders. The RDF can be immediately combusted on-site or transported to another facility for burning, alone or with other fuels. The densification is even more important when RDF is transported off-site to another facility, in order to reduce volume being transported. RDF is often used in waste to energy plants as the primary or supplemental feedstock, or co-fired with coal or other fuels in power plants, in kilns of cement plants, and with other fuels for industrial steam production.

B. Mechanical Separation

Mechanical separation is utilized for removing specific materials or contaminants from the inlet MSW stream as a part of the pre-treatment process. Contaminants may include construction and demolition (C&D) debris, tires, dirt, wet paper, coarse materials, and fine materials. Generally, MSW reaching the dumping sites is unsegregated and mixed, containing C&D debris and other contaminants. Therefore, it is essential to remove these contaminants from the incoming MSW by mechanical separation before processing the waste further by either biological, physical and thermal technologies (except Plasma Arc Technology).

C. Size Reduction

Size reduction is often required to allow for more efficient and easier handling of materials, particularly when the feed stream is to be used in further processes. Sizing processes include vibrating screens and trommels. In order to reduce the size of the entire stream, or portions of it, mechanical equipment, such as shredders, is utilized. This allows for other physical processes, such as dryers, magnetic and eddy current separators, and densification equipment to work more efficiently. Magnetic and eddy current separators may be installed both up- and down-stream of shredders to increase the recovery of metals.

3.9.1.2 Thermal Processing Technologies

Thermal technologies are those technologies that operate at temperatures greater than 200°C and have higher reaction rates. They typically operate in a temperature range of 375°C to 5,500°C. Thermal technologies include advanced thermal recycling (a state-of-the-art form of waste to-energy facilities) and thermal conversion (a process that converts the organic carbon based portion of the MSW waste stream into a synthetic gas which is subsequently used to produce products such as electricity, chemicals, or green fuels).

These technologies are briefly described below.

A. Incineration

Mass-burn systems are the predominant form of the MSW incineration. Mass-burn systems generally consist of either two or three incineration units ranging in capacity from 50 to 1,000 tons per day; thus, facility capacity ranges from about 100 to 3,000 tons per day. It involves combustion of unprocessed or minimally processed refuse. The major components of a mass burn facility include: (1) Refuse receiving, handling, and storage systems; (2) Combustion and steam generation system (a boiler); (3) Flue gas cleaning system; (4) Power generation equipment (steam turbine and generator); (5) Condenser cooling water system; and (6) Residue hauling and storage system.

B . Pyrolysis

In Pyrolysis, at high temperatures of 700°C to 1200 °C, thermal degradation of organic carbon-based materials is achieved through the use of an indirect, external source of heat, in the absence or almost complete absence of free oxygen. This thermally decomposes and drives off the volatile portions of the organic materials, resulting in a syngas composed primarily of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4). Some of the volatile components form tar and oil, which can be removed and reused as a fuel. Most Pyrolysis systems are closed systems and there are no waste gases or air emission sources (if the syngas is combusted to produce electricity, the power system will have air emissions through a stack and air emission control system). After cooling and cleaning in emission control systems, the syngas can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity or used as raw stock in chemical industries. The balance of the organic materials that are non volatile, or liquid that is left as a char material, can be further processed or used for its adsorption properties (activated carbon). Inorganic materials form a bottom ash that requires disposal, although some pyrolysis ash can be used for manufacturing brick materials.

C. Gasification

In the Gasification process, thermal conversion of organic carbon based materials is achieved in the presence of internally produced heat, typically at temperatures of 660°C to 1800°C, and in a limited supply of air/oxygen (less than stoichio-metric, or less than what is needed for complete combustion) to produce a syngas composed primarily of H_2 and CO. Inorganic materials are converted either to bottom ash (low-temperature gasification) or to a solid, vitreous slag (high temperature gasification that operates above the melting temperature of inorganic components). Some of the oxygen injected into the system is used in reactions that produce heat, so that Pyrolysis (endothermic) gasification reactions can initiate; after which, the exothermic reactions control and cause the gasification process to be self-sustaining. Most gasification systems, like Pyrolysis, are closed systems and do not generate waste gases or air emission sources during the gasification phase. After cooling and cleaning in emission control systems, the syngas can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity, or to make chemicals.

D. Plasma Arc Gasification

In Plasma Arc Gasification process, alternating current (AC) and/or direct current (DC) electricity is passed through graphite or carbon electrodes, with steam and/or oxygen/air injection (less than stoichio-metric), to produce an electrically conducting gas (a plasma) typically at temperatures greater than 2,200°C. This system converts organic carbon-based materials, including tar, oil, and char, to syngas composed primarily of H_2 and CO and inorganic materials to solid, vitreous slag. Like Pyrolysis and conventional Gasification, Plasma Arc Gasification is a closed system; therefore there are no waste gases and no emission sources in the Plasma Arc Gasification process. After cooling and cleaning in emission control systems, the syngas produced by plasma arc gasification can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity or to make chemicals. The final emission products are CO_2 and water.

3.9.1.3 Biological Processing Technologies

Biological processing technologies operate at lower temperatures and lower reaction rates. Biological processing technologies are focused on the conversion of organics in the MSW. MSW consists of dry matter and moisture. The dry matter further consists of organics (i.e., whose molecules are carbon-based), and minerals, also referred to as the ash fraction. The organics can be further subdivided into biodegradables or refractory organics, such as food waste, and non-biodegradables, such as plastic. Biological technologies can only convert biodegradables component of the MSW. Byproducts can vary, which include: electricity, compost and chemicals.

Various biological processing technologies are briefly described below.

A. Composting

Composting is a natural micro-biological process, where bacteria break down the organic fractions of the MSW stream under controlled conditions to produce a pathogen-free material called “Compost” that can be used for potting soil, soil amendments (for example, to lighten and improve the soil structure of clay soils), and mulch. The microbes, fungi, and macro-organisms that contribute to this biological decomposition are generally aerobic. A mixture of organic materials is placed into one or more piles (windrows), and the natural microbial action will cause the pile to heat up to 60 - 70°C, killing most pathogens and weed seeds. A properly designed compost heap will reach 70°C within 6 to10 days, and slowly cool off back to ambient temperatures as the biological decomposition is completed. Systematic turning of the material, which mixes the different components and aerates the mixture, generally accelerates the process of breaking down the organic fraction, and a proper carbon/nitrogen balance (carbon to nitrogen or C/N ratio of 20:1) in the feedstock ensures complete and rapid composting. The composting process takes from 17 to 180 days.

There are two fundamental types of composting techniques: a.) open or windrow composting, which is done out of doors with simple equipment and is a slower process, and b.) enclosed system composting, where the composting is performed in some enclosure (e.g., a tank, a box, a container or a vessel).

B Anaerobic Digestion

In anaerobic digestion, biodegradable material is converted by a series of decomposition process by different bacterial groups into methane and CO_2. A first group breaks down large organic molecules into small units like sugar. This step is referred to as hydrolysis. Another group of bacteria converts the resulting smaller molecules into volatile fatty acids, mainly acetate, but also hydrogen (H_2) and CO_2. This process is called acidification. The last group of bacteria, the methane producers or methanogens, produce biogas (methane and CO_2) from the acetate and hydrogen and CO_2. This biogas can be used to fuel boilers or reciprocating engines with minimal pretreatment. In addition to biogas, anaerobic bioconversion generates a residue consisting of in-organics, non-degradable organics, and bacterial biomass. If the feedstock entering the process is sufficiently free of objectionable materials like colorful plastic, this residue can have market value as compost. Anaerobic digestion process is also referred to as Bio-methanation process.

C. Bioreactor Landfill

A bioreactor landfill is a wet landfill designed and operated with the objective of converting and stabilizing biodegradable organic components of the waste within a reasonable time frame, by enhancing the microbiological decomposition processes. The technology significantly increases the extent of waste decomposition, conversion rates and process effectiveness over what would otherwise occur in a conventional wet landfill. Stabilization in this context means that landfill gas and leachate emissions are managed within one generation (twenty to thirty years) and that any failure of the containment system after this time would not result in environmental pollution. There is better energy recovery including increased total gas available for energy use and increased green house reduction from reduced emissions and increase in fossil fuel offsets. These factors lead to increased community acceptance of this waste technology. Management of a bioreactor landfill requires a different operating protocol to conventional landfills. Liquid addition and recirculation is the single most important operational variable to enhance the microbiological decomposition processes. Other strategies can also be used, to optimise the stabilization process, including waste shredding, pH adjustment, nutrient addition and temperature management.

Selection of the Most Suitable Technology

For selection of suitable processing technology following parameters are considered.

1. Indian experience
2. Quantity of waste
3. Quality of waste
4. Capital investments required.
5. Recurring expenditure.
6. Economy of operation.
7. Manpower Requirement
8. Level of skill required.
9. The capability of the ULBs to manage such facility departmentally or through private sector participation.
10. Scale of operation.
11. Environmental impact of such technology.
12. Process aesthetics.

13. Cost of end products.
14. Compatibility of cycle of nature.

3.10 Recommended Integrated Waste Processing Technology

Based on the above criteria's Integrated Municipal Waste Processing facility for at GMADA will consists of RDF and Compost Plant. The schematic diagram of the proposed facility is shown is fig 3.4.

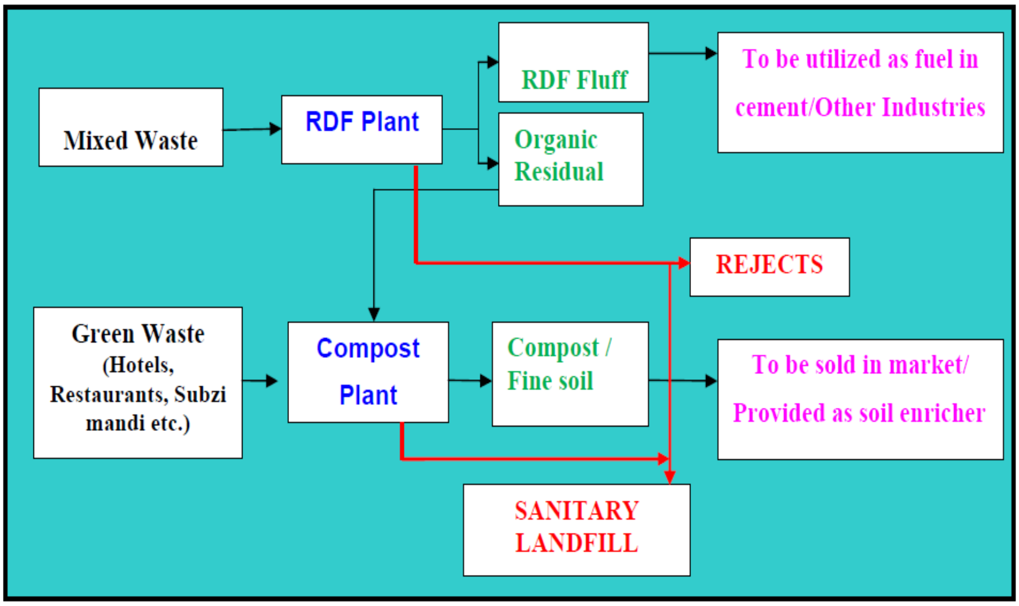
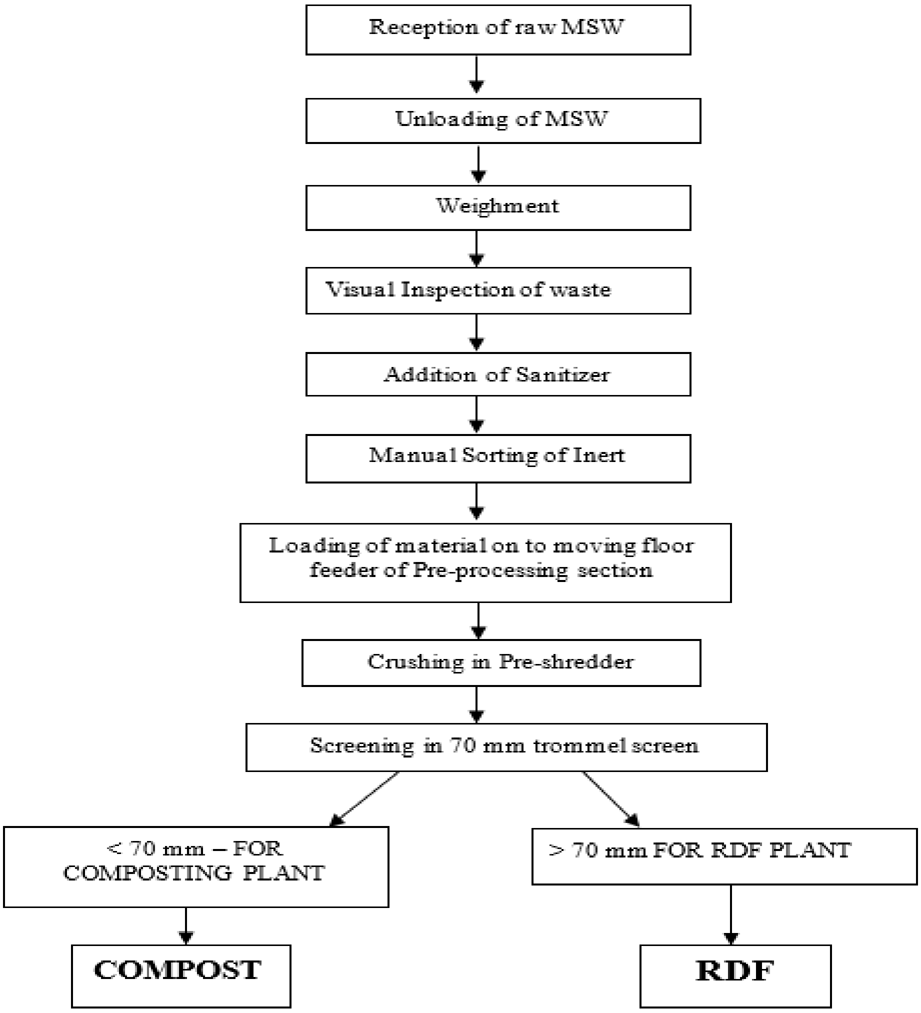


Fig. 3.4. Schematic Diagram of Proposed Processing and Disposal Facilities

3.11 MSW Processing Plant

The plant is designed to process approx. 350 TPD municipal solid waste (MSW) on per day basis and is able to process different kind of waste types. MSW processing unit would have following steps:



3.11.1 RDF Processing Plant

The RDF processing unit would receive MSW of > 70 mm size and produce RDF through following process:

Walking Floor Feeder

Provides constant material feed to the pre-shredder. The feeder works also as a buffer. The feeder is all steel, very wear and impact resistant and almost maintenance free. The walking floor automatically feeds a sufficient amount of waste to the shredder. A sensor above the shredder meters the amount of material in the shredder and thus controls the automatic feeding of material. Once the walking floor is filled, the plant will work automatically for some time.

Pre-Shredder

The pre-shredder (fed by the moving floor feeder) cuts the material to a size of < 300 mm allowing the after coming trommel to work optimally

Pre-shredder is an extremely heavy construction, high capacity, designed for industrial purposes. The machine has a large number of features to ensure reliable and economic operation, for example easily exchangeable knives etc.

Trommel Screen

The MSW crushed in pre-shredder is conveyed to a trommel screen with 70 mm screen size. The below 70 mm size will be taken for composting and above 70 mm size will be further conveyed to the main shredder for size reduction.

Shredder

The shredder cuts the material to a size of approx. 40 - 90 mm, (can be adjusted by means of changeable bottom screens). In case the unshreddable material is detected, the shredder is stopped automatically. The foreign object is also automatically discharged to a dedicated container by means of reversible belt conveyor after the following conveyor. The MIPS (Massive Impact Protection System) protects the knives of the shredder in case of unshreddable material enters the shredder. The shredded material is discharged from the shredder by means of chain/belt conveyor.

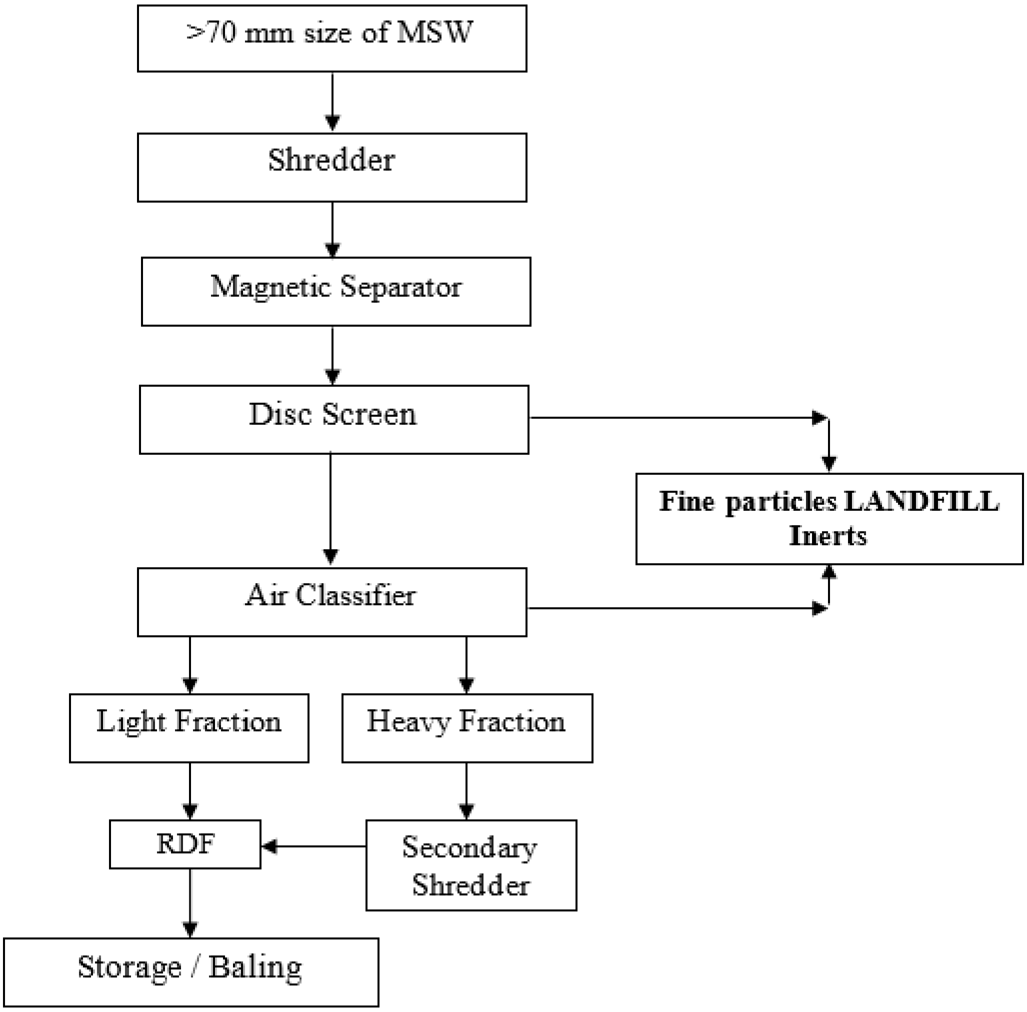
Fines Screening

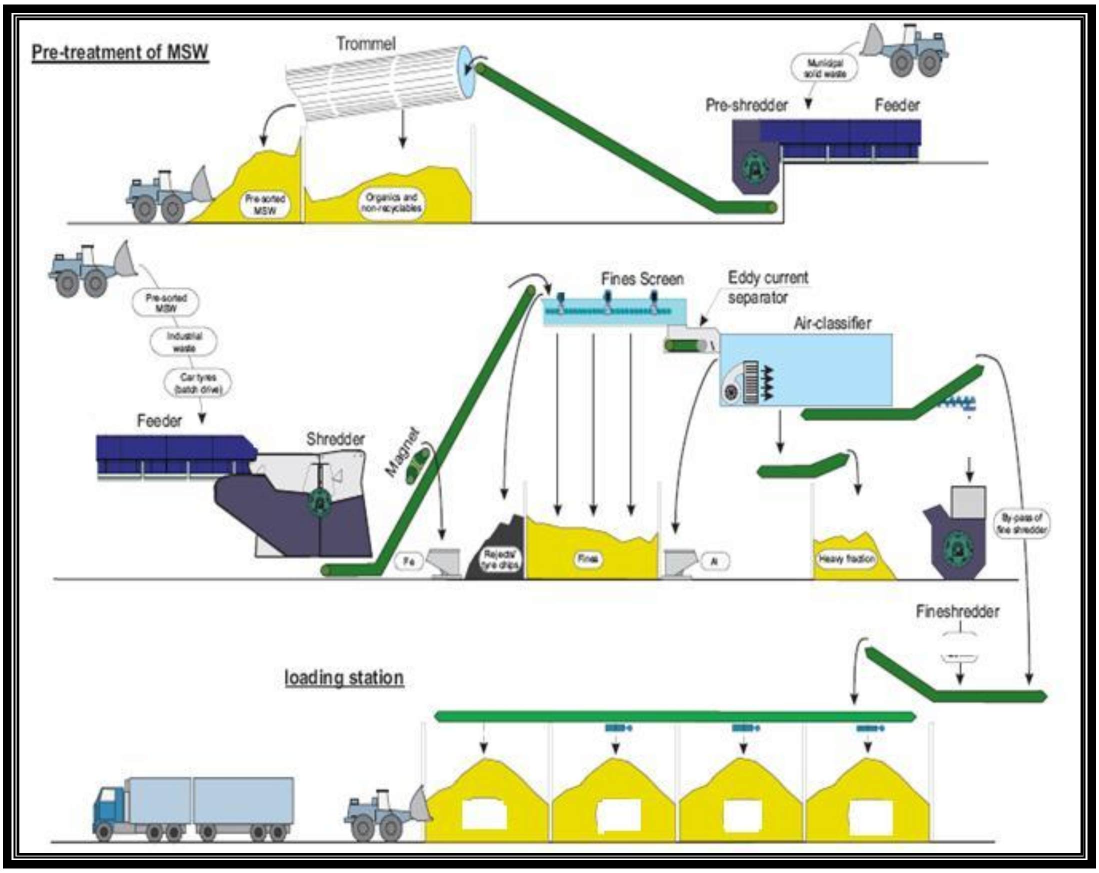
The fines fraction (smaller than approx. 15 – 20 mm) is screened out by means of a rubber disc screen. Typically the fines fraction consists of sand, glass splinter, ceramics and other fines. This fraction is dropped directly in a bunker or container below.

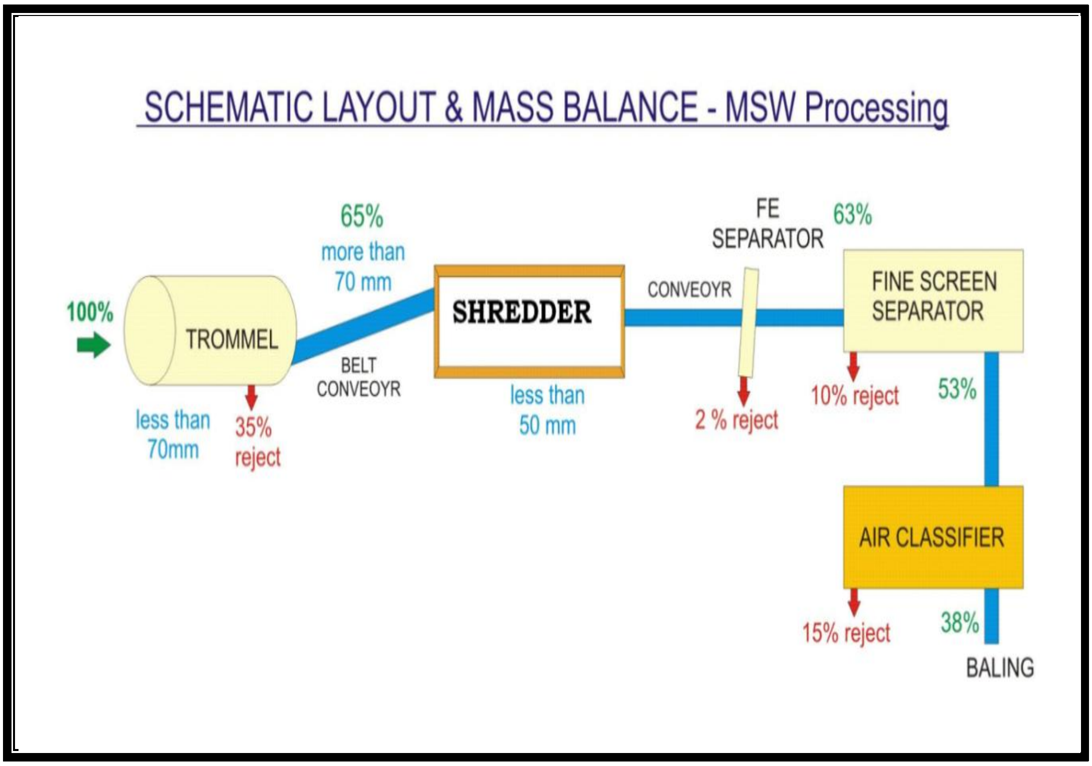
Air Classifier

The air-classifier splits the flow of material into a heavy fraction and into a light fraction. The separation is very effective because the in feed material is small in size (no plastic bags to carry stones etc. to the light fraction) and the generated air flow is laminar (minimal turbulence). The heavy fraction typically consists of stones, rest metals, glass, ceramics, organics and hard plastics. This fraction is conveyed with the conveyor to a designated bunker or container. The remaining light fraction (RDF) is collected by means of integrated chain conveyor and conveyed to a designated storage area. Baling will be carried out for the logistics convenience.

MSW to RDF Process Flow




Pre-treatment of MSW
Trommel
Municipal solid waste
Pre-shredder
Feeder
Pre-sorted MSW
Organics and non-recyclables
Pre-sorted MSW
Industrial waste
Car tyres (batch drive)
Feeder
Shredder
Magnet
Fines Screen
Eddy current separator
Air-classifier
Fe
Rejects/ tyre chips
Fines
Al
Heavy fraction
By-pass of fine shredder
Fineshredder
loading station


SCHEMATIC LAYOUT & MASS BALANCE - MSW Processing
100%
TROMMEL
less than 70mm
35% reject
65% more than 70 mm
BELT CONVEOYR
SHREDDER
less than 50 mm
CONVEOYR
FE SEPARATOR
2 % reject
63%
FINE SCREEN SEPARATOR
10% reject
53%
AIR CLASSIFIER
15% reject
38%
BALING

3.11.2 Compost Plant

Elements of Composting Facility

The elements of composting facility at present, which have been mentioned above, would be further explained here.

Yard Management System

The < 70 mm fraction of MSW screened in the trommel of pre- processing section is conveyed to the designated areas of compost pad for windrow preparation. In windrow type aerobic composting system, the fresh MSW is stacked in the form of trapezoidal heaps called 'windrows' *Sufficient quantity of decomposing microbial cultures (inoculum & sanitizer*) will be inoculated at this point with sprayer to reduce odour and repel vectors.. Moisture will also be supplemented at required levels before windrow preparation. The thoroughly mixed waste is then made to windrows of convenient dimensions and kept for the biologic decomposition.

The Windrows are periodically turned (normally once a week) using hydraulic excavators to provide proper aeration and temperature control. The composting heap is stabilized in about 6 weeks, when it is shifter to the screening plant for removal of the inert and non-composted matter.

In some of the plants, particularly, in high rain-fall areas, a shed is provided called 'rain shed' or 'monsoon shed'. In this case the material is shifted to the rain-shed after about 4 weeks and kept there for a further period of 2 weeks.

*1. After windrowing, water is added to windrow using water tanker to maintain requisite moisture level.

2. Just after windrowing, bacterial activity starts within 2-3 days . Inside temperature of the windrow may go up to 65^{o} C.

Coarse Segregation System

Stabilized material from monsoon shed is then fed to the 'coarse segregation section' using a Skid Steer Loader for intermediate screening. Two stage screening system is adopted to achieve maximum screening efficiency using trommel of different hole sizes. Cascading action inside the trommel ensures better screening of the lumpy and highly heterogeneous municipal solid waste. These days equipment in this section are hydraulically driven to ensure greater safety against breakdowns and to lower power consumption. Hydraulic drive also introduces features like on-load starting, centralized control etc. PLC based controls allows automatic shutdown in case of any emergency.

Screened material coming out of this section is uniform in texture and contains semi–stabilized organic compost. This material needs further stabilization so it is transferred to the curing section.

Curing System

Material coming out of the Coarse Segregation Section is stored in curing section for 15 days for further stabilization and moisture control. Some additives, such as, as rock phosphate may be added at this stage to improve quality of final product. Curing area can hold up to 20 days of material coming to the curing section on daily basis.

Refinement System

As per compost quality norms nationally (FCO) and internationally, the compost should be below 4 mm average particle size and it should not contain impurities such as glass, plastic, other inert material etc. which spoils the overall appearance and creates suspicion in the mind of the end user about quality of the final product. To achieve this, a refinement section is incorporated in the machine line.

Cured material from the curing section is fed to this section using a skid steer loader. First equipment of the refinement section is a drag feeder conveyor. Once this equipment is filled up with cured material, it gradually feeds the same to the consecutive equipment at a controlled rate. This section consists of a trommel screen 4 m.m. which contains the hole size of 4mm. The screened material coming out of the trommel screen is sent to the gravity separator which removes heavy impurities such as glass, metals, sand, silica etc. from the organic manure. The magnetic separator in the production line will take care of all kinds of ferrous impurities in the compost. Organic Manure free from major impurities is passed through a liquid add mixer where quality enhancer in powder or liquid form is added.

High quality organic manure is then passed through the packing spout and final packing of the product takes place.

Packing and Storage System

The mechanized packing section can do the bagging, weighment and stitching of 50 kg bags and finally stacked in the finished product store by using a stacking conveyor.

Leachate, Litter and Odour Management System

During Composting some dark coloured thick fluid may get generated. This fluid is known as ‘leachate’. It should not get percolated in the soil or else it will pollute the ground water. To avoid this, proper concreting of the 'Compost Pad' is done and a peripheral drain is provided to collect the leachate generated during the process. The leachate so collected has to be suitably treated or recycled over the windrows. The air-borne litter is controlled by providing a high wire mesh. A green belt is provided around the plant.

Process Monitoring & Control Systems

i) In Yard Management – Yard management process needs to be monitored in order to achieve proper digestion and obtaining right quality finished product. For aerobic composting, proper temperature, moisture and aeration is required in the windrows. Temperature in the core of the windrow should reach up to 65-75^0 C and a moisture level of 35 – 40 % should be maintained in the windrows. These will ensure proper growth of the bacteria and thus proper stabilization. An operator will take temperature readings of the windrows and also check the moisture level. C : N ratio of the waste must also be checked by sampling, so that corrective measures can be taken at the initial stage if the ratio is found not inline with the requirement. If heavy metals are found in the waste with the values exceeding the stated ones, the waste material should be removed from the windrows and not used for food crops.

ii) In Segregation Plant – Segregation plant is centrally controlled by a control panel. Central panel shuts down the plant automatically in case temperature, pressure and current reading exceeds the stated value. An Inspector will take these three readings of the Control Panel periodically and see if all the readings are within limit.

Removal of Recyclables &Processing Rejects

Recyclables will be sold to authorized recyclers and combustibles fraction will be balled and sold to industries.

Rejects from the compost plant must be regularly removed. These would be loaded in dumpers or tractor trolleys and directed to designated landfill site.

Conclusion

As many municipal authorities continue to develop in-house capabilities to govern their solid waste independently, the central and state governments continue to play an important role in formulating policies, programs, and regulations, as well as providing technical and financial assistance for infrastructure development, including municipal solid waste (MSW) management in urban areas. Despite the fact that municipal solid waste management (MSWM) is an essential service and a mandatory function of municipal authorities across the country, it is still managed in an unplanned manner, resulting in environmental degradation and serious health problems, particularly for women and children. This clearly highlights the importance of urban local governments developing a strategic and detailed MSWM plan. EPR is a policy approach in which a producer is held accountable for the post-consumer stage of a product, typically for defined tasks such as separate collection (e.g., for e-waste or hazardous waste components), reuse (e.g., disposal-refund systems for bottles), recycling (e.g., for used cars), and storage and treatment (e.g., for batteries). EPR programmes are frequently mandated by legislation, but they can also be implemented voluntarily (for example, retail take-back programmes).

References

1. Manual on Solid Waste Management and Handling, Ministry of Urban Development (2000)

2. Nabegu, A. B. (2008). Municipal solid waste characteristics in three residential zones of Kano metropolis. Maiduguri J. Arts Soc. Sci. 6, 199–210

3. Muktar, M. (2008). Analysis of plastic waste recycling in Kano, Nigeria (Ph.D. thesis). Department of Economics, Bayero University Kano, Kano, Nigeria

4. Omole, F. K., and Alakinde, M. K. (2013). Managing the unwanted materials: the agony of solid waste management in Ibadan metropolis, Nigeria. Int. J. Educ. Res. 1, 1–12.

5. Nganda, M. K. (2007). Mathematical Models in Municipal Solid Waste Management. Sweden: Chalmers Tekniska Hogskola.

6. Colón, J., Cadena, E., Pognani, M., Barrena, R., Sánchez, A., Font, X., Artola, A., 2012. Determination of the energy and environmental burdens associated with the biological treatment of source-separated municip.

8. Christensen, T.H., Gentil, E., Boldrin, A., Larsen, A.W., Weidema, B.P., Hauschild, M., 2009. C balance, carbon dioxide emissions and global warming potentials in LCA-modelling of waste management systems. Waste Manag. Res. 27, 707–715. https://doi.org/10.1177/0734242X08096304.

9. Bernstad, A., LaCour Jansen, J., 2011. A life cycle approach to the management of household food waste - a Swedish full-scale case study. Waste Manag. 31, 1879–1896. https://doi.org/10.1016/j.wasman.2011.02.026.