

Technology options for municipal solid waste-to-energy project

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Abstract There are various options available to convert solid waste to energy. Mainly, the following types of technologies are available: (1) sanitary landfill, (2) incineration, (3) gasification, (4) anaerobic digestion, and (5) other types. Sanitary landfill is the scientific dumping of municipal solid waste due to which the maturity of the waste material is achieved faster and hence gas collection starts even during the landfill procedure. Incineration technology is the controlled combustion of waste with the recovery of heat, to produce steam that in turn produces power through steam turbines. About 75% of weight reduction and 90% of volume reduction is achieved through burning. A gasification technology involves pyrolysis under limited air in the first stage, followed by higher temperature reactions of the pyrolysis products to generate low molecular weight gases with calorific value of 1000–1200 kcal/nm³. These gases could be used in internal combustion engines for direct power generation or in boilers for steam generation to produce power. In biomethanation, the putrescible fraction of waste is digested anaerobically (in absence of air), in specially designed digesters. Under this active bacterial activity, the digested pulp produces the combustible gas methane and inert gas carbon dioxide. The remaining digestate is a good quality soil conditioner. Other technologies available are pelletization, pyro-plasma, and flash pyrolysis. All these technologies have merits and demerits. The choice of technology has to be made based on the waste, quality, and local conditions. The best compromise would be to choose the technology, which (1) has lowest life cycle cost, (2) needs least land area, (3) causes practically no air and land pollution, (4) produces more power with less waste, and (5) causes maximum volume reduction.

Introduction

Cities in Maharashtra typically produce MSW (municipal solid waste) of 0.4–0.5 kg/person/day. The rapid urbanization and industrialization has increased the pollution load on the urban environment to unmanageable and alarming proportions. The existing landfill sites are full beyond capacity. It is difficult to get new dumping yards and if at all available, they are far from the city and this adds to the exorbitant cost of transportation. It is high time the municipal corporations, state governments, and policy makers take up the matter seriously. The best option is to reduce the volume by effective treatment of the waste. In recent years, the waste-to-energy project has gained attention due to its double benefit of resource generation and pollution abatement.

Many municipal corporations have shown keen interest though and the high initial cost of such projects were the main inhibiting factors. Rising to the occasion, some private investors / promoters have offered to take up such projects on BOO (build own operate) basis. The main task is to choose a promoter and specifically, to choose a particular technology that is beneficial and environment-friendly. The objective of this article is to review the available technology options in the context of their merits/demerits, based on the waste quality and quantity.

Technology options

Initially, there was a tendency to use well-proven technology such as steam turbines, using conventional boilers with MSW as feed. Subsequently, many other technologies were developed and field-tested. Many other technologies are ready for field trial following successful laboratory tests. It is worth noting here that all demonstration and full-scale plants are available in the West (Parker and Roberts 1985) and they are yet to be launched commercially under Indian conditions. Although many different types of R&D projects have been taken up in India and abroad, only commercially successful projects have been described here since description of R&D projects is beyond the scope of this paper. There are mainly the following types of technologies available on commercial scale.

- Sanitary landfill
- Incineration
- Gasification
- Anaerobic digestion
- Other types

As described in Figure 1, MSW without segregation could be used either in sanitary landfill or

mass burning to produce power. However, after mechanical segregation, an energy-rich fuel called RDF (refuse derived fuel) is obtained, which can be used to produce power either through biochemical or thermal route. In biochemical route, only anaerobic digestion has been used commercially while in the case of thermal route, both pyrolysis and RDF burning have been used successfully for commercial purposes. Each of the categories is described below.

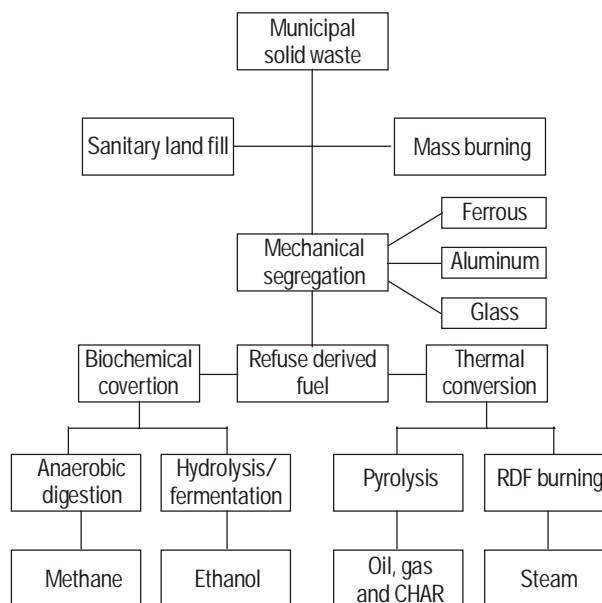


Figure 1 Options for energy production from MSW (municipal solid waste)

Sanitary landfill

What is sanitary landfill?

'Sanitary landfill' is the scientific dumping of MSW using an engineering facility that requires detailed planning and specifications, careful construction, and efficient operation (O'Leary and Walsh 1991a). There are mainly three types of sanitary landfills namely (1) area method, (2) ramp method, and (3) trench method. In all the methods the site is first selected considering the following factors.

- 1 It should be at least 10 000 ft (3048 metres) away from the airport.
- 2 It should not be located in wetlands.
- 3 It should not be in flood- or earthquake-prone areas.
- 4 It should have a stable soil structure.

The proper land preparation is carried out by having (1) 60-cm compacted solid liner,

(2) flexible HDPE (high density poly ethylene) geo-membrane liner, (3) geo-textile liner, (4) 30-cm drainage material layer, and (5) 60-cm protective layer. The provisions for gas collection (through 1.25 cm diameter perforated poly vinyl chloride pipe) and leachate collection (15 cm diameter slotted HDPE pipe) are made. The solid wastes are landfilled by spreading thin layers, compacted to the smallest practical volume and covering it each day or periodically with some suitable substitute material in a way that minimizes environmental problems. Successive layers are built up until a depth of 10–12 feet (304–365 cm) is achieved. Finally, it has to be covered with 60 cm of soil layer for final closure (O'Leary and Walsh 1991 b, c, d).

During the landfill procedure, at least 40% moisture must be maintained to achieve maximum microbial degradation. Periodically the leachate collection in the bottom needs to be pumped out to drying beds specially prepared for this purpose. Due to scientific landfilling, the maturity is achieved faster and hence gas collection starts even during the landfill procedure. The gas generation and complete extraction are achieved even after closure (say up to 10 years). This is faster than the ordinary landfill where gas extraction continues even up to 50 years. Figure 2 shows clearly how, after final soil cover and maturing, the combustible gas could be used for generating power while leachate removal and treatment are carried out simultaneously. Compost retrieval is an optional choice depending on site condition and commercial feasibility.

Why sanitary landfill?

Unscientific and ordinary landfilling is the common practice for MSW disposal in India and many other Asian countries. Even in western countries it was a common practice till the late seventies after which it was legally banned. The ordinary landfills are supposed to adversely affect the environment. The major concern is the groundwater pollution. The chemical reactions, during degradation in presence of moisture and rainwater, allow the pollutant chemicals to dissolve and flow into the groundwater reserve, which is later used for drinking in the nearby areas. Besides this, CH₄ (methane) and other toxic gases evolve which are dangerous for the vegetation and population nearby. Unchecked methane is an explosive gas and is hazardous as it may cause fires. CH₄ released to the atmosphere is responsible for global warming 10 times more deadly than that of CO₂ (carbon dioxide). Alarmed by these factors, the ordinary landfills

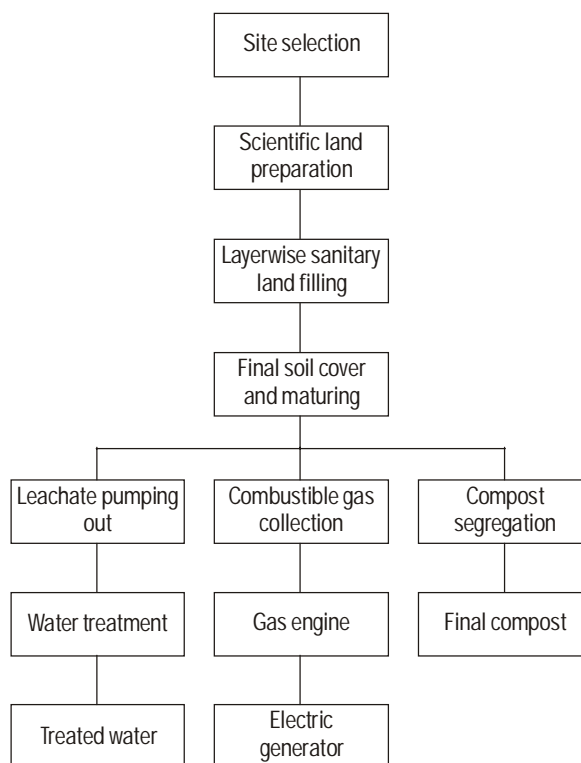


Figure 2 Flow diagram of an MSW (municipal solid waste) power plant based on sanitary landfill technology

were legally banned vide the regulation FR-5/91 in the US and similar regulations in European countries. Only 'Sanitary landfill' was allowed.

Utilization

Concentration of CH₄ over 25% only is worth extracting for energy production. A typical LFG (landfill gas) has CH₄ concentration of 50%. The LFG could be utilized directly for heating, as medium-heating value gas (raw gas), high-heating value gas (filtered gas) and also for power generation in IC (internal combustion) engines, and in gas and steam turbines. However, the most economic option is the direct use for process heating and boiler fuel. In the power generation projects, the cost of engines or turbines is more than 60% of the total plant cost. The only way to make the power generation viable is to force the utilities to purchase power from LFG at higher cost (which is the case in the UK and the US). A survey carried out in the US in 1992 showed the following status (Thorneloe 1992).

- Total LFG plants (1–20 MW): 144
- LFG plants with IC engines (Caterpillar, Cooper Superior and Wunkesha make): 61

- LFG plants with gas turbines (Super Centaur makes): 21
- LFG plants with steam turbines (Fuji Electrical make): 3
- Direct use of LFG as pipeline gas: 6
- Conversion of LFG to diesel: 1

A typical LFG power generation plant in the US costs roughly 15 million dollars per megawatt (1992 price) of which the generators cost 970 thousand dollars. This shows that direct burning is most cost-effective (3500–4000 kcal/m³).

Merits and demerits

The merits of sanitary landfill are many as compared those of the conventional ones. It reduces emission of CH₄, non-CH₄ organic compounds, and toxicants (e.g. vinyl chloride, toluene, benzene, etc.) into the atmosphere. Land and water contamination due to leachate migration is minimized. The main advantage is the protection of public health and environment. The menace of birds and rodents is reduced. Fire hazard is minimized due to regular extraction of gas. The problem of smelly odour wafting to the nearby locality is comparatively reduced.

The major objections to sanitary landfills are high initial costs for design and construction, public opposition when selecting the site, and increasingly, the concern for recovery of materials instead of disposal. The general tendency is 'dump yard not in my backyard'. Even after precautions, the obnoxious gas emission to the atmosphere can never be checked completely and hence some odour is bound to be there. The efficiency of leachate and gas extraction is also doubtful. The problems of pests and rodents are minimized but never completely eliminated. Even after keeping the sanitary landfill area aesthetically presentable, the real estate value of the nearby area is reduced (Thorneloe 1992).

Incineration

The scientific sanitary landfills also have many problems. The main problem is the availability of land located where transportation is economically viable, and with minimum public objection. Accumulation of such a large volume of waste for long time is dangerous for the environment. Hence the best way to solve the problem is to reduce the volume by burning. Even 90% volume reduction can be achieved by burning. But uncontrolled burning causes air pollution and the heat thus generated is wasted and incineration is a

practical solution. Incineration technology is the controlled combustion of waste with the recovery of heat to produce steam that in turn produces power through steam turbines (Bhide and Sunderesan 1983). Figure 3 shows that MSW after pretreatment is fed to the boiler of suitable choice wherein high pressure steam is used to produce power through a steam turbine. Proper air pollution control measures are taken and ash from the boiler is dumped in the nearby landfill. The choice and types of boilers suitable are described below.

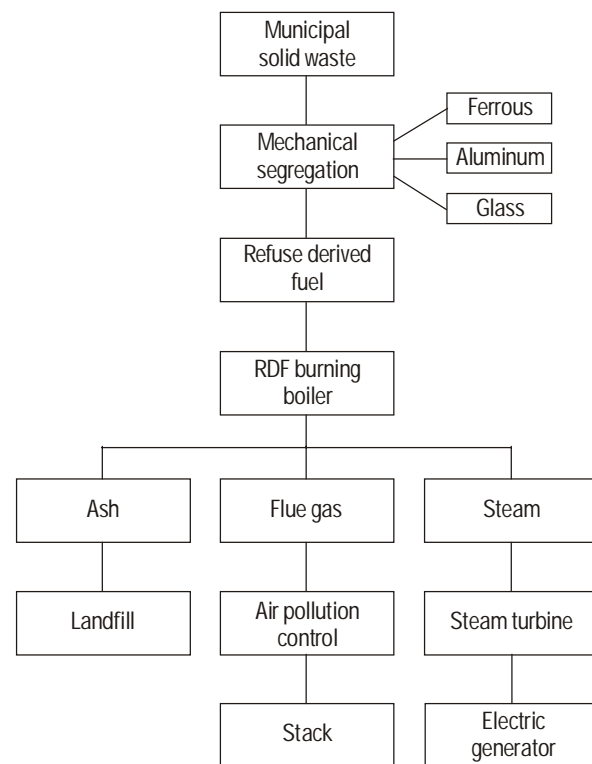


Figure 3 General flow diagram of an MSW (municipal solid waste) power plant based on incineration technology

Technology

Depending upon the pretreatment methodology, there are mainly two types of MSW combustion technologies available.

- 1 Unprocessed solid waste combustion technology (also known as mass burning)
- 2 Processed solid waste combustion technology (also known as RDF burning)

Mass burning

This is the most common technology wherein MSW is burned without significant fuel preparation as discarded form. The MSW undergoes only limited processing to remove non-combustible and oversized items. Mass-burn technologies include water wall furnace, refractory furnace, rotary kiln furnace, water-cooled rotary combustion furnace, and controlled air furnace. Except some design changes, in all types of furnaces, the mass burning of MSW is primarily performed on a grate system that enables combustion air to be provided through the fuel bed with a variety of alternative methods of feeding fuel to the grate. MSW fuel feeder typically includes a feed hopper and hydraulic ram that pushes fuel from the bottom of the grate. Furnace wall can either be water- or air-cooled (Bjeldanes and Beard 1996).

RDF burning

This technology involves various processes to improve physical and chemical properties of solid waste. Basically, RDF systems are used to separate MSW into combustible and non-combustible fractions. The combustible material is called RDF and can be used in boilers. The MSW receiving facility includes an enclosed tipping floor called municipal waste receiving area, with a storage capacity equal to about two days of typical waste deliveries. The sorted MSW is then fed to either of the two equal capacity processing lines. Each processing line includes primary and secondary trommel screens, three stages of magnetic separation, eddy current separation, a glass recovery system, and a shredder. Due to reduction in fuel particle size and reduction in non-combustible material, RDF fuels are more homogeneous and easier to burn than the MSW feedstock. RDF has been successfully burned in a variety of stoker boilers and in suspension as a stand-alone fuel in bubbling and circulating fluidized bed combustion technology boilers. It needs lower excess air and hence works at better efficiency. Also, handling is easier since non-combustibles have been already removed. The RDF burning technology includes spreader stoker fired boiler, suspension fired boilers, fluidized bed units, and cyclone furnace units (Bjeldanes and Beard 1996).

Status and cost

In 1996, there were 140 operating MSW combustion units in the US producing an aggregate of 2400 MW of electricity (Bjeldanes and Beard 1996). Different types of combustion technolo-

gies have been adopted and run commercially. In the case of mass burn types the unit size varies from 50–3200 TPD (tonnes per day). The operating efficiency of 450–580 kWh/tonne has been achieved except in refractory furnaces where it is comparatively less, i.e. around 100 kWh/tonne. The capital cost varies from 80 000 to 200 000 dollars depending upon the unit size and type of technology. All the mass-burn systems generate poor quality of ash, and the flue gas thus formed has higher pollution content.

The RDF-type plants also have different commercially-available technologies working at different sites. The unit sizes are 300–500 TPD. These plants work at slightly higher efficiency, i.e. 550–600 kWh/tonne. The project cost varies from 85 000 to 160 000 dollars per TPD. As predicted, they produce better quality of ash and ash disposal is less problematic. Specially designed fluidized-bed combustors produce less pollutants through the flue gas. The fluidized-bed technology, being new, represents only 23% of the total power plants on MSW.

Merits and demerits

The most important merit of incineration technology is the size reduction that eases the problem of waste dumping. About 75% of weight reduction and 90% of volume reduction is achieved through burning. All the organic matters, whether putrescible or not, are reduced to ash. MSW can be used even without much fuel preparation. A complete sterilization is achieved due to burning of even biologically hazardous waste, thus avoiding epidemics. MSW can also be co-fired as an additional source in coal-based power plants.

The demerit of such plants is the air pollution that can never be avoided even in highly sophisticated power plants. The additional cost of the complete pollution control systems is about 30% of the power plant cost, which makes it financially unattractive to the already high investment system. The pollution is caused mainly due to particulate matter, CO₂, SO₂ (sulphur dioxide), NO_x (oxides of nitrogen), dioxin, and furan. The last two are supposed to be hazardous to health. Dioxin and furan are the generic terms referring to a special family of chlorinated benzene ring compounds (1) polychlorinated dibenzo-p-dioxins and (2) polychlorinated dibenzo-p-furans. Totally 210 different types of toxins and furans exist but the tetra series (containing four chlorine atoms) are believed to be the most toxic. Also the ash contains toxic elements such as arsenic, cadmium, lead, and mercury and

treating the ash for the pollutants beyond limit is another costly affair. Another operational problem found in such plants is the additional maintenance cost to solve the problems of fouling and slagging in the furnace.

Gasification

The extraction of maximum heat from a given fuel depends upon the efficiency of mixing the fuel with oxygen or air. This is perfectly achieved in the case of gaseous fuels. That is why conversion of solid waste into gaseous fuel is considered one of the best options. As described in Figure 4, MSW after pre-treatment is fed into the main gasification chamber wherein biomass is converted into gas, which, in turn, produces power after cooling and cleaning through gas

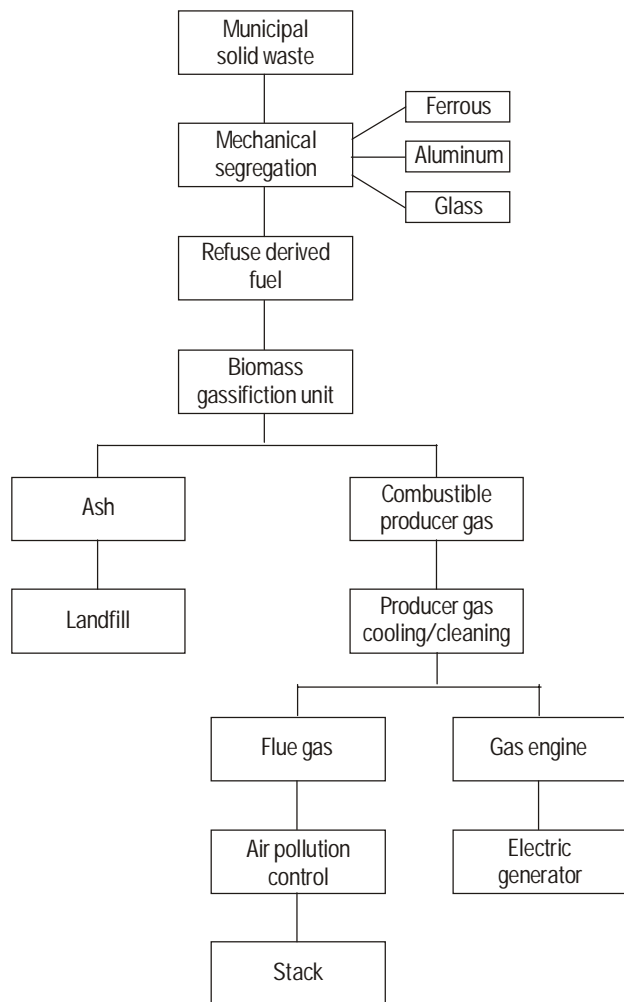


Figure 4 Flow diagram of an MSW (municipal solid waste) power plant based on gasification technology

engine connected to electric generator. A gasifier essentially carry out pyrolysis under limited air in the first stage followed by higher temperature reactions of the pyrolysis products to generate low molecular weight gases such as CO (carbon monoxide), CH₄, hydrogen, nitrogen, etc. The gas known as producer gas has the calorific value of 1000–1200 kcal/nm³, which could be used in IC engines for direct power generation or in boilers for steam generation to produce power.

Process

The MSW that is received is sorted to remove the non-combustible materials. The remaining organic fraction (RDF) is shredded to achieve the feedstock size of less than 5 cm. The moisture content of feed is maintained at less than 20% to maximize the heat recovery.

Densification of RDF is not required, which saves significant capital expenses and operating cost. The RDF is fed into the feed hopper with an agitator and hydraulically driven feed auger. The feedstock then passes to the main thermal reactor where at high temperature (900–1200 °C) the RDF is converted into gas. Ash is removed from the base of reactor in a closed system. There are no fugitive airborne emissions from the ash systems. The gas flows from the top of the reactor vessel through pipes equipped with internal cleaners to mechanical gas cleaner vessel. Then the gas is passed through a series of mechanical cleaners to remove char, particulate matter, and any un-reacted solids carried by the gas stream. The gas is then cooled through heat exchangers to the temperature as required by either IC engine, turbine, or boiler. A high voltage and low amperage electrostatic precipitator completes the gas cleaning and cooling process. A self-contained oil/tar/water separation system receives condensate from the electrostatic precipitator. Oils and tars are separated and re-injected into the reactor. The waste heat recovered from the reactor is used to preheat the feed-stock and reduce moisture to an acceptable limit (Solar Energy Research Institute 1979).

The quality of gas is regularly monitored through a gas meter. As per the requirement, the gas is fed to IC engines to produce power. The engine emissions are usually quite low. Another option is to use the gas in gas-fired boilers for steam generation, which, in turn, produces power through steam turbines.

Status

Many such plants have been reported to be working in the US and Canada successfully.

They range in capacity from 100 to 400 TPD, installed between 1980 and 1992. After gaining the experience of a decade, setting up of many commercial plants are under way. It is expected that some plants of MSW gasification will be installed on BOO basis (Parker and Roberts 1985).

Merits and demerits

One of the merits of gasification is that handling gas is easier than solid fuel. The overall gasification to thermal efficiency is higher than direct burning. Weight reduction of 75% and volume reduction of 90% are achieved. This reduces the daily amount to be dumped at the dumping yard. It produces only 8%–12% ash as compared to 15%–20% during incineration. The most attractive aspect is the pollution control. Practically no hazardous gas is expelled into the environment. Moreover, limited plant area is required as compared to other contemporary technologies.

The demerits are the regular maintenance required for the cleaning system. In case of ineffectiveness or failure of the cleaning system, the tar and volatile gases cause damage to IC engines. Therefore, the better option is to use the gas for thermal applications. The design is fuel- and size-specific and loses versatility. The sophisticated cooling, handling of cleaning system, and regular operation and maintenance make it a costly affair. In some cases the tars and volatile gases are not recirculated as feed for cracking. The release of such chemicals is poisonous to the vegetation and soil environment (Reed and Das 1988).

Biomethanation

Municipal solid waste is a heterogeneous waste and contains the following fractions

- Putrescible fraction. This is also called digestible fraction and contains biodegradable organic matter such as kitchen waste, vegetable market waste, paper, grass cutting, and yard trimmings. Putrescible fraction represents 40% of MSW in India.
- Combustible fraction. Also known as refractory organics, these are either slowly digestible or indigestible organic matter such as wood, plastics, rubber, and other synthetics. They represent around 20% of MSW in India.
- Inert fraction. They are typically non-digestible and non-combustibles such as stones, sand, glass, and metals. They represent 15% of the MSW in India.
- Remaining 25% is the moisture content.

The putrescible fraction is ideally suited to produce biogas and the remaining slurry is a good fertilizer. There are different types of biogas technologies discussed in the next section. However, Figure 5 shows that the MSW is subjected to mechanical segregation to obtain putrescible fraction, i.e. RDF. The digestible organic fraction thus obtained is kept as pulp in hydrolysis tanks for breaking them into smaller molecules. The hydrolysed pulp is then fed into anaerobic digestion tanks. Here it is digested anaerobically (in absence of air), in the specially designed digesters. Under this active bacterial activity, the digested pulp produces the combustible gas CH_4 , and inert gas, CO_2 . The CH_4 gas is then used to produce power through a biogas engine connected to electric generator. The remaining digestate (slurry) is a soil conditioner of good quality and free from pathogens. With the help of a solid/liquid separator, organic fertilizer is obtained and the treated water can be safely used for irrigation.

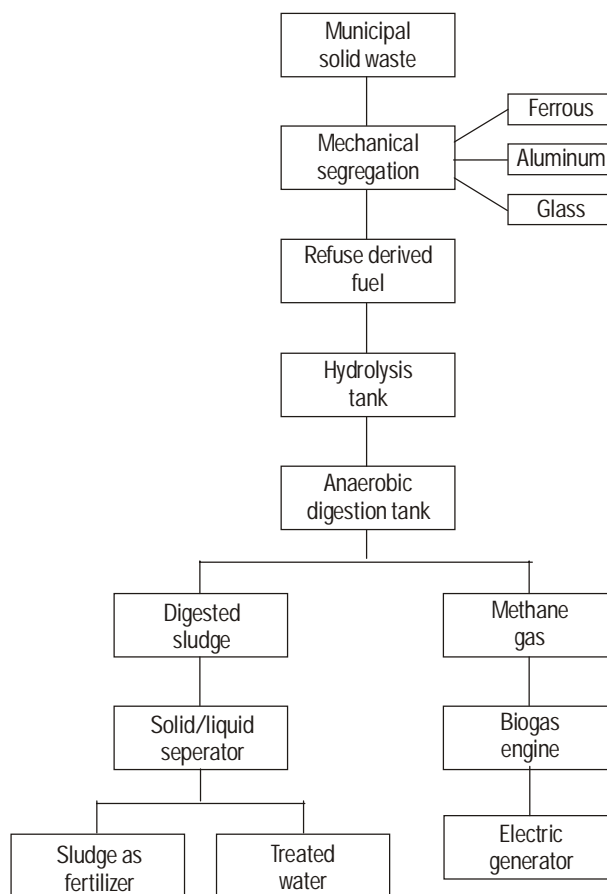


Figure 5 Flow diagram of an MSW (municipal solid waste) power plant based on anaerobic digestion technology

Technology

Depending upon the MSW quality and quantity, local environmental and climatic condition, there are various commercially viable technologies available globally. In all the technologies the following steps are involved.

- Sorting. The putrescible fraction is separated either manually or mechanically.
- Particle size reduction. To provide maximum surface area to the bacteria, the particle size reduction is carried out by using screw cutting, milling, drumming, pulping, or shredding machines.
- Digestion. The material is then fed into anaerobic digesters for gas generation.
- Post treatment. The slurry or digestate is matured for two to four weeks to make an agriculture or horticulture quality fertilizer or soil conditioner.

The core of the whole technology is the anaerobic digestion. There are many technologies for effective digestion which differ from each other depending upon their digestion parameters. They are briefly explained below (IEA 1997; Roos and Moses 1997).

Dry batch

The MSW is fed batchwise in the digester after inoculating it with the slurry of the previous batch. The load is allowed to digest for 20–30 days till maximum gas is recovered. Commercially it is available as BOCELL process. It has the typical disadvantages of instability and material handling, pertaining to batch process.

Dry continuous

DRANCO, VALORGA, and KOMPOGAS are the commercially available technologies in this category. They operate at the solid concentration of 20%–40% and they achieve high loading rates and minimize the requirement of water. Recycled effluent is mixed with fresh charge of MSW during semi-continuous feeding. They are ideally similar for thermophilic digestions (50–55 °C).

Wet continuous

REFCOM technology uses the MSW solid concentration <10% using large amount of water. This is most ideal if mixed with sewage sludge, animal slurries, and industrial waste. To avail the large disposal of liquid, the effluent liquids are used to dilute the feed. This technology is usually not chosen if it is to be used only for MSW.

Wet multistage

BTA and PAQUES designs are commercial technologies available in this category. MSW is converted into slurry with water and fermented in the first stage. The slurry with volatile acids is then converted to biogas in the second stage using high rate anaerobic digesters such as the anaerobic filter or UASB (upflow anaerobic sewage blanket) digesters. The major disadvantage is the complexity in design and operation. Highly skilled manpower is also required.

Sequencing batch

This is a new concept known as SEBAC but yet to be fully commercialized. This is similar to the dry batch type technology except that leachate from the base of one digester is used to inoculate and remove the volatile acid from other digester in the series. The digestion is usually allowed for 20–30 days in one digester and the digesters are filled every week in sequence so that continuous gas supply is available through the centralized gas collection system. High solid content over 30% is used in it. The advantage of this design is that volatile acids are not allowed to accumulate and anaerobic bacteria keeps on getting food continuously. The only disadvantage is the lack of continuous feed.

Status and cost

Anaerobic digestion technology using mix-waste, bio-waste, and manure is working on a commercial basis in at least 15 countries, mostly in Europe, with capacity ranging from 4000 to 220 000 tonnes per year. Only a few of them work purely on MSW but the number of plants working solely on MSW is increasing, and many new ones are on the pipeline. There are some promoters such as ENKEM, CICON, GENL, and NSTLER who have offered to take up such plants using MSW on BOO basis in India. On an average they have estimated the total cost of the plant at 80–100 million rupees per 100 TPD capacity of the system. It has been observed that the cost of anaerobic digestion plants have reduced with time and is expected to be most competitive as compared to the other options. The most attractive aspect is environmental gain, i.e. no pollution and soil conditioning (IEA 1997).

Merits and demerits

An anaerobic digestion technology has many merits.

- Useful products such as biogas and compost are obtained.
- Drastic reduction of pathogens is achieved.
- Needs comparatively much less land.
- No release of greenhouse gases to environment.
- No problem of odour.
- Aesthetically good looking and hence no problem of real estate loss.
- Comparatively more cost effective from the point of view of life cycle cost.

Besides having so many merits it suffers from some demerits.

- It is a slow process and cannot accept shock loading.
- Non-biodegradable organic fraction (i.e. refractory organics) cannot be digested and hence, needs to be disposed of without treatment or, additional technology (such as gasification) needs to be employed for the refractory organics.
- The compost produced is not directly useful for soil, and needs special treatment to remove undesired materials such as glass, metals, and pathogens. This adds to the cost of the plants.

Other technologies

There are other technologies that have been reported to be tried on experimental levels but are yet to be commercially exploited. They are described below (Bhide and Sunderesan 1983).

Pelletization

Pelletization is a process of producing fuel pellets from solid waste. The complete process involves drying, removal of non-combustibles, grinding, mixing, and production of pellets under high pressure. Usually, the conversion time is 25 minutes. The calorific value of raw garbage is around 1000 kcal/kg while the pellets also known as RDF have the calorific value around 4000 Kcal/kg. About 15–20 tonnes of fuel pellets can be produced after treatment of 100 tonnes of raw garbage. These pellets could be used for heating in the boilers and the steam thus generated, in turn, is used to produce power. A power plant of 5 MW based on RDF will need 12 acres (4.85 hectares) of land and 600 TPD of raw garbage. It will cost 220–240 million rupees (1996 price). Two such plants are reported to be working in Bangalore and Mumbai.

Plasma arc (pyro-plasma process)

This system uses a heat source called a plasma arc flame. Two electrodes are precisely shaped

and distanced. A highly ionized gas is passed between them and high voltage discharge occurs between the electrodes causing a hot plasma zone to be created. The plasma gas around the electrodes is of extremely high temperature ranging from 5600–30 000 °F (3093–16 649 °C). At such a high temperature the molecules within that zone dissociates into their individual atoms. Thereafter, 'quenching' allows for the controlled cooling of the hot plasma gas. The reintegration process produces synthesis gas. Since the process occurs in the vacuum the intermediary products (pollution causing) NO_x and SO_x (oxides of sulphur) are not formed. It takes care of all organic matters whether biodegradable or not. The cost is expected to be Rs 40–50 million rupees. A fully commercial plant is yet to be installed. One such demonstration plant is expected to be installed in Taiwan.

Garret flash pyrolysis process

This low temperature pyrolysis process yields fuel oil. In this system, plant refuse is initially coarse shredded to less than 50 mm size, air classified to separate organics, and dried in an air drier. The organic portion is then screened, passed through a hammer mill to reduce the particle size to less than 3 mm, and then pyrolysed in a reactor at atmospheric pressure. The heat exchange system allows pyrolytic conversion of the solid waste to a viscous at 500 °C.

Status of MSW power projects in India

The first MSW power plant was a project with incineration technology using 300 TPD waste to produce 3.5 MW power installed at Timarpur, Delhi, with financial aid from the Danish government and the MNES (Ministry of Non-conventional Energy Sources), Government of India, during 1989/90. The plant has been reported to be running without commercial viability, probably due to some design problem and therefore, finally was closed. The lesson from the above plant had taught all the concerned agencies to take up the future projects carefully. At the same time, the municipal corporations were skeptical about venturing in this field. A ray of hope came from the private investors / promoters who offered to take up the waste-to-energy projects with their own investment on BOO basis during 1993/94. The proposals on BOO basis were invited from private investor by many municipal corporations. As a result the municipal corporation signed agreements with the private promoters wherein, the municipal corporation

was expected to provide land and garbage free of cost while the promoter would run the plant commercially. Only a few agreements appear to have been converted into real projects.

The status of projects in India is as follows.

- An MSW project with 500 TPD capacity has been installed at Hyderabad Municipal Corporation by Selco International Ltd wherein the waste is converted into energy-rich fuel pellets. The energy plant installed with the help of the MNES and the APTDC (Andhra Pradesh Technology Development & Promotion Centre) is expected to expand further to treat 1500 TPD of waste to produce 20 MW power.
- Nagpur Municipal Corporation signed an agreement with ENBEE Infrastructure Ltd, Bhopal, for installation of a 500 TPD 4 MW waste-to-power project using biogas technology with foreign collaboration. The construction work started at the site after the project received the sanction of subsidy from the MNES and loan from IREDA (Indian Renewable Energy Development Agency Ltd) and HUDCO (Housing and Urban Development Corporation Ltd). The administrative approval from the Government of Maharashtra has been already accorded to the project.
- The other municipal corporations who are in the process of signing agreements with private promoters are Mumbai – 1000 TPD (10 MW); Pune – 450 TPD (4 MW); Solapur 300 TPD (3 MW); and Kalyan – 600 TPD (6 MW) all in Maharashtra. It is also reported that the Chennai Municipal Corporation is planning to take up a 600-TPD project.

Considering the above situation, it is obvious that there is no commercially running power project based on MSW. Probably the Nagpur project will be first of its kind involving the Indian private investor with foreign collaboration.

Conclusion

The above discussions about the options of various technologies show that the choice of technology has to be done judiciously. Sanitary landfill is a good choice if sufficient land is available and proper care is taken to treat the leachate collector from the bottom of the landfill. Also the area near the landfill should be kept aesthetically presentable. As regards incineration, it has the advantage of 90% of volume reduction. The technology is also available locally. Of course, one has to be very careful to make sure that flue gas coming out of the stack

must not pollute the environment. The gasification technology is relatively new and appears to be suitable for the treatment of solid waste. It does not cause atmospheric pollution and works at higher efficiency. Biomethanation is the most widely used technology all over the world, more so in Europe. The main advantage is that it is an environment-friendly and reliable technology. The only disadvantage is that it cannot treat non-biodegradable organic fractions. Other technologies such as pyrolysis, pelletization, and plasma arc are new and are yet to be commercially established.

It is obvious from the above discussion that no technology is perfect. All of them have merits and demerits. The choice of technology has to be made based on the waste quality and local conditions. The best compromise would be to choose the technology that fulfils these criteria.

- Lowest life cycle cost
- Needs least land area
- Causes practically no air and land pollution
- Produces more power with less waste
- Causes maximum volume reduction.

The recent trend is that many private investors / promoters are now offering to take up the projects on BOO basis. The whole project is to be run on their own investment. Obviously, they take greater risk and the investment is not possible unless they are sure about the techno-economic viability. In that case any of the above technologies could be accepted by the municipal corporations as long as the promoter fulfils all the technical, legal, financial, and pollution control requirements. The best and judicious choice lies in opting for a promoter who provides the technology with a well-balanced compromise.

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