FINAL

"Selection Criteria for Waste Processing Technologies"

[In compliance with Hon'ble National Green Tribunal Order Dated 25th May & 1st August, 2016 in the Matter of OA No. 199 of 2014, Almitra H. Patel &Anr. Vs Union of India &Ors.]

CENTRAL POLLUTION CONTROL BOARD

(Ministry of Environment, Forests and Climate Change)
PARIVESH BHAWAN, EAST ARJUN NAGAR, SHAHDARA

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SELECTION CRITERIA OF WASTE PROCESSING TECHNOLOGIES

1.0 Introduction:

Selection of appropriate technology is one of the key considerations for success of a waste management system for a particular town/city besides taking consideration of other aspects like resource recovery, environmental soundness, financial support, involvement of stakeholders/ public and institutional capability.

Many waste processing technologies are available and in practice world-wide. However, efficiency of a particular technology depends upon the criteria for which it is designed and planned. The major criteria considered for selection of technologies are the waste quantity, waste characteristics, physical properties and composition of wastes, availability of land, social factors, capital investment, duration of treatment, products market, etc.

A wrong selection of waste processing technology can cause failure of the entire waste management system leading to bad economics and environmental cost.

2.0 SelectIon of Best Available Technology for Waste Processing

The available waste processing technologies can be broadly divided into two categories-

(1) Biological treatment and
(2) Thermal treatment.

The Biological treatment process is accomplished by allowing to micro-organisms to degrade waste components by creating conducive environment for growth of microbial organisms. In the biological process, the biodegradable organic portion of waste is broken down into gaseous products (CO_2, Methane gas, etc) and water molecules leaving behind carbon rich byproduct called compost. The biological activities depend upon several criteria- C/N ration, pH value, moisture content, supply of oxygen, etc. Biological processes for waste treatment can be further divided into two categories-

(a) Aerobic treatment (in presence of Oxygen) and

(b) Anaerobic treatment (absence of Oxygen).

The thermal process of treatment is applied to destroy the harmful potential of wastes together with energy recovery. In this process, the waste components are incinerated in controlled oxygen supply so that maximum heat energy can be recovered without causing the air pollution. During incineration, the waste undergoes chemical changes to release gaseous byproduct, water vapour along with heat energy. The heat energy can be utilized for generating electricity through boiler. The efficiency of heat recovery depends upon the calorific value of incinerated waste.

Details of the available technologies are discussed below;

2.1 Aerobic Composting

Composting is the process of aerobic decomposition of biodegradable organic matter in a warm, moist environment by the action of bacteria, yeasts, fungi and other organisms. MSW in India has an initial C/N ratio of around 30:1, ideal for decomposition. The organisms involved in stabilization of organic matter utilize about 30 parts of carbon for each part of nitrogen. Compositing requires approx 25 m^2 area per ton of MSW (only for windrow formation for 21 days composting and maturity yard for 30 days stabilization). The additional area required is for machinery, packing and storage. Facilities also required for recycling and treatment of effluent (leachate) and sanitary landfill for rejects (inert materials, sludge from ETP). The compost products should comply with the standards prescribed in the SWM Rules, 2016.

2.2 Vermi -composting

Vermi compost is the end-product of the breakdown of organic matter by particular species of earthworm. Vermi compost is a nutrient-rich, natural fertilizer and soil conditioner, cultured on a specially made vermi-bed. The earthworm species most often used are Eudrillus eugineae, Eisenia foetida or Lumbricus rubellus. It can treat any organic waste, not appreciably oily, spicy, salty or hard and that do not have excessive acidity and alkalinity. The C/N ratio preferred is 30:1 where, carbon matter comes from brown matter (wood products, saw dust, paper etc) and nitrogen from green matter (food scraps, leaves etc). Overabundance of greens generates ammonia. The moisture content of 40-55% is preferable and maintained by covering the tank with wet sack and sprinkle water as required. Vermi-compositing can be done in tank with size of 4m x 1m x 0.5m for waste input of 10kg/day of semi decomposed waste.

2.3 Biomethanation /Bio-waste Derived Fuel

It is a process based on anaerobic digestion of organic matter in which microorganisms break down biodegradable material in the absence of oxygen. The process is widely used to treat wastewater sludge and organic wastes because it provides volume and mass reduction of the input material. It produces methane and carbon dioxide rich biogas suitable for energy production and hence, is a renewable energy source. The nutrient-rich solids left after digestion can be used as a fertilizer. It generally treats Sorted organic fraction only (highly putrescible) for better gas yield. Fibrous organic matter is undesirable as the anaerobic microorganisms do not easily break down woody molecules such as lignin, cellulose, hemicelluloses, etc.. Preferred C/N ratio is 25-30. Moisture content should be >50% which implies on feed, gas production, system type, system efficiency. Area requirement for bio-methanation is approximately 25 m^2

per tonne of MSW. Extra area required for machinery, gas containing and storage facilities.

2.4 Incineration

The incineration of MSW involves combustion of waste leading to volume reduction (90-95%) and recovery of heat to produce steam that in turn produces power through steam turbines (Bhide and Sunderesan 1983). Basically, it is a furnace for burning waste and converts MSW into ash, gaseous and particulate emissions and heat energy. The efficiency of the technology is linked to the waste characteristics and their properties such as moisture content and calorific values. It requires high temperature of the order of 800-1000^{o}C and sufficient air and mixing of gas stream. The minimum temperature for burning carbonaceous wastes to avoid release of smoke and prevent emissions of dioxin and furans is 850^{o}C. Depending on the nature of wastes and the operating characteristics of combustion reactor, the gaseous products derived from the combustion of MSW may include carbon dioxide (CO_2), water (H_2O, flue gas), oxygen (O_2), nitrogen oxides (NOx), sulphur dioxide (SO_2) and small. Minimum Moisture content should be <45%. Calorific value should be as high as possible; >1500 kcal/kg. Incineration of chlorinated plastic should be avoided as far as possible. The emission standards are prescribed in SWM Rules, 2016.

2.5 **Plasma pyrolysis**

Plasma pyrolysis or plasma gasification is a waste treatment technology that gasifies matter in an oxygen-starved environment to decompose waste material into its basic molecular structure. The process demands high electrical energy for creating high temperature by an electrical arc gasifier. It does not combust the waste as incinerators do. In a plasma converter, the arc breaks down waste primarily into elemental gas and solid waste (slag). The objective of the process is to generate net electricity, depending upon composition input wastes, and to reduce the volumes of waste being sent to landfill sites. Relatively high voltage, high current electricity is passed between two electrodes, spaced apart, creating an electrical arc where temperatures as high as 13,871°C is reached. The temperature from one meter arc can reach up to ~4000°C. At these temperatures most types of waste are broken into basic elemental components in a gaseous form, and complex molecules are atomized - separated into individual atoms. Depending on the input waste (plastics tend to be high in hydrogen and carbon), gas from the plasma containment can be removed as Syngas, and may be refined into various fuels at a later stage. There has been issues of plasma systems regarding high temperatures requirement and short life of liners which are highly susceptible to both chlorine attack and to local variability in such high temperatures, not likely to last more than a year in service.

2.6 Pelletization /Production of Refuse Derived Fuel (RDF)

It is basically a processing method for mixed MSW, which can be very effective in preparing an enriched fuel feed for thermal processes like incineration or for use in industrial furnaces. It is a fuel produced by shredding municipal solid waste (MSW) and steam treatment for reducing moisture content. RDF consists largely of organic components of municipal waste such as plastics and biodegradable waste, which are compressed into pellets, bricks, or logs. Non-combustible materials such as glass and metals are removed during the treatment process with an air blow or other mechanical separation processing. The MSW collected for disposal is tested for its moisture content and when the moisture content is more than 35- 40%, it requires drying to produce fuel pellets with reasonable calorific/heating values. The reduction in moisture can be done artificially or by natural sun drying. The sun dried garbage is then uniformly fed into a rotary drying system i.e. Hot Air Generation burning oversize garbage or other fuel to further bring down the moisture level to about 10-12%. RDF is an alternative to WTE and is a potential waste management technology

3.0 Criteria for selection of Waste Processing Technology

For planning and designing of a waste management plan, some preliminary survey is required to be obtained from the city/town and accordingly selection of waste processing technologies can be done for the city/town. In case of waste quantity is found less than requirement, a regional plan may be prepared for clusters of towns to achieve the desired quantity of waste. In case of excessive generation of waste, the waste can be reduced by adopting decentralized treatment process (vermin-composting/Biogas) in pockets – within garden premises, large residential complex, etc. However, Integrated waste processing plants are capable of processing both organic and incinerable wastes.

The primary criteria for selection of waste processing technologies are as under;

1. Quantity of waste generation
2. Characteristics of waste (Physical and chemical property)
3. Based on land availability **(Annexure-I)**
4. Prevailing environmental conditions
5. Climatic condition and terrain
6. Social acceptance
7. Market for the products
8. Capital investment
9. Siting criteria
10. Environmental norms

The quantity of waste generation plays vital role in selection of waste processing technologies. Vermi-composting and Biogas plants are capable of handling effectively up to 30 Tonne/per day and suitable for small towns. Aerobic composting plants are found operational up to 500 Tonnes/day. The waste-to-Energy plants are found cost-effective for processing waste 500 Tonnes/day and above. The indicative land requirements for different composting technologies are given at **Annexure-I**.

Waste characteristics such as C/N ratio, moisture content, calorific value, etc. indicate the treatment technology to be adopted. The desirable C/N ratio for composting is 30:1 with moisture content 50-60%.; otherwise, the these parameters are maintained by addition of some selected wastes. The desirable calorific value of waste considered for incineration should not be less than 1500 Kcal/kg (SWM Rules, 2016). The desired calorific value of waste can be achieved practicing effective segregation of wastes. However, multiple technologies can be selected for a city for processing solid wastes in an integrated way depending upon the quantity and characteristics of wastes as under (Table-1);.

Table-1: Options for Integrated Technologies as per waste quantity generation

Sno.	Population range	Waste Gen.TPD	Composition	Technological options
1	Above 2 Million	>1100 TPD	Biodegradables 35 to 50 %	IWP comprising -BM +CC+ RDF. W to E plant for power, based on: gasification, pyrolysis, incineration and mass burning. RDF to cement industry Plastic to fuel oil
2	1 M to 2 Million	550 to 1100 TPD	Biodegradables 40 to 55 %	IWP comprising -BM +CC+ RDF. W to E plant for power, where wastes exceeds 500 TPD based on: gasification , pyrolysis, incineration and mass burning. RDF to cement industry Plastic to fuel oil
3	1 Lakh to 10 Lakh	30 to 550 TPD	Biodegradables 40 to 55 %	IWP-BM, CC + RDF as feed stock to power plant / cement industry. Plastic to fuel oil
4	50,000 to 1 Lakh	10 to 30 TPD	Biodegradables 45 to 60 %	BM, VC or CC RDF
5	Less than 50,000	Less than 10	Biodegradables 45 to 65 %	BM,VC / CC and RDF
6	Hill towns	State capitals	Biodegradables 30 to 50 %	BM, CC / RDF as feed stock. Plastic to fuel oil

*IWP- Integrated Waste Plant, BM- Biomethanation, VC- Vermi compositing,CC- Chemical Conversion, RDF-Refused Drive Fuel

From the above table, cities having population 1 lakh to above 2 million can adopt the most common technology to treat waste 500TPD to above 1100 TPD in an Integrated way comprising waste treatment plants of Biomethanation, Chemical Conversion and Refused Drive Fuel. For treating the waste the composition of biodegradable waste should be varies from 30 to 60 % depending upon the generation of waste and the technologies those are in practice. For population less than 50,000 technologies like vermin-compositing and biomethanation can be used as they are more effective. The Hilly areas having land crisis, the technologies like biomethanation, vessel composting, static pile composting, RDF, etc. can be used. The desired characteristics of waste for various technologies are given at **Table-3 (Annexure-II).**

4.0 Key Criteria For Solid waste Incineration

MSW incineration projects are appropriate only if the following overall criteria are fulfilled:

- A mature and well-functioning waste management system has been in place for a number of years.
- Incineration is especially relevant for the dry bin content in a 2-bin system . For unsegregated waste, pre-treatment is necessary.
- The lower calorific value (LCV) of waste must be at least 1450 kcal/kg (6MJ/kg) throughout all seasons. The annual average LCV must not be less than 1700 kcal/kg (7 MJ/ kg) .
- The furnace must be designed in line with best available technologies to ensure stable and continuous operation and complete burn out of the waste and flue gases.
- The supply of combustible waste should be stable and amount to at least 500 tonnes/ day.
- Produced electricity and/ or stream can be sold at a sustainable basis (e.g. feeding into the general grid at adequate tariffs). It is possible to absorb the increased treatment cost through management charges, tipping fees
- Skilled staff can be recruited and maintained.

- Since the capital investment is very high, the planning framework of the community should be stable enough to allow a planning horizon of 25 years or more.
- Pre-feasibility study for the technology led to positive conclusions for the respective community.
- Strict monitoring systems are proposed and monitored.

5.0 Key Considerations for operation of Incinerators

Incineration of municipal solid waste should meet with the following criteria:

- Minimum gas phase combustion temperature of 850 °C and a minimum residence time of the flue-gases, of two seconds after the last incineration air supply.
- Optimum oxygen content (~lower than 6%) should be maintained in order to minimize corrosion and ensure complete combustion. The carbon monoxide content of the flue gas is a key indicator of the quality of combustion
- Fly ash acts as a catalyst for de-novo synthesis (at 200-450°C) of dioxins and furans. In order to reduce formation of dioxins and furans, it is imperative that maximum fly ash is removed before gases cool down to 200-450°C.
- The flue gases produced in the boilers should be treated by an elaborate flue gas treatment system.

6.0 Waste to Energy Initiatives:

The Ministry of New & Renewable Energy (MNRE) granted 5 waste to-Energy projects under their programme on energy recovery from municipal waste. Waste-to-Energy plants are intended to comply with international emission standards. Details of the 5 plants supported by MNRE are given below:

Delhi: Timarpur-Okhla Waste Management Co Pvt Ltd: an initiative of M/s Jindal ITF Ecopolis. The incineration plant was commissioned in January 2012 and is processing 2000 tons per day (TPD) for generating power of 16 MW.

Delhi, Ghazipur: out of the 2,000 TPD of waste received at the landfill site daily, the facility is processing 1,300 TPD to generate 750 TPD of RDF and 12 MW power. The project is under trial run with effect from March 2016. The operator is M/s ILFS on PPP mode.

Bangalore: BBMP has initiated installation of 8 MW power plant in Bangalore for processing 1000 TPD of waste. M/s Srinivasa Gayithri Resources Recovery Ltd is operator on PPP mode. The project is under installtion.

Pune: A 10 MW gasification plant is being set up in Pune with funds from MNRE. The plant will need 700 TPD of waste for production of 10 MW of electricity.

Hyderabad: 11 MW power plant, which will utilize 1,000 TPD of MSW, is being installed in the Nalagonda district. The plant will produce RDF for in-house incineration and power generation. The plant is currently under construction.

In general, three different designs can be distinguished. The nomenclature comes from the flow direction of the flue-gases in relation to the waste flow: unidirectional current; counter-current and medium current/centre flow furnace. The centre flow furnace is most ideal for mixed MSW which is highly variable in quality. A good mixture of all partial fluegas currents must be considered through mixture-promoting contours and/or secondary air injections.

References:

(i) Report of the Taskforce on Waste to Energy (Vol-I), Planning Commission , May, 2014
(ii) Manual on Solid Waste Management and Handling, Ministry of Urban Development (2000)
(iii) Solid Waste Management Rules, 2016

Annexure-I

Table-2: Indicative Land Requirements for Different Composting Technologies

Parameters	Windrow	Static	In-vessel	Vermicomposting
General	Simple Technology	Effective for farm and municipal use	Large- scale systems for Commercial applications	Suitable for quantities less than 50 TPD generation of mixed MSW
Amount of waste treated	1 ton-500 tons per Module	1 ton-500 tons per module	1 ton-300 tons per module	1 ton- 50 tons
Land Requirement	8 ha – 500 TPD	5 ha - 500 TPD (Less land required given faster rates and effective pile volumes)	4 ha - 500 TPD (Very limited land due to rapid rates and continuous operations)	2 ha: 50 TPD
Time	8 weeks	5 weeks	3 weeks (3-5 days in vessel; 3 weeks to mature)	8 weeks
Ambient Temperature	Not temperature sensitive	Not temperature sensitive	Not temperature sensitive	Temperature sensitive (30-40°C ideal range; 35-37°C specific to particular earthworm sp.)
Energy Input	Moderate	Moderate (2-3 hours aeration)	High	Low
Financial Implications	Moderate	Costly	Very Costly	Moderate. Purchase of exotic Earthworms suitable for MSW composting are expensive
Odour/ Aesthetic Issues	Odour is an issue if turning is inadequate	Moderate. Odour can occur but controls can be used such as pile insulation and filters on air system	Minimum. Odour can occur due to equipment failure or system design failure	None

(Source: Manual of MSW, May 2014)

Annexure-II

Table-3: SPECIFICATIONS FOR VARIOUS TYPE OF WASTE PROCESSING TECHNOLOGIES

S.No.	Method	MSW characteristics	C/N ratio	pH Control	Temperature required	Moisture Content
1	**Compositing**	Sorted organic fraction of MSW, preferable with same rate of decomposition	Between 25 – 50 initially. Release of ammonia and impeding of biological activity at lower ratios	7 – 7.5 (optimum). Not above 8.5 to minimize nitrogen loss in the form of ammonia gas	50-55°C for first few days and 55-60°C for the reminder composting period. Biological activity reduces significantly at higher temperature	55% (optimum)
2	**Incineration**	MSW with calorific value as high as possible; Volatile matter >40%; Fixed carbon <15%; Total inert <35%	Calorific Value-As high as possible; >1200 kcal/kg	_	850°C to 1400°C	As minimum as possible; <45%
4	**Pyrolysis**	_	_	6.5-8.5 (optimum)	elevated temperatures 700°C-900°C	_
5	**Gasification**	_	_	_	Temperature greater than 1000°C	_
6	**Biomethanation**	Sorted organic fraction only; Higher the putrescibility, better is the gas yield; Fibrous organic matter is undesirable as the anaerobic microorganisms do not break down woody molecules such as lignin	25-30 (preferable)	Acidogenic bacteria through the production of acids reduce the pH of the tank. Methanogenic bacteria operates in a stable pH range and temperature	Mesophilic bacteria act optimally around 37°-41°C or at ambient temperatures between 20°-45°C. Thermophilic bacteria act optimally around 50°-52° and at elevated temperatures up to 70°C. Mesophiles are more tolerant to changes in environmental conditions and hence more stable, but thermophiles act faster.	>50%; Implications on feed, gas production, system type, system efficiency

	Vermi composting	Any organic waste which are not appreciably oily, spicy, salty or hard and that do not have excessive acidity and alkalinity	30:1 (preferred). Brown matter (wood products, saw dust, paper etc) is rich in carbon and green matter (food scraps, leaves etc) in nitrogen.	Slightly alkaline state preferable. Correction by adding small dose of calcium carbonate	20 – 30oC	40-55% preferable; cover the tank with wet sack and sprinkle water as required