WASTE TO WEALTH: A SUSTAINABLE WASTE MANAGEMENT PRACTICE

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Abstract

The generation of Municipal solid waste (MSW) has increased to a great extent in India and its management is becoming difficult day by day. The total MSW generation in our nation i.e. India is around 48 million tons per annum, and it is estimated that this would increase to 300 million tons up to the year 2047. The Municipalities are facing a challenge in their sustainable management. The MSW includes the waste discarded from municipalities mainly household waste, garden waste, commercial wastes, etc. It contains a fraction of paper, food waste, wood and yard trimmings, cotton, and leather, biomass, plastics, rubber, and fabrics, which could be further utilized as renewable energy resource i.e., waste to energy. According to the pyramid of waste management, the minimization of waste generation should be encouraged, after that reuse, recycling to be promoted, i.e., 100% composting of organic waste and landfilling of non-recyclable waste. But presently, there is a scarcity of land to dispose of waste and with multiple increments in generation of solid waste. The waste-to-energy is the best option to derive wealth from waste. With the accessibility of technologies, e.g., **anaerobic digestion, refuse-derived fuel (**RDF), **incineration, pyrolysis**, **gasification, plasma technology,** we can utilize waste as an energy source. Globally app. 130 million tonnes per annum of MSW is combusted in 600 WTE facilities for production of energy like electricity and steam for heating. The above- mentioned technologies are used world over to utilize municipal waste. India can also opt these technologies to utilize MSW and can reduce pollution being increase due to improper disposal, thus according to present observations feasibility study is required to carried out with all waste to energy technologies so that its implementation ensure energy recovery from discarded wastes and a wealth source. In this chapter here are some methods discussed by which we can use waste to produce eco-friendly products.

Keywords:

Municipalities, sustainable management, reuse, recycling, waste to energy.

1. Introduction:

India is considered as significant fastest developing countries across the globe and its economy has supressed the economy of UK for the first time in about 100 years. With the growth level of 7.6% in fiscal year 2016, India has become the fastest-developing economy and second most populated country in world. It is been estimated that the population of India may increase from 1,029 million to approximately 1,400 million during 2001–2026 which will result in an annual population rate of growth of 3.3. The urbanization in India reached to 31.6% from 27.8% in 2001–2011, and it is projected that up to 50% of the total Indian population will shift in the cities in coming 10 years (Gupta & Arora, n.d.). This rapid industrialization, population expansion, and economic evolution in India led to the movement of people from villages to cities, generating thousands of metric tons of MSW daily in as kg per capita per day, as a consequence of improved lifestyle leading to improper waste management (Kumar & Goel, 2009). So, at present, waste management and its disposal are the most important problem which India is facing as approximately 90% of waste is openly dumped (Narayana, 2009). A sustainable waste management process to implement and follow is a difficult task in India because of waste composition changes with time and waste generation rates vary. The effects of futile waste management could be local, regional, or global and climate change and environmental degradation (Fauziah, 2007) . Municipal solid waste management was initially an ignored issue in India until the Municipal Solid Waste (Management and Handling Rules) 2000 were declared. Table 1 illustrates the initiatives taken by India to manage waste.

According to Lansink's stepladder – following steps should be opted for waste management: prevention > recycling > incineration with energy recovery > incineration > landfilling. In India, the ISWM (Integrated Solid Waste Management) followed by Swachhta Bharat Mission, order of managing waste gives priority to the waste minimisation by reducing and reusing the waste (Figure 1). Municipal solid waste mainly includes agricultural wastes, plant waste and animal wastes, industrial waste like sugar refinery, dairy wastes, confectionary waste, pulp and paper, tanneries, and slaughterhouses, and residential waste like kitchen and garden. Urban areas manage their generated waste by dumping it into low lying areas called landfills and it is the extremely used mode of waste management as it is economically feasible and does not require any kind of skilled workers (Chen et al., 2016). According to the Indian Municipal Solid Wastes (Management and Handling) Rules, 2000, Landfilling should be confined to non-biodegradable, inert waste and waste which is not appropriate for recycling and for biological handling. Landfills are mainly responsible for the production of greenhouse gases like methane because of the decomposition of MSW. Therefore, it is required to harness the locked energy resource from organic components of MSW and these wastes have the capability to be a resource by their conversion into energy derived fuels using waste-to-energy routes (WTER) (Kothari, Tyagi, & Pathak, 2010a).

By 2015, 18 nations in the EU banned the landfilling of recyclable waste and countries like the United Kingdom, Poland, and France imposed taxes on landfilling to convert it into a less preferable option for waste disposal. As per USEPA 2016, the number of active landfills in the United States declined from 6,326 during1990 to about 2,000 in 2010. Thus, it becomes necessary to invent and employ environment friendly Municipal Waste Management Techniques to redirect the waste from landfill sites. Studies related to strategies involved in discovering alternative energy sources are the present necessity for the proper sustainability of the world. A source which is compatible to environment makes it an important alternative energy source. Thus, transformation of organic portion of waste into energy will become the most favourable option in future sustainable management**.**

India is majorly using three technologies to recover energy from MSW namely refused derived fuel (RDF), bio methanation and incineration (Chakraborty, Sharma, Pandey, & Gupta, 2013a). India has the possibility to produce about 3000 MW energy from MSW by 2020 (Saini, Rao, & Patil, 2012) and there were about 27 energy out of waste plants in different Indian cities through 2005 which were based on either gasification or pyrolysis with the total 45.5 MW capacity (Chakraborty, Sharma, Pandey, & Gupta, 2013b). This chapter aims to review the calibre of alternative renewable energy sources from organic waste and biomass to promote conventional energy production processes by adopting WTER technologies. Such technologies help in generating electricity and production of alternative fuels like biogas and hydrogen gas.

2. World global problems and renewable energy:

Increased usage of fossil fuels effects changes in climate globally, creates conflicts related to energy (Chakraborty et al., 2013b)consumption, scarcity of energy sources and threatens the stability of world. Such problems are witnessed locally, regionally and globally also which are described below:

1. Lost fossil fuel reserves and higher-level consumption of resources with increased population growth.
2. Increased waste generation with increased population.
3. Global climate change because of increased concentration of GHGs in atmosphere.

Thus, distinct varieties of municipal solid waste generated have the ability to serve as renewable energy resources to achieve the sustainable development. Such categories of waste are advantageous because they tend to shift the present energy requirement by switching over to waste to energy routes. Other main benefit for these energy routes is that they are environment friendly and are long lasting without causing any negative social impact. A few studies are going on in this area to find the solutions for global problems. According to several researchers, renewable energy skills have the capability to promote sustainable development. European countries have performed the maximum studies on these routes like Meyer et al. determined sustainable development scenario using renewable energy sources for countries like Denmark, Norway and Sweden independently for 2030 and Panoutsou et al. studied the future capability of biomass resources as a renewable source in Europe on the basis of various divisions like agriculture, industrial, etc.(Kothari, Tyagi, & Pathak, 2010b)

The benefits of waste to energy products are:

a. These products will manage the extremely crucial concern of today i.e., energy requirement by improving the reliability of energy supply, will increase the standard of living and will promote the sustainability of environment (Zakhidov, 2008)
b. Establishment of waste to energy projects in rural areas will create job opportunities for the local population residing there and will prevent migration to urban areas (Bergmann, Colombo, & Hanley, 2008).
c. Production of energy from waste will help meeting the energy demands in a consistent, inexpensive, and environmentally balanced way (Hiremath, Kumar, Balachandra, & Ravindranath, 2011).

d. Production of such energy efficient products will prevent air, water, land pollution and forest loss.
e. These sources will provide alternative sources of energy fabrication and will reduce human suffering.

3. Types of waste management practices in India:

The figure 2 describes the pathways for waste processing technology to be pursuedb based on type of waste which are described further below.

Anaerobic digestion: Biogas is majorly consisting CH_4 40–70%, CO_2 30–60%, and additional gases 1–5% and its calorific value is around 16–20 MJ m^{-3} (Kurchania, Panwar, & Pagar, 2010). Biogas is manufactured by anaerobic consumption of organic waste and it is very advantageous over more forms of bioenergy production (Panwar, Kaushik, & Kothari, 2011). It is recognized as a most energy-effective and environment favouring technology for the producing energy using biomass (Weiland, 2010). The raw materials used for the biogas production are organic waste from households, food industry, crops, and agricultural waste products, such as crop residues and manure (Börjesson & Berglund, 2007) . The procedure of digestion occurs in warm, humid, and anaerobic condition, where bacteria ferment the organic matter into biogas. It consists of four basic steps: hydrolysis, acidogenesis, acetogenesis/dehydrogenation, and methanation (Weiland, 2010)and each stage is held out by different groups of microorganisms. There are mainly takes two types of digestion, i.e. mesophilic digestion where temperature range is 30–35 8°C and the retention time for 15–30 days and thermophilic digestion where temperature range 55- 80°C with retention time for 12–14 days. The benefits of biogas generation are discussed below (Kothari et al., 2010a):

a. Amount of biomass sludge is generated less as compared to aerobic treatment technologies.
b. It successfully treats wet waste of less than 40% dry matter.
c. Odour emissions are minimum because of the completed oxidation of volatile compounds.
d. Effectively removes pathogen.
e. The produced slurry work as fertilizer to improve the nutrient quality of plants (Tafdrup, 1995)
f. It serves as a supply of carbon neutral energy in the production of biogas.

The minimization of environmental pollution and fulfilment of energy requirement for various purposes makes biogas production the most economical beneficial. In 1994, The Ministry of New and Renewable Energy, India announced a National Master Plan, according to which Biogas technology is the major waste-to-energy alternatives to be established and accepted in the country. But the major factor responsible for the inappropriate management of biogas manufacture is the arrival of waste in mixed form containing a lot of non-organic material like plastics. Due to the absence of waste segregation, it becomes difficult to use waste to produce biogas (Narayana, 2009).

Refuse derived fuel: RDF consists of the dry combustible fraction of the MSW which includes paper, textile, rags, leather, rubber, non-recyclable plastic, jute, multi-layered packaging and other compound packaging, cellophane, thermocol, melamine, coconut shells, and other elevated calorific fractions of MSW. RDF is treated as a fuel or resource if it has Calorific value; Water content; Ash content; Sulphur content; and Chlorine content. The conversion of MSW into RDF is generally followed by shredding, screening, sorting, drying and palettization. These steps improve the attributes of municipal waste (Bosmans & Helsen, 2010). Such energy recovery technologies are further divided into incineration, pyrolysis, gasification, and plasma-based technologies. These are the conventional approaches for generating energy out of waste by combusting the waste. It has been observed that the potentials for RDF process range from 9 to 19, 8 to 18, 6 to 15 MW/day from GL, BL and OL respectively (Chakraborty et al., 2013a).

Incineration: It is a concocted phenomenon which engages thermal decomposition as contrasted to thermal oxidation at increased temperatures about 900°C or greater to destroy the organic component of the waste for volume reduction. Mainly, wastes having high organic content are the highly suitable for incineration (Oppelt, 1987). The major steps which are required to incinerate hazardous waste are: (1) waste preparation and feeding (2) combustion chamber (3) control of air pollution (4) residue handling i.e., ash.

An incinerator is major concern to municipality because it promotes air pollution which directly deteriorates the environment. The residue from incinerators creates water pollution which is a secondary issue. But an incinerator causes undesirable noise and causes the surroundings to be unpleasant because of litter and kinds of trashes. The most occurring forms of air pollution are fly ash, smoke, odors, noxious gases like nitrogen, oxygen, water vapour, carbon dioxide with small amounts of sulphur oxides, nitrogen oxides, and dust (Niessen, 1980). The type of chemicals present in stack gases may contain dioxins, polychlorinated biphenyls

(PCBs), polychlorinated naphthalene, chlorinated benzenes, polyaromatic hydrocarbons, various volatile organic compounds, heavy metals like lead, cadmium, and mercury. These chemicals are persistent, bio accumulative and toxic (Allsopp, Costner, & Johnston, 2001). Polluted water is immediately discharged from incinerators after use. Such polluted water has high biological and chemical oxygen demands and mainly contain inorganic or organic suspended and dissolved solids.

MSW incinerators produce energy inefficiently with only 20% generated energy by the captured waste. In 1999, Murray described incineration as inefficient energy source production. It does not lead to material conservation and hazard reduction but to material destruction and hazard creation. Advantages of Waste incineration includes decrease in waste quantity, effective waste management, production of heat and power, saves waste transportation, provide control over noise and odour, prevents the invention of methane, recycles metals effectively, prevents contamination of groundwater, benefits of obtained ash etc. With this, it has certain advantages also which includes environmental pollution, high expense of maintenance, health damage to workers and nearby community.

Biomass gasification: Plant-based products are commonly known as biomass which may include agriculture wasted and residues, forestry and industry wastes which are biodegradable in nature. Biomass can be transformed into various energy forms like liquid biofuels for transport and solid biomass for heat and electricity generation (Abbasi & Abbasi, 2010a). The biomass consists of organic matter where sunlight energy is stored with the help of photosynthesis. The decomposition of the bonds between carbon, oxygen and hydrogen molecules takes place which release stored, chemical energy (McKendry, 2002). Converting biomass to energy uses different technologies i.e., thermochemical, bio-chemical, and physio-chemical. Gasification technology converts biomass into energy forms by the inadequate oxidation of biomass at extreme temperatures, about 800– 900°C (Kumar Mishra, Singh, & Pingita Mishra, 2015). It is an efficient technology for the energy production to produce electricity without increasing CO_2 concentration in the atmosphere (Nakamura et al., 2014) .

Biomass gasification technology has some detrimental effect on environment like other technologies. Lata et al. explained that while processing, each part of the system creates occupational, health and safety hazards. Gasification causes environmental problems like water pollution, air pollution, disposal of ash and other by-products. Products like tars, alkaline compounds, halogens with heavy metals are released in this process which deteriorates environment (Abbasi & Abbasi, 2010b) . Using non-woody biomass as a natural material in the procedure creates excess sulphur, chlorine, as compared woody biomass (di Blasi, Signorelli, & Portoricco, 1999). Sulphur and chlorine have the destructive impression on environment.

***Landfilling:** Landfill is a constructed structure which resist the degradation to prevent the harmful contamination in environment. Leached out liquid waste from landfill contains hazardous chemical compounds, which might be threatening to quality of life and nature if exposed to environment (Demirbas, 2006). Leachate's rate of flow and its structure varies geographically, seasonally and depends on landfill age also. Decomposition in landfills follows a sequence of process in which each stage is specified by the change in bacterial population and the establishment and usage of specific metabolic products. The initially stage normally persists less than one week and degradation of oxygen on or after the waste by aerobic bacteria takes place (Demirbas, 2006). Second stage is characterized as anaerobic and acid stage where a distinct population of fermentative and hydrolytic bacteria which hydrolyses polymers, like cellulose, hemicellulose, proteins, and lipids, into soluble sugars, amino acids, long-chain carboxylic acids, and glycerol (Micales & Skog, 1997). Leachate treatment is an important aspect to be focussed upon. The treatment including chemical and physical processes are to be used in treating effluent. Such processes consist of chemical oxidation, coagulation–flocculation, chemical precipitation, absorption via activated carbon, ozonation, and pressure-led membrane processes. For treating effluent biologically, Ozonation including reverse osmosis are preferred to get a good quality effluent. Moreover, physio-chemical units are not capable enough for removal of organic compounds out of leachate. The drawback of leachate treatment using precipitation process and coagulation is the creation of excess sludge post treatment application, which becomes tough to manage. With respect to the same, biological treatment individually is not highly removal efficient due to reticence effect of few contaminants like ammonium and heavy metals. For instance, physio-chemical treatment removes metals and partially ammonium, where biological treatment stabilizes and degrades organic matter, and removes nutrients (Hasar et al., 2009).

Composting: Composting is the reclamation of organic matter by regular decomposition process using biological methods. Decomposition of organic material warrants nutrient recycling in nature. Composting of municipal solid waste has been used since long back and is involved to recycle organic matter back into the soil to enhance fertility of soil increasing crop productivity. Composting is seen as an eco-friendly method of waste processing for treating it. It is an aerobic, biological process which uses naturally occurring microorganisms to convert biodegradable organic matter in humus-like product (Gómez, Lima, & Ferrer, 2006). The process devastates pathogens, converts N from volatile ammonia to balanced organic forms, and diminishes the waste volume and improves the quality of the waste.

Composting has become a successful strategy for sustainable recycling of organic wastes. It is an ecological alternative to mass burning and landfilling of MSW. Composting reduces the waste volume to dispose to landfill and incineration and it recovers the useful organic matter to use it as soil amendment. By contrast, odors, noise, vermin annoyance, bio aerosol generation and productions, release of volatile organic compounds (VOCs), and potential passage from land for contaminants to go into food chain, are the disadvantages of composting. Composting is an component of an integrated solid waste management plan that can be utilized to mixed municipal solid waste (MSW) or to collect leaves separately, yard wastes, and food wastes.

Compost results in a basic breakdown of organic material layered with small amounts of soil by a process known as aerobic disintegration. Structure of the matter is cracked down by bacteria and fungi of decay until it is part of the soil mass. For example, a piece of newspaper would, under ideal conditions, become a part of the humus in soil within two to four weeks. A tin can biodegrades in about 100 years and an aluminium can in about 500 years. During composting, heat is generated because of interaction of organic matter content with moisture, air, bacteria, and fungi.

Composting typically is an ecological succession of microbes almost consistently present in wastes. The succession starts with the formation of favourable conditions for composting. “Resident” (indigenous) microbes efficient of applying nutrients in the raw waste to proliferate. Due to this activity, conditions become promising for some indigenous microbes to proliferate. Composting occurs in 3 stages, i.e., (1) initial lag period and (2) Exponential growth period and accompanying strengthening the activity i.e., active phase that (3) ultimately tapers into final decay, which continues while waiting for ambient levels are reached as maturation phase.

Overall, conversion of municipal solid waste in compost is a favourable option of managing waste in Indian cities. It is an environmentally friendly, creates wealth and enables sustainable development. This technique has been widely used for bioremediating the populated sites. Effect of heavy metals on microbes present in soil depend upon soil as well as the characteristics of municipal solid waste and its application rates. Thus physio-chemical analysis of compost generated from municipal solid waste is necessary before its application on the agricultural land.

Vermicomposting: Another major type of composting method is vermicomposting. Vermicomposting is regarded as a clean, sustainable, and zero-waste approach to manage organic wastes. Vermicomposting is a modern and alternative to traditional composting techniques which are inexpensive, and eco-friendly in which earthworms are used as natural bioreactors in to decompose the organic matter. Their metabolic activity and presence with microorganisms reduce 40-60% of waste volume and increase of bioavailability of nutrients to plants gets increased, reduces the C/N ratio, and decreases of the availability of metals (Manaf et al., 2009). In Vermicomposting, worms are used that convert organic matter present in wastes into a humus-like material known as vermin-compost. Vermicompost appears is considered superior to conventionally produced compost because Vermicomposting and vermiculture is a potential benefit to organic farmers and work as a source of supplemental income.

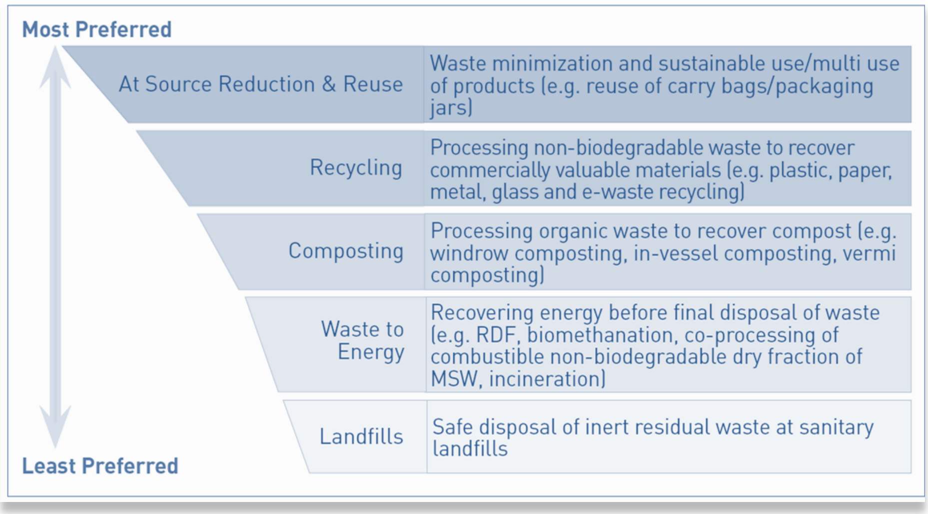
Aspects of waste to energy production technologies: The world’s policies to reduce landfilling and favouring “hierarchy of waste” by implying it, will decrease the waste and promote recovery and recycling of materials. Landfills create a type of limitless burden on the future generations and should be realised only as a transitory option. Life cycle Assessments should be selected in the country; other waste management options also should be incorporated in future like recycling and energy recovery processes, like gasification and the pyrolysis of the MSW (Leme et al., 2014). Small-scale gasification plants can be economically feasible according to present scenarios and it is a potentially environmentally attractive method of generating electricity and heat using biomass feedstock (Wood & Rowley, 2011). The addition of plasma units to existing Incineration practices is economically achievable and technical solution to present difficulties to treat hazardous waste (Filion, Munz, & Salin, 2001). With this WTER technologies have some limitations also like according to the present scenario “profit” through MSW is not favouring because the price of WTE technologies are not economically sufficient yet. The government should deal with the issues related in the transaction of cleaner environment and the preservation of cost. Anaerobic digestion technologies in use are not energy efficient as associated to fossil fuel technologies (Kothari et al., 2010b) **.**The mixed waste arrived containing a large amount of non-organic material is a challenge for the process of separation before processing for composting. Incineration is a poor technology that does not fulfil the criteria of zero discharge (Allsopp et al., 2001).

4.Conclusion

The steps taken for waste management in order with no emissions strategy and sustainable approach, lies in prevention, re-use and recycling the waste with eminent principle of 3Rs "REDUCE, RE-USE AND RECYCLE". This chapter describes that WTE technologies have both advantages and disadvantages when processed improperly but, obtained products from them have a great potential for high energy content which would further help in the sustainable development of society by decreasing the use of non-renewable sources. India is working on The Swachh Bharat Mission (SBM) which has the objective of achieving 100% municipal solid waste processing and its disposal by 2019. India is on the verge of becoming the most populated nation over the globe which is directly proportional to the waste generation.

The Swachh Bharat Mission 2014 the most popular mission has taught us to keep our country clean. That is why it brings us the need of 'Clean and Green' to which the second SWACHH BHARAT MISSION with NO LANDFILL could be the best possible initiative. Public consciousness and their attitudes concerning waste affects the waste management system. Municipalities and local authorities alone cannot overcome this problem of SWM, that's why participation of public is essential. And production of products of from waste and their utilisation among people should be encouraged.

Figure 1: Hierarchy of Waste Management in India (Source: CPHEEO, 2016).



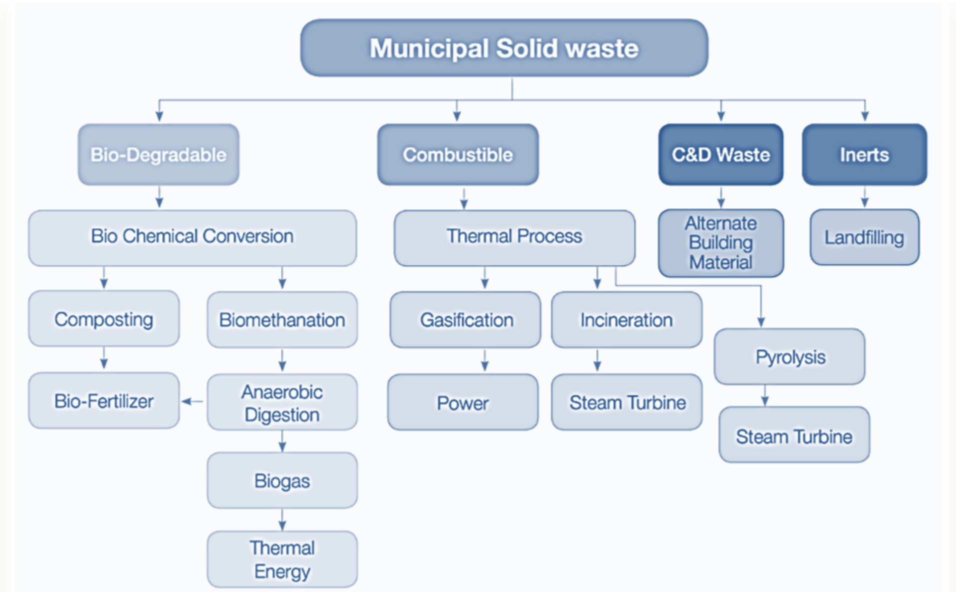


Figure 2: Various waste processing technologies based on the type of waste
Source: Report of the Task Force on Waste to Energy, Planning Commission, May 2014

YEAR	RULES, POLICIES, SCHEMES, FINANCIAL PLANS
1989	The Hazardous Waste (M&H) Rules
1994–1995	MSWM strategy paper by NEERI
	J.S. Bajaj Committee (The High Powered Committee on Urban Solid Waste Management)
1998	Bio-medical Waste (M&H) Rules
	Supreme Court appointed Barman Committee
2000	MSW (M&H) Rules
	CPHEEO Manual on MSW
2005	Report of the Technology Advisory Group on SWM
	JNNURM (2005–2012)—40 MSW projects costing Rs. 2,186 Cr sanctioned from a total of 65 cities covered
	UIDSSMT (2005–2012)—51 MSW projects costing Rs. 327 Cr sanctioned from a total of 632 cities covered
	12th Finance Commission (2005–2010)—Rs. 2,500 Cr for 423 Class I cities
2006	Strategy and Action Plan-Use of compost in cities
2007	11th Five-Year Plan (2007–2012)—Rs. 2,210 Cr for MSWM
2008	National Urban Sanitation Policy (NUSP)
	Service Level Benchmarks (SLBs) in MSWM
	Hazardous Waste (Management, Handling & Transboundary Movement)Rules
	National Mission on Sustainable Habitat (NAPCC)
2010	13th Finance Commission (2010–2015)—Establishing standards for delivery of essential services
2011	Plastic Waste (M&H) Rules
	E-Waste (M&H) Rules
	Draft Bio-medical Waste (M&H) Rules
2014	Swachh Bharat Mission, October 2014
2016	Waste Management Rules, 2016 comprising of Solid Waste Management Rules, Plastic Waste Management Rules, Bio-Medical Waste Management Rules, E-Waste Management Rules, Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 and Construction and Demolition Waste Management Rules, 2016.

Table 1: Waste Management Initiatives taken by India
Source: Toolkit for Solid Waste Management (2012), Jawaharlal Nehru National Urban Renewal Mission, Ministry of Urban

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