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Waste to energy technologies in India: A review

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A B S T R A C T

In recent past years,municipal solid waste generation and management are the challenging problem to the developing countries. However, waste to energy technologies are used to produce various by-products like electricity, heat, compost and biofuels. The present study focuses on different waste to energy technologies used in India along with their working status in different states and union territories of the country.The waste to energy technologies mainly are incineration, pyrolysis, gasification, composting and anaerobic decomposition. Furthermore, it also assesses the future aspects of waste to energy in India.

1.Introduction

In developing countries like India waste generation is increasing day by day due to boom in industrialization, urbanization and population. This also causes greater amounts of socio-economic and environmental issues[Moya et al., 2017]. India is the second leadingnation in the world in terms of population with a nearly 1.2 billion population, has continue to raise population at the rate of 3-3.5% per annum[Census, 2011].The rapid growth of population in India, gives a strong dip on the natural resources [Kalyani and Pandey, 2013; Ghatak, 2016].

Urban part of India generates approximately 0.136 million tonnes per day or 52 million tonnes per year of municipal solid waste (MSW),increases nearly 5% annually [CPCB, 2016]. The lifestyle of people in India, is changing gradually which is the cause of huge amount of waste generation. Also, there is almost no segregation of MSW, plastic wastes, commercial wastes, industrial refuses and e-wastes [Joshi and Ahmed, 2016]. This createscontinuous pressure on the government, local authority and the urban local bodies to manage the collection, segregation, treatment and disposal of waste and make cost effective changes [Bag et al., 2015; Ghatak, 2016].

Thus, there is an urgent need to improve planning of collection, segregation and disposal of wastes so that solid waste management process works significantly to create environmental friendly environment. Therefore, the usage of 3Rs (Reduce, Reuse and Recyle) should be done for environmental sustainability. The municipal solid waste management sector is governed by the Municipal Solid Waste Management Rules, 2016, Government of India. The typical municipal solid waste management value chain includes various stages i.e. primary and secondary collection, transportation, intermediary storage in a transfer station, process and disposal in an environmentally sound and appropriate manner describes in Figure 1.These rules provide clear guidance for the treatment of waste using different technologies[MSWM rules, 2016].

Most of the municipal solid wastes are disposed into land and water bodies without proper treatment, which produce severe water, land and air pollution. By adopting different eco-friendly waste to energy technologies, this severe lost to the environment can be reduced.Waste to energy generates energy and heat from a renewable fuel source, that eases dependency on fossil fuels and the combustion which is the chief contributor to greenhouse gas emissions [Chinwan and Pant, 2014].

2. Waste generation in India

India is a challenging rapid urbanization country with varying differences in climate, geography, ecology, social, culture and language. Population growth is a major factor to increase MSW in India [Kumar et al., 2018]. Generation of MSW in India is 0.136 million tonnes per day, out of these 0.111 million tonnes per day is collected, 0.026 million tonnes per day is treated and 0.073 million tonnes per day is landfilled [CPCB, 2016]. This shows that only 75-80% of the municipal waste gets collected and only 22-28% of this waste is processed and treated. Per captia waste generation rate in Indian cities ranges between 0.2 to 0.87

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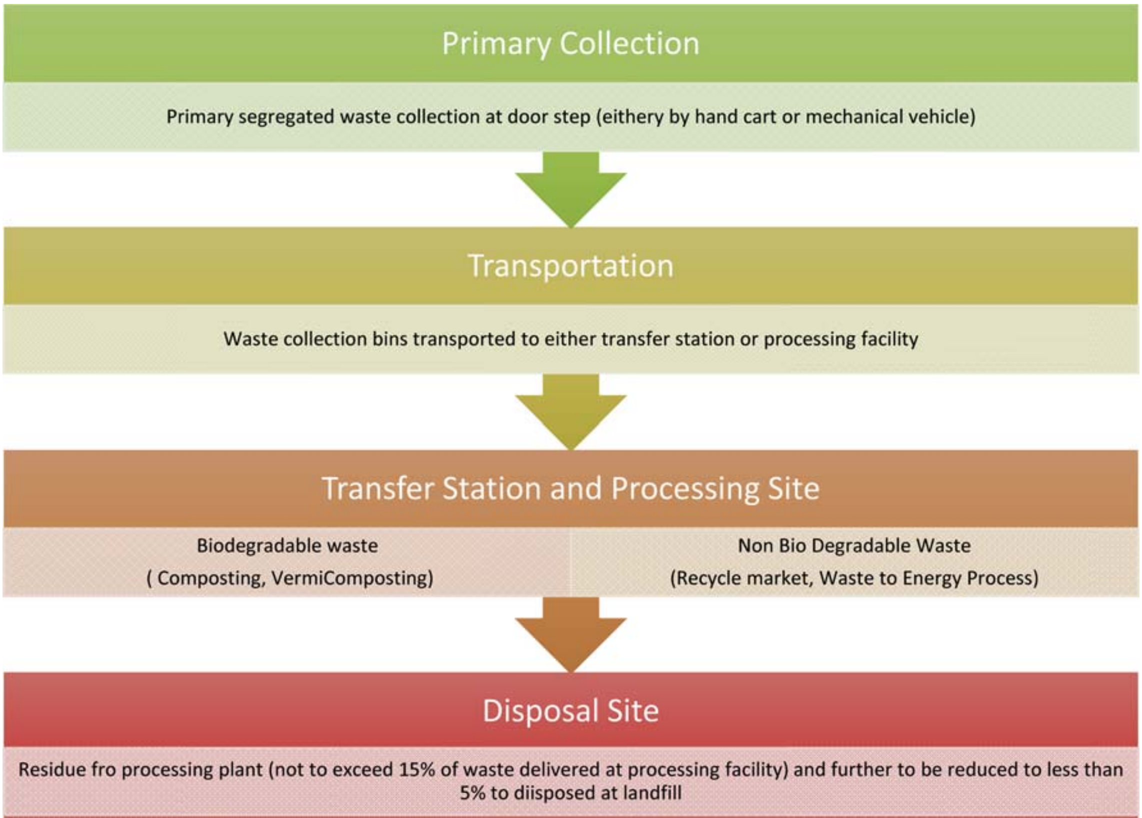

Figure 1. Municipal solid waste management chain [Source: MSWM rules, 2016]

Kg/d. The quantity of waste depends on living standards, food habits, commercial activity and population density [Bag et al., 2015; Joshi and Ahmed., 2016].It seems like, the scenario when earth converts into waste will come soon.

The categorization of MSW is indicated in the Table 1, based on their types and source of generation (i.e. residential, commercial, industrial, etc.). The composition of MSW generated in Indian cities is generally due to biodegrable portion i.e. 42.51% of the total MSW [CPCB, 2016]. Most of the biodegradable waste is coming from household activities [Jain et al., 2014; Kumar et al., 2018].

3. Waste to energy technologies

There are several waste to energy technologies available based on the type, quantity and characteristics of raw material, the required method of the energy, economic conditions, environmental standards and specific factors [Kalyani and Pandey, 2014].The most commonly used waste to energy technologies are thermal,bio-chemical and chemical technologies[Chinwan and pant, 2014; Moya et al., 2017]. Table 2 represents an overview of waste to energy technologies commonly used in worldwide.

3.1 Thermal technologies

Incineration, pyrolysis, gasification and refused derived fuel (RDF) are included in thermal technologies of waste. In this process, numerous byproducts are formed that can be referred to different energy generation and resource recovery techniques for treatment [Gupta et al., 2017].

3.1.1 Incineration

One of the most common waste treatment technology is incineration, in which waste mass is reduced by 70% and waste volume is reduced up to 90%. Incineration is suitable for high calorific value wastes. In this process, produced energy is converted in electricity generation[Cheng and Hu, 2010; Kalyani and Pandey, 2014; Gupta et al., 2017].

The whole process carried out in three phases i.e. incineration, energy recovery and control of air pollution. The whole process is illustrated in Figure 2. In the first phase (incineration process), waste is directly burned at 700-1000^{o}C in the combustion chamber by using flue gas and pre-heated air. Ultra-hot steam is produced after combustion of waste and this steam is used to create heat energy. Turbine is connected to generator which produces energy, heat and bottom ash. Bottom ash primarily contains of silicon, iron, calcium, aluminum, sodium and potassium.Heat and energy are recovered in second phase of incineration process. The biggest disadvantage of incineration process is the production of greenhouse gases. Thus, it is of prime concern to install emission control equipment to the incinerator, which is the third phase of incineration process [Kalyani and Pandey, 2014; Moya et al., 2017; Ouda et al., 2017].

Incineration technology of Indian MSW is not convenient as it contains high organic composition, moisture content or inert content (range 30-60% each) and low calorific value (range 800-1100 kcal/kg) [Joshi and Ahmed, 2016].Usually, in India small incinerators are used for burning of hospital waste. Still, a medium sized incinerator plant was installed to dispose of 300 tonnes of day-to-day waste at Delhi, India in 1987. However, the plant remained out of order currently, because non-availability of waste having required calorific value for incineration [Sharholy et al., 2008; Garg, 2012]. At present, there is no large-scale incinerator working in India.

3.1.2. Pyrolysis

Pyrolysis is the thermal waste method, uses heat at 300-800^{o}C to break down organic constituents in the anaerobic environment. It produces the syngas (methane, carbon dioxide, hydrocarbons, hydrogen and carbon mono-oxide), liquids and solids residues. The produced syngas can be

Table 1. Classification of MSW [Source: CPCB, 2016]

Component	Biodegradable	Paper	Plastics/Rubber	Metal	Glass	Inerts
Percentage by weight (%)	42.51	9.63	10.11	0.63	0.96	17.00

Table 2. Overview of various waste to energy technologies

Criteria	Waste to energy technology						
	Incineration	Pyrolysis	Gasification	Refuse derived fuel	Composting	Anaerobic digestion	References
Status of technology used	Widely used in developed countries	Mostly used in developed countries	Mostly used in developed countries	Widely used	Widely used	Widely used	[Gupta et al., 2017; Jayaprakash et al., 2018]
Types of solid waste	Unsorted waste	Specific type of recyclable plastic waste	Unsorted waste	Unsorted waste without hazardous and infectious waste	Sorted organic waste, high lignin material is acceptable	Sorted organic waste, animal or human excreta, less suitable for high lignin waste	[Chinwan and Pant, 2014; Jayaprakash et al., 2018]
Final products	Heat	Heat, pyrolysis oil	Heat, char	RDF	Compost/ humus product	Compost/humus product, low calorific RDF, heat	[Moya et al., 2017; Gupta et al., 2017]
Adverse impacts	Pollution from air emission toxic gases	High energy consumption, during operation, noise and air pollution	High energy consumption, during operation, noise and air pollution	Uncertain heating value	Odor and insect problem	Problem of leakage of methane gas	[Jain et al., 2014; Jayaprakash et al., 2018]
Air Pollution	High	High	Medium	High	Low	Low	[Planning Commission Report, 2014; CPCB, 2016]
Solid waste generation due to rejects	Low	Low	Low	Low	High	Low	[Planning Commission Report, 2014; CPCB, 2016]
Volume reduction of waste	75-90%	75-90%	75-90%	75-90%	15-30%	45-50%	[Planning Commission Report, 2014; CPCB, 2016]
Contribution to energy	Power generation from heat	Power generation, pyrolysis oil used as raw material	Power generation	Energy from RDF	None	Power generation from biogas	[Moya et al., 2017; CPCB, 2016]
Contribution to food	None	None, high contamination	None	None	Used as compost for cultivation	Used as compost for cultivation	[Planning Commission Report, 2014; Jayaprakash et al., 2018]

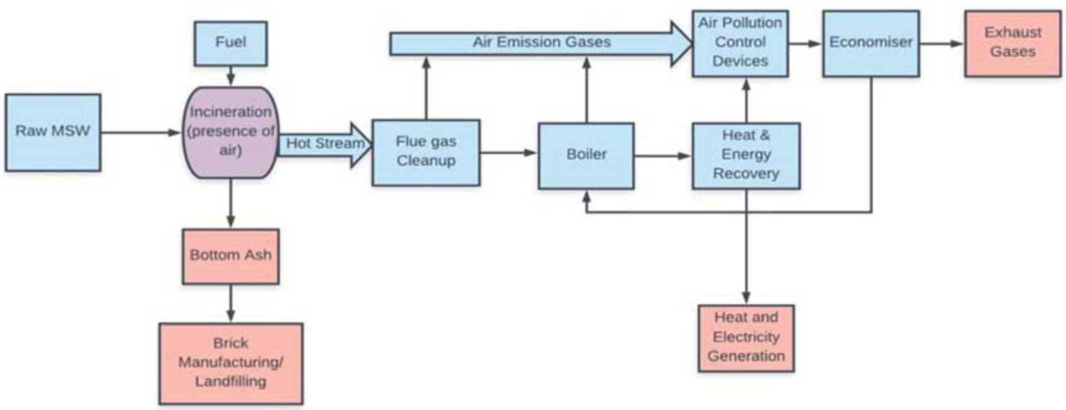

Figure 2. Incineration process to produce electricity and heat [Source: Kalyani and Pandey, 2014; Moya et al., 2017]

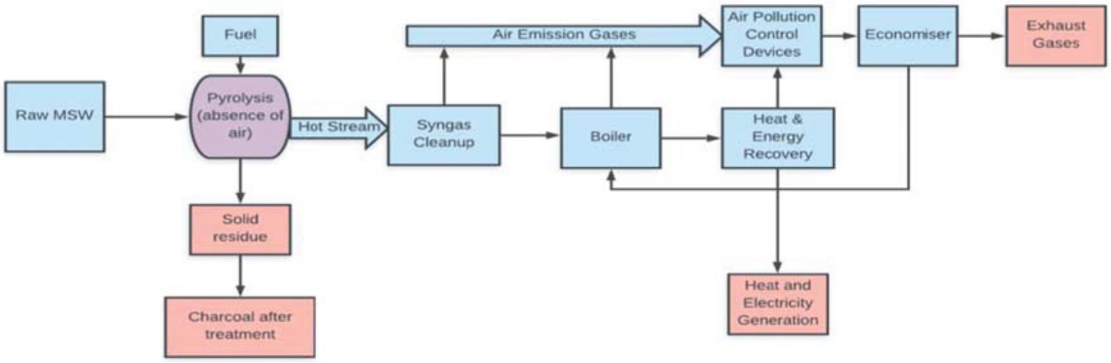

Figure 3. Pyrolysis process to produce energy and heat[Source: Jain et al., 2014; Moya et al., 2017]

utilized in different energy applications such as engines, boilers, turbines, heat pumps. Small temperature pyrolysis can also be used to generate a synthetic diesel fuel from plastic waste [Jain et al., 2014; Moya et al., 2017]. Currently there is no pyrolysis plant working in India [Sharholy et al., 2008; Garg, 2012].Figure 3 shows the pyrolysis process of MSW to produce energy.

3.1.3. Gasification

Gasification process contains partial combustion of waste to generate energy.This is accomplished by providing high temperature (>700^{o}C) with a limited amount of air (i.e. partial combustion).The final product of the gasification process are char, tar and syngas. Syngas is energy rich content and clean through gas turbine or engine to produce energy and heat. This process can reduce about 70% mass and 90% volume of waste [Elwan et al., 2013; Kalyani and Pandey, 2014;Moya et al., 2017].

Limited gasifiers were installed in India, mostly used to burn agro biomaterial. There are two different projects of gasifiers existing in India. First is NERIFIER gasifier installed at Nohar, Hanugarh, Rajasthan by Navreet Energy Research and Information (NERI). It is used to burn agrobiomass, sawmill dust and forest dust. Second is TERI gasifier installed at Gaul Pahari Campus, New Delhi by Tata Energy Research Institute (TERI) [Sharholy et al., 2008]. Figure 4 illustrates the gasification process.

3.1.4. Refuse-derived Fuel (RDF)

RDF technology stipulates safe and eco-friendly disposal of MSW. It is an alternating fuel which can be used in boilers in place of fossil fuels. The process of RDF generation is described in Figure 5. A few RDF plants were setup in India [Joshi and Ahmed, 2016; Shukla and Shrivastava, 2017], shown in Table 3. RDF pellets is frequently used for pulp, paper industry, wood industry waste and saw-mill industry [Ouda et al., 2017].

3.2. Biological technologies

Biological treatment of waste to energy is much more safe, economical and eco-friendly technologies as compared to the previous thermal technologies. In this composting, and anaerobic digestion methods are adopted in India generally [Chinwan and pant, 2014].

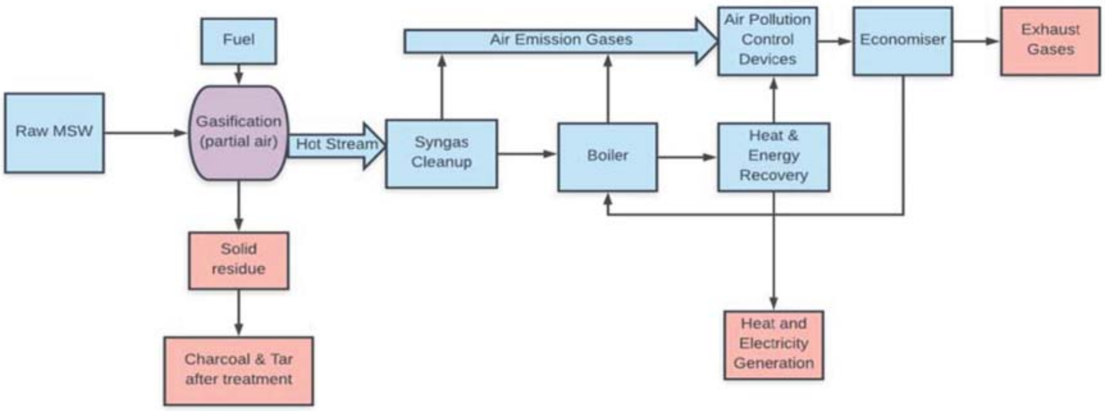

Figure 4. Gasification process to produce energy and heat[Source: Elwan et al., 2013; Kalyani and Pandey, 2014]

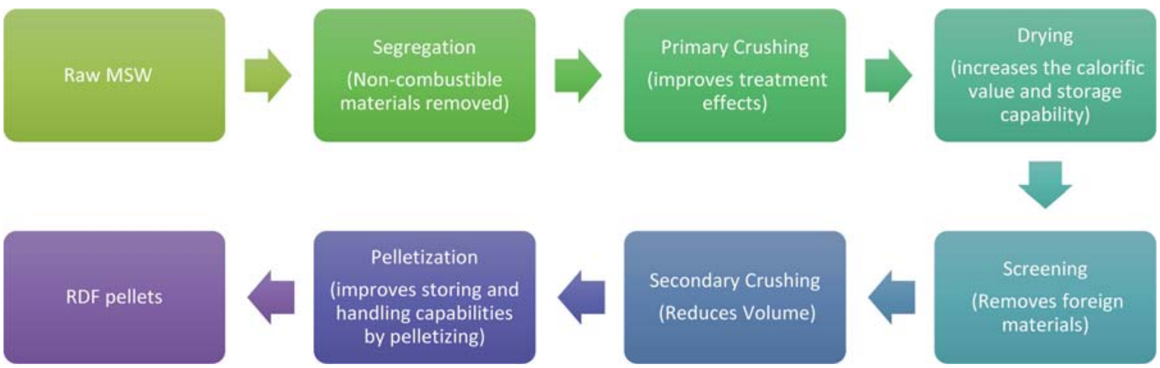

Figure 5. Refuse derived fuel process [Source: Shukla and Srivastava, 2017; Jain et al., 2014]

3.2.1 Composting

Composting method comprises decomposition of organic MSW by microorganisms under controlled aerobic conditions i.e. in the presence of air under humid and warm environment [Jayaprakash et al., 2018]. This method is divided into two different processes i.e. aerobic and anaerobic composting [Moya et al., 2017]. The end product of composting is rich in excessive nutrients called humus or compost. This compost solid product is used to fertilize crops [Jayaprakash et al., 2018]and combustible gas, mixture of carbon dioxide and methane called biogas, is used to produce heat and/or electric energy. [Moya et al., 2017].The composting process is illustrated in Figure 6.

3.2.2 Anaerobic digestion

Anaerobic digestion of waste is also signified as a biomethanation process. In this process, organic waste material is decomposed by microorganisms in the anaerobic environment. This reduces amount of wastes and produces biogas (carbon dioxide and methane) which is used to heat and electricity generation [Kalyani and Pandey, 2014; Tan et al., 2014; Joshi and Ahmed, 2016]. Anaerobic digestion process illustrates in Figure 7. Currently in India, many biomethanation plants are working to generate energy from vegetable and food waste, describes in Table 3.

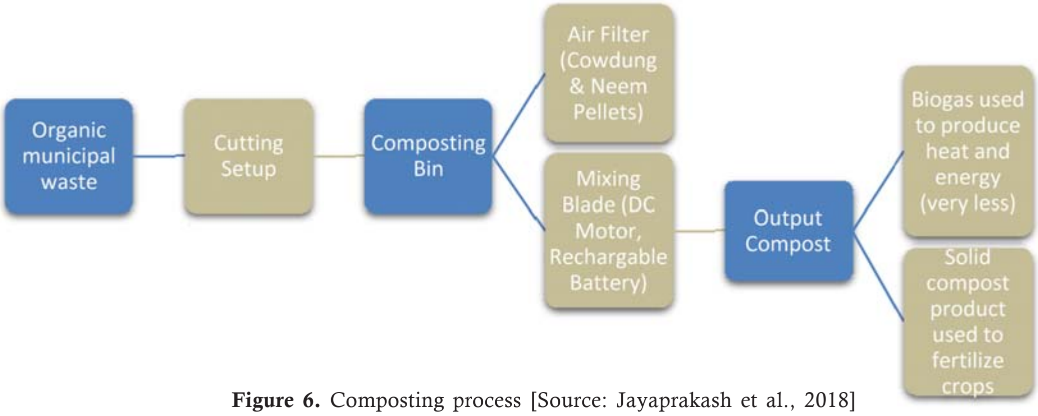

Figure 6. Composting process [Source: Jayaprakash et al., 2018]

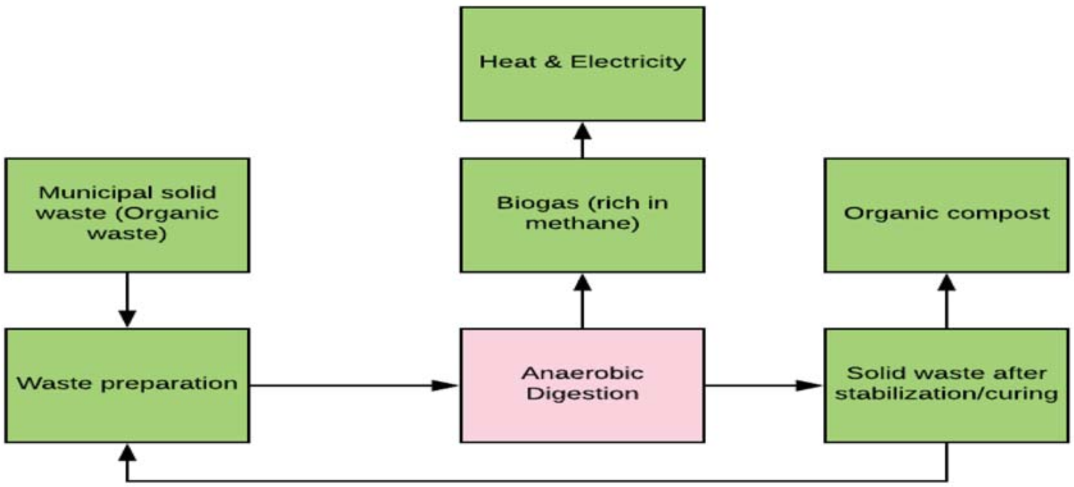

Figure 7. Anaerobic digestion process[Source: Tan et al., 2014; Joshi and Ahmed, 2016]

4. Waste to energy plants status in India

The present status of solid waste management in India is very poor. This is due to lack of using best and suitable techniques of waste collection, treatment and disposal [Kumar et al., 2018]. In the different cities of India, waste to energy methods has been long attempted but these has remained unsuccessful at the end [Kalyani and Pandey, 2014]. This may be cause because of various operational and design problems, lack of awareness, inadequate funding, unaccountability and inappropriate technical knowledge.

Table 3 shows treatment facilities of municipal solid waste available in different states in India. It includes composting plants 209 numbers, vermicomposting plants 207 numbers, biomethanation plants 82 numbers and refuse derived fuel plants 45 numbers under setup condition [CPCB, 2016]. There are five incineration/gasification plants with a cumulative installed capacity of 66.5 MW are currently working/under trial run state in India.Only one plant at Okhla, Delhi is in operational condition, another one at Ghazipur, Delhi is under commissioning and the remaining three projects are under trial run. It has also been shown that 53 numbers of waste to energy plants are under various stages of construction or tendering with a proposal to generate cumulative 405 MW[MNRE, 2018].

Further,the government of India is scheduling many waste to energy projects in different cities in the next years. There are total six projects are working on generation of electricity from municipal solid waste of installed capacity of 65.75 MW, listed in Table 4 [MNRE, 2018]. This may help in reduction the waste condition to a certain range. As a part of corporate social responsibility activity, government reorganized pyrolysis plants. Large scale companies like Hindustan Petroleum Corporation Limited (HPCL), Indian Oil Corporation Limited (IOCL) and Engineers India Limited (EIL) have already proposed tenders to set up pyrolysis plants. Also, the municipalities of Thane of Maharashtra and Chandigarh of Punjab had discussed the setting of pyrolysis plant [Sharma, 2017; Zafar, 2018].

Table 3. Waste to energy plants currently operational/under trial run [Source: CPCB, 2016; MNRE, 2018]

S.No.	States	Composting	Vermi-Composting	Bio-methanation	Refuse Derived Fuel	Incineration/ Gasification
1	Andaman Nicobar	-	-	-	-	-
2	Andhra Pradesh	-	18	8	-	-
3	Arunachal Pradesh	-	-	-	-	-
4	Assam	1	-	-	-	-
5	Bihar	-	-	-	-	-
6	Chandigarh	-	-	-	-	
7	Chhattisgarh	-	-	-	-	-
8	Daman Diu	-	-	-	-	-
9	Delhi	1	-	-	-	3
10	Goa	7	-	-	-	-
11	Gujarat	-	93	1	3	-
12	Haryana	4	-	-	4	-
13	Himachal Pradesh	-	-	-	-	-
14	Jammu & Kashmir	-	2	-	-	-
15	Jharkhand	-	-	-	-	-
16	Karnataka	104	57	27	4	-
17	Kerala	-	-	-	-	-
18	Lakshadweep	-	-	-	-	-
19	Madhya Pradesh	11	-	-	1	1
20	Maharashtra	43	31	42	5	1
21	Manipur	-	-	-	-	-
22	Meghalaya	1	1	-	-	-
23	Mizoram	-	-	-	-	-
24	Nagaland	-	-	-	-	-
25	Odisha	1	-	-	-	-
26	Pondicherry	-	-	-	-	-
27	Punjab	-	1	-	2	-
28	Rajasthan	-	-	-	-	-
29	Sikkim	-	-	-	-	-
30	Tamil Nadu	12	-	3	19	-
31	Telangana	10	3	1	3	-
33	Uttar Pradesh	13	-	-	4	-
34	Uttarakhand	-	-	-	-	-
35	West Bengal	-	-	-	-	-
	Total	209	207	82	45	5

Table 4. Electricity from municipal solid waste [Source: MNRE, 2018]

S.No.	State	Project/Under Trial	Installed Capacity (MW)
1.	Delhi	M/s Ramky Group, Narela-Bawana	24.0
2.	Delhi	M/s Jindal Urban Infrastructure Pvt Ltd., Okhla	16.0
3.	Delhi	M/s IL&FS Environment Infrastructure and Services Ltd., Ghazipur	12.0
4.	Madhya Pradesh	M/s Essel Infra at Jabalpur	9.0
5.	Maharashtra	M/s Solapur Bio-energy Systems Pvt. Ltd., Solapur	3.0
6	Himachal Pradesh	M/s Elephant Energy Private Ltd., Shimla	1.75

5. Conclusion

Waste to energy technologies provides safe and environmental friendly disposal of municipal solid waste. It creates electricity and heat along with resolves the problem of solid waste management.By the above study it has been shown that in India waste to energy methods has long tried but it has remained unsuccessful. It is due to lack of significant and logistic planning, incompetent financial funding, inappropriate technical attentiveness and improper resource management. There is a need to develop environmental awareness and change the manner of people regarding waste for sustainable waste management systems.Presently government and citizens of India are trying to take various actions regarding solid waste management and to generate energy from waste. Until these activities are met, India will remain to suffer from improper waste management and many health impacts to the people.

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