Screening Model for Evaluation of MSW Treatment Technologies with Special Context to Indian Conditions

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Abstract

The Municipal Solid Waste (MSW) management is one of the major challenges for cities and towns of India. As per the 2018-19 data, daily MSW generation of Urban India is around 152,000 metric tons or approximately 55 million metric tons annually. It is the responsibility of the municipal corporations and Urban Local Bodies (ULBs) of the concerned cities to provide proper Municipal Solid Waste (MSW) processing and disposal facilities. However, in most of the cities, Municipal Solid Wastes are not treated properly in an integrated manner, while claim being made to utilize its energy and material.

In this paper, an effort has been made to formulate screening criteria for the MSW treatment technologies. This will provide a foundation to develop the way to manage and treat solid waste while giving importance to environmental sustainability, economics, regulatory compliance and costs associated with MSW treatment and its management. Since the government of India has come up with Swachh Bharat Mission (SBM) in 2015 with municipal solid waste management as one of its components and many states have adopted the MSW treatment technologies by implementing SBM. This paper will act as a toolkit for ULBs to select the MSW treatment technologies.

Keyword: Municipal Solid Waste, Screening, Sustainability, MSW Treatment

1. INTRODUCTION

Current pace of urbanization, industrialization, consumerist societies and waste generation pose formidable challenges to global sustainability in many ways. With the unplanned urbanizations and rapid growth of middle-class families with changing lifestyles, most of the Asian countries are facing the mammoth challenge of managing urban waste. There is no reliable national-level data on the technical or financial aspects of waste management in India. Therefore, in the present paper, fair approximations are made for different figures.

The scale of the problem however is fairly clear. Indian urban areas generate around 152,000 metric tons of MSW daily as per the Central Pollution Control Board (CPCB) annual report 2018-19. This volume is likely to be doubled by 2030, which may double further by 2040. The scale will be perhaps more comprehensible at the level of the individual city. Mumbai today generates about 11,000 tons per day (TPD)[†] and Delhi generates about 8700 TPD (CPCB, 2015-16). These figures clearly indicate that the growth of MSW in our urban centers has outpaced the ongoing population growth of the recent years.

Different waste treatment options are available in the current time with various levels of problem solving and resource recovery facilities. All of the waste management technologies have some benefits and limitations while applied in the field conditions. There is no single treatment technology available that can solve the waste management problem comprehensively. Therefore, it is important to integrate different waste management technologies in a strategic manner to achieve the sustainable waste management objectives (Schunke 1999).

It is difficult to select a particular technology for sustainable waste management decision or policy making processes without knowing the pros and cons of different technologies along with their impacts on the environment (Task Force Report on Waste to Energy (WtE), of Planning Commission-2014). Due to lack of available information on impacts from technology, sometimes wrong decision may be taken that might pose adverse and critical situation in the future. Therefore, it's important to know the different energy efficient and viable technologies through comparative study for different options that could be a guiding tool for decision making processes.

Considering the above facts, the present study proposes a model for screening and evaluation of various MSW treatment technologies in Indian conditions. The same can be used for selection of possible integrated treatment options. This paper describes a model considering multiple criteria to be developed and evaluate alternative waste treatment technologies for the treatment of municipal solid waste. The evaluation is based on Indian legal requirements, while covering technical, environmental and cost considerations.

2. CHOICE OF TECHNOLOGY

In order to assess various options of Municipal Solid Waste (MSW) treatment technologies, the project team collected relevant information from available sources, both through review of literature, discussions and field observations. Waste processing technologies based on waste qualities can be broadly divided into three categories mentioned in Table 1.

- Thermal Technologies
- Biological/ Chemical Technologies
- Physical Technologies

[†] Mumbai generates about 8500TPD – NEERI Report 2015.

Table 1: Identified MSW Treatment Technologies

Sr. No	Technology	Details
1.	Thermal Processing Technologies	<ul style="list-style-type: none"> ➤ Incineration (Mass Burn) ➤ Pyrolysis ➤ Gasification Plasma Arc Thermal Treatment
2.	Biological Processing Technologies	<ul style="list-style-type: none"> ➤ Composting <ul style="list-style-type: none"> • Vermi -composting • Windrow Composting • Static Aerated Pile Composting • In Vessel Composting ➤ Bio methanation ➤ Bioreactor Landfill
3.	Physical Processing Technologies	<ul style="list-style-type: none"> ➤ Pelletisation ➤ Refuse Derived Fuel (RDF)

2.1 Thermal Processing Technologies

2.1.1 Incineration:

This method, commonly used in developed countries, which is the most suitable for the MSW having high calorific value with a large component of paper, plastic, packaging material, pathological wastes, etc. It can reduce waste volumes by over 90 per cent and convert waste to innocuous material, with energy recovery. The method is relatively hygienic, noiseless, and odorless, and land requirements are minimal. The plant can be located within municipal city limits, reducing the cost of waste transportation with the provision of reduction for air pollutants.

2.1.2 Pyrolysis/ Gasification/ Plasma Arc:

Pyrolysis and gasification processes are established for homogenous organic matter like wood, pulp, etc., while plasma pyrolysis vitrification is a relatively new technology for disposal of particularly hazardous wastes, radioactive wastes, etc. Toxic materials get encapsulated in vitreous mass, which is relatively much safer to handle than incinerator/ gasifier ash. In all these processes, besides net energy recovery, proper destruction of the waste is also ensured. These processes, therefore, have an edge over incineration.

2.2 Biological Processing Technologies

2.2.1 Composting:

Composting is the decomposition of organic matter by microorganism in warm, moist, aerobic and anaerobic environment. Composting of MSW is the most simple and cost effective technology for treating the organic fraction of MSW. Waste is built up to rotting windrows which are either self aerated or the air is passed through the windrows (in order to supply a sufficient oxygen demand for the aerobic degradation processes). The aim is

to reduce the volume as much as possible as well as the contamination through leachate and gaseous emissions, if any.

2.2.2 *Biomethanation:*

Anaerobic digestion is one of the favorable organic waste management options which have higher resource recovery potentials. Biological process of the anaerobic digestion is taking place in the absence of oxygen with the help of microbes. Its application to the organic fraction of MSW is more recent and less extensive. It leads to bio-gas/ power generation in addition to production of compost (residual sludge). This method provides a value addition to the aerobic (composting) process and also offers certain other clear advantages over composting in terms of energy production/ consumption, compost quality and net environmental gains. This method is suitable for kitchen wastes and, other putrescible wastes, which may be too wet and lacking in structure for aerobic composting.

2.2.3 *Bioreactor Landfill:*

"Bioreactor landfill" allows active landfill management based on an understanding of the biological, chemical and physical processes involved. It focuses on enhancing the degradation processes to stabilize the waste and aims to bring forward the inert state of a landfill in a relatively short time. The process basically utilizes a landfill as a bioreactor to process and stabilize the waste rather than merely as a solid waste dumping ground.

2.3 **Physical Processing Technologies**

2.3.1 *Palletization/ Refuse Derived Fuel:*

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 industrial furnaces. As palletization involves significant MSW sorting operations, it provides a greater opportunity to remove environmentally harmful materials from the incoming waste prior to combustion. The process, however, is energy intensive and not suitable for wet MSW during rainy season.

3. **METHODOLOGY FOR SCREENING AND EVALUATION CRITERIA**

Different technologies have been tried in different parts of the country at different points of time and in different scale of operation. Some of them have failed outright whereas some had limited success on overall techno-economic parameters including marketing and product pricing (Sharholy et.al. 2008). Therefore, it is necessary to have an effective screening mechanism considering suitable criteria to find out the best suited technology/ system which should be techno-economically viable solution.

After the review of various available national and international documents pertaining to MSW treatment and best practices in municipal solid waste management and by exploring the concept of sustainable provision of this basic service, a framework (evaluation model) has been developed (Table 2). This framework is based on the study objectives and the available background information on performance of the various technologies actually installed and operated for processing municipal solid waste, especially in India.

Table 2: Evaluation Criteria for Screening of Technologies

Sr. No.	Evaluation Criteria	Parameters
I	Basic Requirements	<ul style="list-style-type: none"> • Modularity • Scalability • Upgradability • Flexibility in operation/ Ease of Operation
II	Primary Screening	<ul style="list-style-type: none"> • Techno-economic viability for the given waste material • Compliance with applicable laws including environmental and health (EHS) compliances • Long term sustainability • Reliability under expected variations • Quantum of process rejects, extent of landfill diversion and total land requirement for the project • Social acceptability and public perception
III	Secondary Screening	<ul style="list-style-type: none"> • User friendly (operator friendly) • Skill set requirement (technical, financial, managerial)
IV	Commercial Evaluation	<ul style="list-style-type: none"> • Capital Cost • O & M cost/ Energy cost/ labor(manpower) cost/ land cost/ payback tariffs

3.1 Basic Requirements

Before screening of various technologies, the basic requirements such as modularity, scalability, flexibility in operation, upgradeability should be fulfilled.

3.1.1 Modularity:

In systems engineering, modular design - or "modularity in design" — is an approach that sub-divides a system into smaller parts (modules) that can be independently created and then used in different systems to drive multiple functionalities. Modular design is an attempt to combine the advantages of standardization (high volume normally equals low manufacturing costs) with those of customization.

It would not be prudent to design the facility for the maximum expected waste; modular plants are a logical solution because as the population and the waste quantity increases modular units can be added without disturbing the system at periodical interval of 8-10 years.

3.1.2 Scalability:

It is the property of a system, by which it can accommodate changes in transaction volume without making major changes to the system within a certain scale. The treatment facility/ facilities located at one or different

sites may not receive constant quality and quantity of the waste everyday throughout the year. The quantity and quality coming for processing may vary with change in population and development of cities. Therefore, it would be desirable that the technology (ies) should be flexible enough to handle the variations with minimum alterations in the plant/ system for limited quantity of the waste.

3.1.3 Flexibility:

It is the ability of a system to respond to potential internal or external changes that affects its functioning in a timely and cost-effective manner. Technology should adapt itself, when external changes occur (variation in waste quantity or quality, climatic changes etc.). While assessing various treatment technologies, flexibility requirements should be taken into consideration like machine, material handling, operation, process, volume, expansion, production, market flexibility etc.

3.1.4 Upgradeability:

The term 'upgrade' refers to the replacement of a product with a newer version of the same product that may handle higher capacity. Required improvement in a particular technology may be brought about by adding or replacing certain component(s) to achieve the desired result. The technology should be able to adopt the changes made in the system to improve product quality and its value, effectiveness of the process and performance of the system.

3.2 Technological Evaluation

3.2.1 Primary Screening

The primary screening of the considered technologies are based on a set of crucial issues and performance indicators as mentioned in the Table No. 2, which allow technologies to be assessed for suitability under the given circumstances.

a. Techno-economic viability: It is important to assess the suitability of technology to properly address the issue of its relevance to local conditions, including waste characterization, and operational capacity. For the purpose, it is crucial to evaluate the techno-economic viability that should include technical viability, capital investment, operation and maintenance cost, possibility of accrual from carbon revenue etc.

Apart from technical viability, financial viability is very important for overall techno-economic viability without which a project cannot be sustainable for a long term, especially if Private Sector Participation (PSP) is considered. The following components need to be included:

- Capital investment on civil structure and provision of other infrastructure facilities
- Capital investment on plant and equipment purchase including foreign exchange requirement for import, if any.
- Capital investment on vehicle and mobile equipment required for material movement.
- Cost of regular operation and maintenance of the facility (fixed and variable costs, which include interest on capital, depreciation, manpower, establishment and utility cost etc.)

- Major repair/ replacement of plant and equipment at the end of every 8-10 years
 - Revenue accrual through sale of various recycled/ recovered products (such as compost, biogas, power, RDF etc.)
 - Market risks in terms of product sale.
 - Revenue accrual prospects through sale of CERs.
 - Leakage through use of fossil fuel with respect to calculation of carbon revenue.
 - Market risks in terms of carbon revenue.
- b. Compliance with applicable laws including environmental and health (EHS) compliances:** The applicable rule for municipal solid waste management is Solid Wastes Management Rules, 2016, in short SWM Rule 2016. This rule stipulates various waste processing technologies like composting, incineration, refuse derived fuel (RDF), energy recovery or any other process approved by CPCB. It is recommended that the selected technologies should meet the compliance criteria prescribed under SWM rules 2016.
- c. Long term sustainability:** Long term sustainability of any project is important for justifying investment, be it from the public or private sector. For a service sector like municipal solid waste management, self-sustenance of the project is extremely important for the public health and the environment. Long term sustainability of municipal solid waste management project can be achieved by the following:
- Extent of product recovery
 - Product quality
 - Market prospects of the products and byproducts
 - Investment vs. revenue accrual
- d. Reliability under expected variations:** The reliability pertaining to SWM treatment system is its ability to absorb expected variations with reasonable process efficiency. Reliability of technology is ascertained by collecting data on failures and successes, for operating units in India. For setting reliability, the technologies will be graded for each of the key aspect under three categories viz., Proven, Yet to be proven and Unproven.
- This categorization will lead to benchmark the performance of different treatment technologies at national and international level. Minimum cut off level considered for reliability is, at least two successful installations followed by commercial operation of that technology for minimum three to five years in India.
- e. Quantum of process rejects, extent of landfill diversion and total land requirement for the project:** The extent of process rejects is an important consideration in making a choice of technology. This was one of the main reasons for the popularity of incineration (mass burn). Among the other factor is the processing time, which is also the least in case of thermo-chemical systems like incineration. With growing disenchantment with incineration, the focus is shifting to combination of technologies to minimize total process rejects because the rejected material from one process becomes the raw material for the other. For

example, combination of composting and RDF can significantly reduce total process rejects that maximizes landfill diversion.

The extent of process rejects/ residues and the land requirement for different processing technologies are listed in the following Table:

Table 3: Process Remnants from MSW Treatment Technologies

Sr. No.	Technology	Value
1.	Composting	20 – 30%
2.	Biomethanation	25 – 40%
4.	RDF	25 – 30%
5.	Incineration	8 – 12%
6.	Composting + RDF	10 – 15%

Land/ area requirement for waste treatment and disposal is a significant factor while making selection of technology. Footprint of MSW processing technologies and land requirement to house these technologies is a significant constraint in urban conditions, where the availability of suitable land of the required area and meeting CPCB siting guidelines is a challenge. Therefore, the technology which requires less land should be preferred over the technologies requiring more land.

- f. Social acceptability and public perception:** Solid Waste Management (SWM) in ULBs is one such activity, where active public participation and accepting the technology/ process is the key for success. The health and environmental risks of solid waste management has been the subject of controversy due to NIMBY (Not In My Back Yard) factor. Social acceptance is one of the major criteria, while suggesting any treatment technology at any location. The technology should be widely accepted by the public; only then chances of the project being successful would brighten up.

For conducive public perception and social acceptability, the following points must be taken into consideration:

- Inter-active planning involving the public and the civil society.
- Appropriate planning of the system keeping in view all the environmental norms.
- Proper execution of the project facility.
- Standard operational procedure (SOP) must be followed without resorting to any short-cuts.
- Observation of all safety norms so that neither the workers nor the surrounding environment is adversely affected due to any unforeseen incident. This will enable the project to have a good name and perceived as acceptance for the neighborhood.
- Employment potential for the local public.
- Sustained awareness generation for the public that will encourage the interaction.

3.2.2 Secondary Screening

In the secondary screening, software filters are proposed:

- User friendly (Operator friendly) operation and maintenance
- Skill-set requirement (from the planning and designing stage to operation and maintenance stage)

User/ operator friendly technology is linked to viability and long term sustainability as well. Skill-set requirement is another important issue. This is an important issue because there is acute shortage of properly qualified and experienced (actual hands-on experience) personnel in the waste management sector. As the sector is growing, there is a trend of increasing attrition.

- In the first stage screening, efforts were made to narrow down the selection by applying various suitability Need for auxiliary fuel
- Marketing of end products (Energy/ fuel/ compost/ slag)

filters. Now with the second screening step, it is possible to measure the performance of the selected technologies in terms of input required and output received. Following criteria are considered for secondary screening:

Need for auxiliary fuel: The high organic content and higher moisture content of Indian MSW indicates that a self-sustaining combustion reaction cannot be obtained from MSW. This waste needs to be sufficed with auxiliary fuel during combustion. Moisture content and calorific value are the key factors to determine the feasibility of thermal treatments. Incineration (Mass burn) can be made suitable by addition of auxiliary fuels.

Marketing of end products (Energy/ fuel/ compost/ slag): Effective marketability of end products (thermal energy in the form of steam /power/ fuel oil/ gas/ RDF/ compost material) will be a crucial factor determining the project viability and needs to be tied-up in advance with the respective technologies. There are technologies having the capability of recovering recyclables, converting waste into intermediate fuel products (e.g., biogas, syngas, steam,) efficiently using the fuel products and other byproducts on-site for power generation. End product generated from processing of the waste should meet all regulatory standards and should not create harm to environment. End product generated preferably should have continuous demand in the market. Technology provider should have firm agreements and institutional arrangements with the company/ agency/ industry, which will off take the end product on continuous basis.

3.3 Commercial Evaluation

The decision to implement any particular technology needs to be based not only on its technical viability but also on its economic viability, operation sustainability, as well as environmental implications. Keeping in view the local conditions and the available physical and financial resources, the key factors considered for the criteria of commercial evaluations are mentioned below:

- Energy requirement and prices/ buyback tariff for energy purchase
- Cost of alternatives, land price and capital and labor cost

- O& M cost, energy generation, payback period and tipping fees
- Capabilities and credentials of the technology provider/ agency

The monetary aspect identifies the relation between technical or environmental standards of the treatment technology compared to the costs they cause.

The costs considered, fall into two basic categories, capital costs and recurrent costs. Capital costs are the costs incurred for setting up of the project on the ground. Further the capital cost includes:

- Cost of planning and designing the work,
- Construction costs,
- Supervision costs, and
- Overheads

In some cases, facility financing cost and land cost are also associated with capital cost.

Operation and maintenance costs or recurrent costs are the costs incurred after execution of the project for its routine maintenance and operations. The operation and maintenance cost includes manpower cost, miscellaneous expenses, administrative expenses, routine maintenance cost, electricity and fuel consumption charges, sanitization treatment, inoculants, additives etc. However, it does not include debt charges, interest on loan repayment. Therefore, it is essential that the operation and maintenance costs be carefully assessed as SWM operation and maintenance costs are substantial.

Waste recycling, composting, waste-to-energy may generate additional revenues or reduce the cost of processing of waste. Such technologies provide tangible financial benefits from recovered materials, final products and conserved energy, and have additional benefits by avoiding costs of land filling. Further, these help in increasing the life of a landfill/ disposal facility.

Summary of cost estimates, land and electricity requirement for the selected treatment technologies are provided in the Table 4.

Table 4: Tentative Summary of Land, Energy Requirement and cost for MSW Treatment Technologies of 500 TPD

Sr No.	Technology	Land Requirement (500 TPD) in Ha	Capital Cost in (Crores)	Operation & Maintenance Cost, per year (Crores)
1.	Composting	6- 8	15-20	1.5-2
2.	Anaerobic Digestion	4- 5	75-80	3-5
3.	Composting + RDF	8- 10	25-30	3-5

Sr No.	Technology	Land Requirement (500 TPD) in Ha	Capital Cost in (Crores)	Operation & Maintenance Cost, per year (Crores)
4.	Incineration	2- 3	75-100	10-15

Source: CPHEEO Manual on MSWM, 2016 and TCE project experiences.

4. EVALUATION OF TECHNOLOGIES: SCREENING MATRIX

The appropriateness of technology is decided if it pass the set basic requirements like modularity, scalability, upgradability and flexibility, primary screening parameters like suitability to MSW characteristics, regulatory acceptability, reliability, environment impact (air, water, land, biodiversity) and social Impact/ public acceptance, secondary screening parameters like need for auxiliary fuel, end product market (Energy/ compost/ash) and various auxiliary parameter assessment. Commercial viability was also assessed based on parameters like capital cost, land, energy and labor requirement, O&M cost, energy generation, end product market.

Based on the Screening criteria proposed in this paper, a screening matrix has been proposed to evaluate all the existing and popular MSW technologies on the same scale and result of screening exercise summarized in following Table 5:

Table 5: Technology Screening Matrix

Screening Parameters		MSW Treatment Technologies							
		CO	BM	CO + RDF	IN	PY	GA	PA	BL
Basic Requirements	Modularity	M	H	M	H	H	H	H	M
	Flexibility	H	H	H	H	H	H	H	H
	Upgradeability	H	H	H	H	H	H	H	L
	Scalability	H	H	H	H	H	H	H	H
Primary Screening	Regulatory Acceptability	H	H	H	H	H	H	H	N
	Suitability	H	H	H	L	L	L	L	H
	Reliability	H	H	M	L	L	L	L	M
	Env. Impact	M	H	M	M	H	H	H	L
	Public Accept.	H	H	M	M	M	M	M	L
Secondary Screening	Need for Auxiliary fuel	-	-	-	M	-	-	-	-
	End Product	H	H	H	H	H	H	H	M

Remarks		H	H	H	H	L	L	L	L
Commercial Evaluation	Land Requirement	L	M	L	H	Low preference has been given to thermal treatment technologies (Pyrolysis, Gasification, Plasma Arc & Bioreactor Landfill)			
	Capital Cost	H	L	M	L				
	O and M Cost	L	M	M	M				
	Energy Requirement	M	M	M	L				
	Manpower Requirement	L	M	M	H				
	Energy Generation	-	M	H	H				
Remarks		√ (M)	√ (H)	√ (H)	√ (M)				
Abbreviations: CO: Composting, BM: Biomethanation, RDF: Refuse derived Fuel, IN: Incineration, PY: Pyrolysis, GA: Gasification, PA: Plasma Arc, BL: Bioreactor Landfill									
Rating: H: High matrix rating, M: Medium matrix rating, L: Low matrix rating, N: Not accepted, √: Viable, X: Not Viable									
<u>Note/ Explanation:</u> All weightages (H, M, and L) are given on matrix ratings L: Low matrix in the screening criteria will get eliminated at first stage itself. N: Regulatory acceptance will result in non selection of technology Medium and High Matrix Rating: Technologies are selected after first stage screening.									

It is clear from evaluation of the above table that overall technology winners are Composting + RDF and Biomethanation as (H), followed by Composting and Incineration technologies as (M), which are satisfying the overall criteria. However, other thermal treatment technologies (Gasification, Pyrolysis, and Plasma Arc) can also be used but have given low preference.

Overall criterion means, the evaluation of efficiency of waste treatment technology in four categories: the Technical, the Regulatory/ compliance, the Environmental and the Monetary aspects, which are further categorized into lower level criteria. Besides, term efficiency is meant to describe the overall quality/ suitability of the treatment technologies rather than being a measure for the effectiveness at converting input into outputs.

No single technological option is able to provide complete solution for waste management. The selection of waste treatment technology needs to be done carefully only after considering the following factors:

- a) Mixed form of MSW
- b) Excess moisture content in MSW
- c) Low Calorific Value

Therefore, it could be seen that MSW composition plays a major role in selecting and zeroing on the suitable technology to be used for treatment.

5. CONCLUSIONS

Overall technology winners are Composting + RDF & Biomethanation as (H), followed by Composting and Incineration technologies considered as (M), which are satisfying the overall criteria. All treatment technologies claim to be reasonable to the certain extent as for as technical, environmental and economic criteria are concerned. The decision pertaining to the selection of particular waste treatment technology may be the best or most appropriate within certain boundary limits. However, this decision requires a reliable basis of data and information together with good understanding of the decision-making process.

The important aspects are not only the technology which are mentioned in the above section, but also the aspect of the building and closing down phase of the treatment plant, the input material, the output of the treatment process, the recovery process and disposal of the output, etc.

This evaluation guideline is another step in the right direction in order to establish a sensible and responsible waste management concept. This concept still leaves much scope for further investigation, research, and refinements based on practical experience of available case studies of waste management practices using the applicable environmental regulations and guidelines.

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7. BIBLIOGRAPHY:

- [1]. CPCB Annual Reports on Implementation of MSW Rules, 2018-19.
- [2]. U. Schunke, (1999) An Evaluation Guideline for Waste Treatment Technologies, Master of Management Studies (in Technology) Thesis, VUW.
- [3]. Planning Commission (2014), 'Report of the Task Force on Waste to Energy', Vol. I, Planning Commission, New Delhi, May.
- [4]. Sharholly, M., Ahmad, K., Mahmood, G., Trivedi, R.C. (2008) Municipal solid waste management in Indian cities-A review. *Waste Management*. 28(2), 459-467.
- [5]. Guidelines on usage of Refuse Derived Fuel (RDF) in various Industries, Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Housing and Urban Affairs (MOHUA), October 2018

- [6]. Solid Waste Management Manual, Central Public Health and Environmental Engineering Organization (CPHEEO), 2015
- [7]. Development of Solid Waste Management Project at Mumbai (Jan 2015) Draft Project Report, by Infrastructure Development Corporation (Karnataka) Limited (iDECK), Infrastructure Development & Finance Company (IDFC) and SENES Consultants India Pvt. Ltd.
- [6]. MCGM Report on Waste characterization-2007.
- [7]. NEERI Revised Final Report on Waste characterization of Mumbai- 2015 (Deonar Site- Freshly dumped waste values considered).
- [8]. NEERI's study on "Assessment of Status of Municipal Solid Wastes Management in Metro Cities and State Capitals" in 2004-2005.
- [9]. Status of solid waste generation, collection, treatment and disposal in metro cities, (CPCB, 2000) for Mumbai.
- [10]. Waste composition for city more than 5 lakh population, Background material for Manual on SWM, NEERI 1996.
- [11]. World Bank (2012). What a waste: a global review of solid waste management. Urban development series knowl- edge papers.
- [12]. World Energy Council 2013: <http://www.worldenergy.org/news-and-media/news/22nd-world-energy-congress-reflects-concerns-about-shifting-energy-agenda/>
- [13]. The World Bank Publication (2008), Improving Municipal Solid Waste Management in India (A Sourcebook for Policy Makers and Practitioners), Da Zhu, P. U. Asnani, Chris Zurbrugg, Sebastian Anapolsky and Shyamala Mani.