Open dumping of solid wastes in India

Sustainable Solid Waste Management in India

by

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EXECUTIVE SUMMARY

This study examined the present status of waste management in India, its effects on public health and the environment, and the prospects of introducing improved means of disposing municipal solid waste (MSW) in India. The systems and techniques discussed are Informal and Formal Recycling, Aerobic Composting and Mechanical Biological Treatment, Small Scale Biomethanation, Refuse Derived Fuel (RDF), Waste-to-Energy Combustion (WTE), and Landfill Mining (or Bioremediation).

This report is the result of over two years of research and includes data collected from the literature, communication with professionals in India, US and Europe; and extensive field investigations by the author in India and the US. Two field visits in India over a period of fifteen weeks covered 13 cities (Figure 1) representing all sizes and regions in India. The visits included travelling to informal recycling hubs, waste dealers shops, composting facilities, RDF facilities, WTE facilities, sanitary and unsanitary landfills, landfill mining sites, and numerous municipal offices. These visits provided the opportunity to closely observe the impact of waste management initiatives, or lack thereof, on the public in those cities. The author has also visited different WTE plants in the US to study the prospects of this technology in India.

The main objective of the study was to find ways in which the enormous quantity of solid wastes currently disposed off on land can be reduced by recovering materials and energy from wastes, in a cost effective and environmental friendly manner. The guiding principle of this study is that "responsible management of wastes must be based on science and best available technology and not on ideology and economics that exclude environmental costs and seem to be inexpensive now, but can be very costly in the future" (Annexure I).

Lack of data and inconsistency in existing data is a major hurdle while studying developing nations. This report attempted to fill this gap by tabulating the per capita waste generation rates and wastes generated in 366 Indian cities that in total represent 70% of India's urban population (Appendix 1). This is the largest existing database for waste generation in individual cities in India. Estimations made by extrapolating this data puts the total MSW generated in urban India at 68.8 million tons per year (TPY) or 188,500 tons per day (TPD). The data collected indicate a 50% increase in MSW generated within a decade since 2001. In a "business as usual scenario", urban India will generate 160.5 million TPY (440,000 TPD) by 2041 (Table 7); in the next decade, urban India will generate a total of 920 million tons of municipal solid waste that needs to be properly managed in order to avoid further deterioration of public health, air, water and land resources, and the quality of life in Indian cities. In a "business as usual" scenario, India will not be able to dispose these wastes properly.

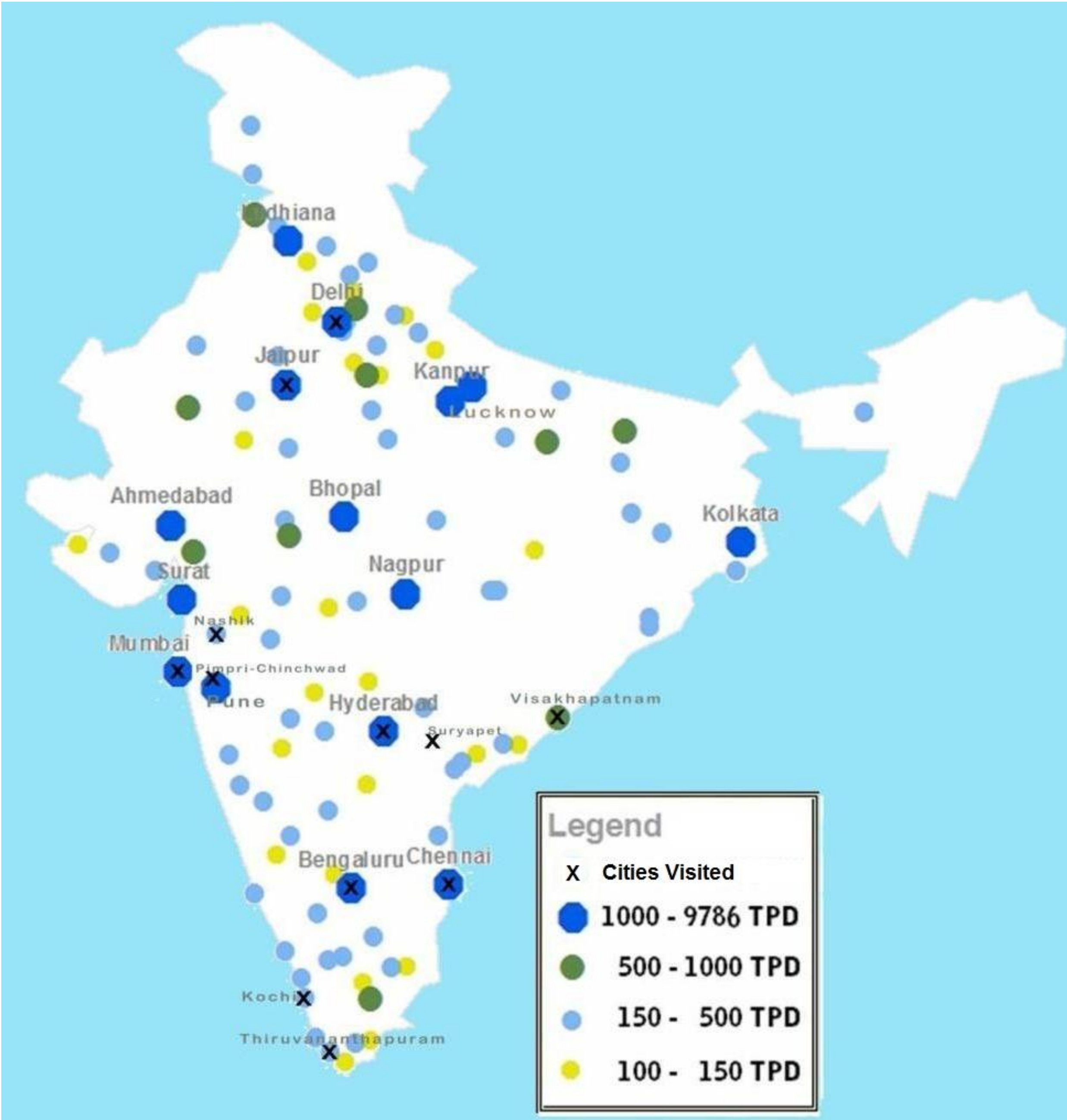

Figure 1, Map of Cities Generating Different Quantities of MSW; Cities Visited by the Author during Research Visits

The composition of urban MSW in India is 51% organics, 17.5% recyclables (paper, plastic, metal, and glass) and 31 % of inerts (Table 6). The moisture content of urban MSW is 47% and the average calorific value is 7.3 MJ/kg (1745 kcal/kg). The composition of MSW in the North, East, South and Western regions of the country varied between 50-57% of organics, 16-19% of recyclables, 28-31% of inerts and 45-51% of moisture (Table 6). The calorific value of the waste varied between 6.8-9.8 MJ/kg (1,620-2,340 kcal/kg).

This report has also updated the "Status of Cities and State Capitals in Implementation of MSW (Management and Handling) Rules, 2000" (1), jointly published by the Central Pollution Control Board (CPCB) and the National Environmental Engineering Research Institute (NEERI), with respect to waste disposal options. The updated information is included as a table comparing the waste handling techniques in 2008 and 2011 (Table 9, also see Appendix 3). Since 2008, the number of composting facilities in the 74 cities studied (Appendix 3) increased from 22 to 40. Currently, India has more than 80 composting plants (Appendix 8). During the same period, the number of sanitary landfills (SLF) has increased from 1 to 8 while the number of RDF and WTE projects has increased from 1 to 7 (Appendix 3).

The study also found that open burning of solid wastes and landfill fires emit nearly 22,000 tons per year of pollutants into the air in the city of Mumbai alone (Figure 15). These pollutants include Carbon Monoxide (CO), Hydrocarbons (HC), Particulate Matter (PM), Nitrogen Oxides (NO_x) and Sulfur Dioxide (SO_2) plus an estimated 10,000 TEQ grams of dioxins/furans (Appendix 14). Open burning was found to be the largest polluter in Mumbai, among the activities that do not contribute any economic value to the city. Since open burning happens at ground level, the resultant emissions enter the lower level breathing zone of the atmosphere, increasing direct exposure to humans.

The author has observed that the role of the informal sector in SWM in developing nations is increasingly being recognized. There is a world-wide consensus that the informal sector should be integrated into the formal system and there are numerous initiatives working with such goals. This report estimates that, every ton per day of recyclables collected informally saves the urban local body USD 500 (INR 24,500) per year and avoids the emission of 721 kg of carbon dioxide per year (Appendix 11).

There is no sufficient information on the performance of India's MSW composting facilities. However, an important observation made during this study is that the compost yield from mixed waste composting facilities (MBTs) is only 6-7% of the feed material. Up to 60% of the input waste is discarded as composting rejects and landfilled (Figure 28); the rest consists of water vapor and carbon dioxide generated during the composting processes. The compost product from mixed wastes was found to be of very low quality and contaminated by heavy metals (Figure 30). The majority of the mixed waste compost samples fell below the quality control standards for total potassium, total organic carbon, total phosphorus and moisture content; and exceeded the quality control limits for heavy metals (lead, Pb, and chromium, Cr). If all MSW generated in India in the next decade were to be composted as mixed waste and used for agriculture, it would introduce 73,000 tons of heavy metals into agricultural soils (Appendix 13).

This study also found that the calorific value (lower heating value) of some composting rejects (up to 60% of the input MSW) is as high as 11.6 MJ/kg (2,770 kcal/kg) (Table 14). This value is much higher than the minimum calorific value of 7.5 MJ/kg (1,790 kcal/kg) recommended for economically feasible energy generation through grate combustion WTE (2). This data is important, considering the notion that the calorific value of MSW in India is not suitable for energy generation. Therefore, the residues of mixed MSW composting operations can be used for producing RDF or can be combusted in a WTE plant directly.

Landfill gas (LFG) recovery has been shown to be economically feasible at seven landfills located in four cities, Delhi, Mumbai, Kolkata and Ahmadabad (Table 10). Development of these seven LFG recovery projects will result in an overall GHG emissions reduction of 7.4 million tons of CO_2 equivalents. One of these landfills, the Gorai dumpsite in Mumbai, has already been capped in 2008 for capturing and flaring LFG. This project will result in an overall GHG emissions reduction of 2.2 million tons of CO_2 equivalents by 2028.

Assuming a business as usual scenario (BAU), by the end of the next decade, India will generate a total of 920 million tons of MSW, landfill or openly dump 840 million tons of it and produce 3.6 million tons of mixed waste compost. It will also produce 33.1 million TPY of potential refuse derived fuel (RDF) in the form of composting rejects that will also be landfilled.

A review of the present status of SWM in India, from a materials and energy recovery perspective, showed that in 2011 India will landfill (Appendix 15)

- 6.7 million TPY of recyclable material which could have been used as secondary raw materials in manufacturing industries, due to the absence of source separation;
- 9.6 million tons of compost which could have been used as a fertilizer supplement, due to the absence of source separation and enough composting facilities; and
- 58 million barrels of oil energy equivalent in residues of composting operations that could have been used to generate electricity and displace fossil fuels in RDF co-combustion plants or WTE power plants; due to the absence of WTE facilities, and proper policies and pollution control regulations for co-combustion of MSW in solid fuel industries.

This report proposes a waste disposal system which includes integrated informal recycling, small scale biomethanation, MBT and RDF/WTE.

Informal recycling can be integrated into the formal system by training and employing waste pickers to conduct door-to-door collection of wastes, and by allowing them to sell the recyclables they collected. Waste pickers should also be employed at material recovery facilities (or MRFs) to increase the percentage of recycling. Single households, restaurants, food courts and other sources of separated organic waste should be encouraged to employ small scale biomethanation and use the biogas for cooking purposes. Use of compost product from mixed wastes for agriculture should be regulated. It should be used for gardening purposes only or as landfill cover. Rejects from the composting facility should be combusted in a waste-to-energy facility to recover energy. Ash from WTE facilities should be used to make bricks or should be contained in a sanitary landfill facility.

Such a system will divert 93.5% of MSW from landfilling, and increase the life span of a landfill from 20 years to 300 years. It will also decrease disease, improve the quality of life of urban Indians, and avoid environmental pollution.

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అందరికీ, నా మనః పూర్వక కృతజ్ఞతలు

Words would not be enough to express the love and affection of my parents, brother, our ‘Babai, Pinni and Chinnu’ and Sona.

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- Ranjith Kharvel Annepu, New York City, January, 2012

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SCOPE OF STUDY

This report focuses on various options available for the disposal of municipal solid waste (MSW) sustainably and attempts to provide a documented picture of their suitability to India. The report is divided into two parts, Part I and Part II. The first part will explain the present solid waste management (SWM) crisis in India, its impacts on public health, environment and quality of life and touch upon efforts towards SWM in the past. The second part deals with the Earth Engineering Center's initiative, WTERT – India to help improve SWM in India and presents some articles viewership statistics of the internet blog (www.swmindia.blogspot.com) based upon this research.

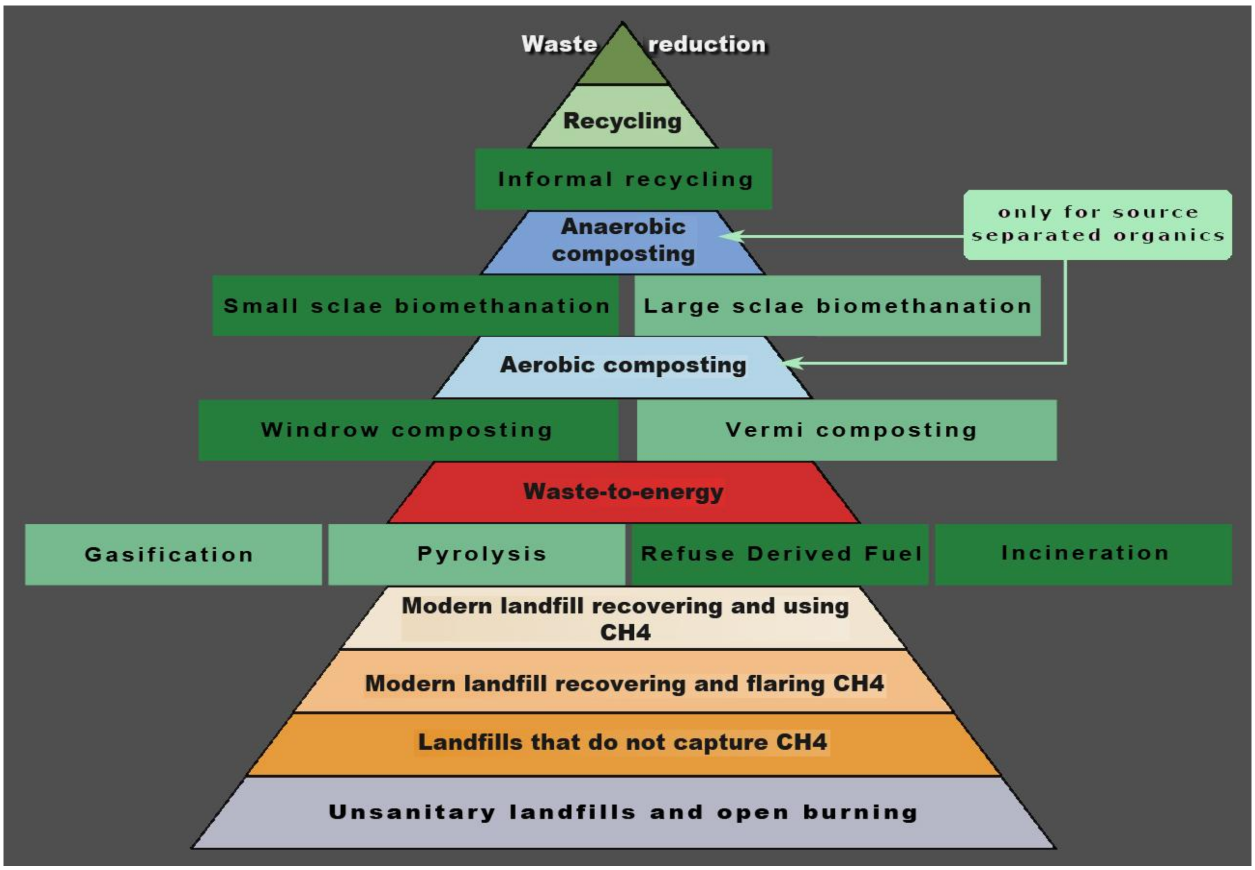


Figure 2, Scope of the Study: Green Boxes Indicate the Methods of Waste Disposal Studied in Comparison to the Hierarchy of Sustainable Waste Management

The first part introduces the Hierarchy of Sustainable Waste Management (Figure 10), which will act as the framework for the rest of this report. It then presents the current situation of SWM in Indian cities, discussing unsanitary landfilling and open burning of wastes; and their effects on the day-to-day lives of urban Indians. Part I also discusses specific technologies and mechanisms as probable solutions to India's SWM crisis. The areas of focus were Recycling, Aerobic Composting (or Mechanical Biological Treatment), Small Scale Biogas (or Biomethanation), Refuse Derived Fuel (RDF) and Waste-to-Energy Combustion (WTE), as represented by the green boxes in (Figure 2). These technologies were selected based upon their success inside and outside India, suitability to Indian conditions, environmental impact and economics. Composting and small scale biomethanation were chosen specifically due to their success in India in treating organic wastes. Composting was also chosen to point out a likely side-effect of mixed waste composting. Mixed waste composting is also called as Mechanical Biological Treatment (MBT). Use of compost from MBT facilities for agricultural purposes introduces heavy metals into human food chain. Small scale biomethanation was chosen due to its high position on the hierarchy of sustainable waste management and its collective potential to divert waste from landfills.

Informal recycling is studied as an integral part of SWM considering its effectiveness in recycling waste and its robust collection and supply chains in large Indian cities. Informal recycling is getting due recognition and gaining wider consensus around the world for its role in SWM in middle and low income nations. RDF and WTE are chosen based upon their potential to divert wastes from landfill and their potential to generate energy from residual mixed wastes. Failures of RDF and WTE plants are analyzed and compared to the initial failures of MBT plants. Despite the best waste handling practices, a fraction of MSW that has to be landfilled will always exist; therefore an introduction to sanitary landfilling is included as an end-of-the-loop solution.

Short details of other sources of information about government policy and regulations, theoretical aspects of SWM, and specifications followed in Indian SWM projects are provided in Section 7.

INTRODUCTION

India is the second largest nation in the world, with a population of 1.21 billion, accounting for nearly 18% of world's human population, but it does not have enough resources or adequate systems in place to treat its solid wastes. Its urban population grew at a rate of 31.8% during the last decade to 377 million, which is greater than the entire population of US, the third largest country in the world according to population (3). India is facing a sharp contrast between its increasing urban population and available services and resources. Solid waste management (SWM) is one such service where India has an enormous gap to fill. Proper municipal solid waste (MSW) disposal systems to address the burgeoning amount of wastes are absent. The current SWM services are inefficient, incur heavy expenditure and are so low as to be a potential threat to the public health and environmental quality (4). Improper solid waste management deteriorates public health, causes environmental pollution, accelerates natural resources degradation, causes climate change and greatly impacts the quality of life of citizens (See Section 4).

Figure 3, Impact of Improper SWM on Pristine Ecosystems, Landfill Fires in Visakhapatnam Landfill, which is Located in a Valley

The present citizens of India are living in times of unprecedented economic growth, rising aspirations, and rapidly changing lifestyles, which will raise the expectations on public health and quality of life. Remediation and recovery of misused resources will also be expected. These expectations when not met might result in a low quality of life for the citizens (See Section 4.6). Pollution of whether air, water or land results in long-term reduction of productivity leading to a deterioration of economic condition of a country. Therefore, controlling pollution to reduce risk of poor health, to protect the natural environment and to contribute to our quality of life is a key component of sustainable development (5).

The per capita waste generation rate in India has increased from 0.44 kg/day in 2001 to 0.5 kg/day in 2011, fuelled by changing lifestyles and increased purchasing power of urban Indians. Urban population growth and increase in per capita waste generation have resulted in a 50% increase in the waste generated by Indian cities within only a decade since 2001. There are 53 cities in India with a million plus population, which together generate 86,000 TPD (31.5 million tons per year) of MSW at a per capita waste generation rate of 500 grams/day. The total MSW generated in urban India is estimated to be 68.8 million tons per year (TPY) or 188,500 tons per day (TPD) of MSW. Such a steep increase in waste generation within a decade has severed the stress on all available natural, infrastructural and budgetary resources.

Big cities collect about 70 - 90% of MSW generated, whereas smaller cities and towns collect less than 50% of waste generated. More than 91% of the MSW collected formally is landfilled on open lands and dumps (6). It is estimated that about 2% of the uncollected wastes are burnt openly on the streets. About 10% of the collected MSW is openly burnt or is caught in landfill fires (5). Such open burning of MSW and landfill fires together releases 22,000 tons of pollutants into the lower atmosphere of Mumbai city every year (Figure 15). The pollutants include carbon monoxide (CO), carcinogenic hydro carbons (HC) (includes dioxins and furans), particulate matter (PM), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) (5).

Most of the recyclable waste is collected by the informal recycling sector in India prior to and after formal collection by Urban Local Bodies (ULB). Amount of recyclables collected by informal sector prior to formal collection are generally not accounted. This report estimates that 21% of recyclables collected formally are separated by the formal sector at transfer stations and dumps. Even though this number does not include amount of recycling prior to formal collection, it compares fairly well with the best recycling percentages achieved around the world (See Section 5.1.1). Informal recycling system is lately receiving its due recognition world-wide for its role in waste management in developing nations. In India, government policy and non-governmental organizations (NGOs) are expected to organize the sector present in different regions, and to help integrating it into the overall formal system. 'Plastic Waste Management and Handling Rules, 2011' by the Ministry of Environment and Forests (MOEF) is a step ahead in this direction. These rules mandate ULBs to coordinate with all stake holders in solid waste management, which includes waste pickers.

Figure 4, Impact of Improper SWM on Public health: Direct Exposure of Children to Emissions from Open Burning, Hyderabad

All attempts to recover materials and energy from MSW have encountered initial failures. Ten aerobic composting (MBT) projects in 1970s, a WTE project in 1980s, a large scale biomethanation project, and two RDF projects in 2003 have failed. Anaerobic digestion of MSW on a large scale does not work in India due to the absence of source separated organic waste stream. The large scale biomethanation plant built in Lucknow to generate 6 MW of electricity, failed to run because of this. Anaerobic digestion has however been successful at smaller scales, for vegetable and meat markets, restaurants or hotels and at the household level. Twenty thousand household biogas units installed by Biotech, a bio gas technology company from Thiruvananthapuram, Kerala divert about 2.5% of organic waste from landfill. By doing so, they save up to USD 4.5 million (INR 225 million) to Thiruvananthapuram, and Kochi ULBs every year in transportation costs. These biogas units also avoid around 7,000 tons of CO_2 equivalent (TCO_2) emissions every year (See Section 5.3).

Aerobic composting is the most widely employed SWM technology in India. It is estimated that up to 6% of MSW collected is composted in various MBT facilities (7). There are more than 80

MBT plants in India treating mixed MSW, most of them located in the states of Maharashtra (19), Himachal Pradesh (11), Chhattisgarh (9) and Orissa (7) (Appendix 8). More than 26 new MBT plants are proposed in different cities and towns across India (Appendix 8). Even though composting of mixed wastes is a better solution compared to landfilling or openly burning those wastes, it is not the best (8). Compost from MBT facilities was found to be of low quality and to contain toxic heavy metals which could enter human food chain if used for agriculture (See Section 5.2.3).

India has a total of five RDF processing plants, located near Hyderabad, Vijayawada, Jaipur, Chandigarh and Rajkot. The first two plants burn the RDF produced in WTE boilers, whereas the next two burn the RDF in cement kilns. Details about the Rajkot facility are not available. All these facilities have encountered severe problems during operation. Problems were majorly due to lack of proper financial and logistical planning and not due to the technology.

Only two WTE combustion plants were built in India, both in New Delhi. The latest one among them has finished construction in Okhla landfill site and is about to begin operations. It is designed to generate 16 MW of electricity by combusting 1350 TPD of MSW.

All technological solutions attempted in India have encountered initial failures in India. These include the ten MBT (composting) facilities built in 1975-1976, the WTE facility built in 1985 in Delhi, the two RDF plants built in 2003 near Hyderabad and Vijayawada. None of these plants are currently in operation. The ten MBT and the 1985 WTE plant are now completely closed. Major reasons for these failures are, the plants were designed for handling more waste than could be acquired; allocation of funds for plant maintenance was ignored; and local conditions were not considered while importing the technology. The success of MBT in India is partly due to the lessons learned from such failures. The failure of WTE however raised enormous public opposition and has hindered any efforts in that direction. Failure of biomethanation plants was also attributed to WTE combustion due to the confusion in the terminology. Failure of RDF plants has attracted attention and opposition too; however, numerous attempts at installing this technology are continuously made.

MSW rules 2000 made by the Government of India to regulate the management and handling of municipal solid wastes (MSW) provide a framework for treatment and disposal of MSW. These rules were the result of a ‘Public Interest Litigation (PIL)’ in the Supreme Court of India (SC). The MSW rules 2002 and other documents published by the Government of India (GOI) recommend adoption of different technologies, which include biomethanation, gasification, pyrolysis, plasma gasification, refuse derived fuel (RDF), waste-to-energy combustion (WTE), sanitary landfills (SLF). However, the suitability of technologies to Indian conditions has not been sufficiently studied, especially with regard to the sustainable management of the entire MSW stream and reducing its environmental and health impacts.

Due to lack of data and infrastructural, financial and human resources, the Supreme Court mandate of complete compliance to the rules by 2003 could not be achieved by urban local bodies (ULBs) and that goal still remains to be a distant dream (7). As a result, even after a decade since the issuance of the MSW Rules 2000, the state of MSW management systems in the country continues to raise serious public health concerns (9). Although some cities have achieved some progress in SWM, many cities and towns have not even initiated measures (7). Initiatives in Mumbai were the result of heavy rains and consequent flooding in 2006 due to drains clogged by solid waste. The flood in Mumbai in 2006 paved the way for enacting State level legislation pertaining to the collection, transport and disposal of urban solid waste in the state of Maharashtra (7). Bubonic plague epidemic in Surat in 1994 increased awareness on the need for proper SWM systems all over India and kick started measures to properly manage wastes in Surat.

Scarcity of suitable landfill sites is a major constraint, increasingly being faced by ULBs. Such difficulties are paving the way to building regional landfills and WTE and mechanical biological treatment (MBT) solutions. The tremendous pressure on the budgetary resources of States/ULBs due to increasing quantities of MSW and lack of infrastructure has helped them involve private sector in urban development (7). GOI has also invested significantly in SWM projects under the 12th Finance Commission and Jawaharlal Nehru National Urban Renewal Mission (JnNURM). The financial assistance provided by GOI to states and ULBs amounted to USD 510 million (INR 2,500 crores) (7).

PART I, PRESENT SITUATION OF SWM IN INDIA

1. MUNICIPAL SOLID WASTE (MSW)

Waste is defined as any material that is not useful and does not represent any economic value to its owner, the owner being the waste generator (10). Depending on the physical state of waste, wastes are categorized into solid, liquid and gaseous. Solid Wastes are categorized into municipal wastes, hazardous wastes, medical wastes and radioactive wastes. Managing solid waste generally involves planning, financing, construction and operation of facilities for the collection, transportation, recycling and final disposition of the waste (10). This study focuses only on the disposal of municipal solid waste (MSW), as an element of overall municipal solid waste management or just solid waste management (SWM).

Table 1: Sources and Types of Municipal Solid Waste; Source (11)

Sources	Typical waste generators	Components of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil, tires) and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, government center, hospitals, prisons	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Municipal services	Street cleaning, landscaping, parks, beaches, recreational areas	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas

MSW is defined as any waste generated by household, commercial and/or institutional activities and is not hazardous (10). Depending upon the source, MSW is categorized into three types: Residential or household waste which arises from domestic areas from individual houses; commercial wastes and/or institutional wastes which arise from individually larger sources of MSW like hotels, office buildings, schools, etc.; municipal services wastes which arise from area sources like streets, parks, etc. MSW usually contains food wastes, paper, cardboard, plastics, textiles, glass, metals, wood, street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas (11). Sometimes other household wastes like batteries and consumer electronics also get mixed up with MSW.

1.1. SOLID WASTE MANAGEMENT (SWM)

A solid waste management (SWM) system includes the generation of waste, storage, collection, transportation, processing and final disposal. This study will focus on disposal options for MSW in India.

Agricultural and manufactured products of no more value are discarded as wastes. Once items are discarded as waste, they need to be collected. Waste collection in most parts of the world is centralized and all kinds of waste generated by a household or institution are collected together as mixed wastes.

Solid waste management (SWM) is a basic public necessity and this service is provided by respective urban local bodies (ULBs) in India. SWM starts with the collection of solid wastes and ends with their disposal and/or beneficial use. Proper SWM requires separate collection of different wastes, called source separated waste collection. Source separated collection is common in high income regions of the world like Europe, North America and Japan where the infrastructure to transport separate waste streams exists. Most centralized municipal systems in low income countries like India collect solid wastes in a mixed form because source separate collection systems are non-existent. Source separated collection of waste is limited by infrastructure, personnel and public awareness. A significant amount of paper is collected in a source separated form, but informally. In this report, unmixed waste will be specially referred to as source separated waste, in all other cases municipal solid waste (MSW) or solid waste would refer to mixed wastes.

Indian cities are still struggling to achieve the collection of all MSW generated. Metros and other big cities in India collect between 70- 90% of MSW. Smaller cities and towns collect less than 50% (6). The benchmark for collection is 100%, which is one of the most important targets for ULBs at present. This is a reason why source separated collection is not yet in the radar.

1.2. PER CAPITA MSW GENERATTION

The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a country (Table 2). Per capita waste generation is the amount of waste generated by one person in one day in a country or region. The waste generation rate generally increases with increase in GDP. High income countries generate more waste per person compared to low income countries due to reasons discussed in further sections. The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China (12) (13) (14).

Table 2 Comparison between the per capita MSW generation rates in Low, Middle and High Income Countries

Country	Per Capita Urban MSW Generation (kg/day)	
	1999	2025
Low Income Countries	0.45 - 0.9	0.6 - 1.0
Middle Income Countries	0.52 - 1.1	0.8 - 1.5
High Income Countries	1.1 - 5.07	1.1 - 4.5

Waste generation rate in Indian cities ranges between 200 - 870 grams/day, depending upon the region's lifestyle and the size of the city. The per capita waste generation is increasing by about 1.3% per year in India (7).

Table 3, Highest and Lowest Waste Generation and Waste Generation Rates Among Metros, Class 1 cities, States, UTs, and North, East, West, South regions of India

		Waste Generation (TPD)		Per Capita Waste Generation (kg/day)	
		Low	High	Low	High
Metros	Value	3,344	11,520	0.445	0.708
	City	Greater Bengaluru	Greater Kolkata	Greater Bengaluru	Chennai
Class 1 Cities	Value	317	2,602	0.217	0.765
	City	Rajkot	Pune	Nashik	Kochi
All Cities	Value	5	11,520	0.194	0.867
	City	Kavarati	Kolkata	Kohima	Port Blair
States	Value	19	23,647	0.217	0.616
	State	Arunachal Pradesh	Maharashtra	Manipur	Goa
Union Territories (UT)	Value	5	11,558	0.342	0.867
	UT	Lakshadweep	Delhi	Lakshadweep	Andaman & Nicobar
Regions	Value	696	88,800	0.382	0.531
	Region	East	West	East	West

Cities in Western India were found to be generating the least amount of waste per person, only 440 grams/day, followed by East India (500 g/day), North India (520 g/day), and South India. Southern Indian cities generate 560 grams/day, the maximum waste generation per person. States with minimum and maximum per capita waste generation rates are Manipur (220 grams/day) and Goa (620 grams/day). Manipur is an Eastern state and Goa is Western and both are comparatively small states. Among bigger states, each person in Gujarat generates 395 g/day; followed by Orissa (400 g/day) and Madhya Pradesh (400 grams/day). Among states generating large amounts of MSW per person are Tamil Nadu (630 g/day), Jammu & Kashmir (600 g/day) and Andhra Pradesh (570 g/day). Among Union Territories, Andaman and Nicobar

Islands generate the highest (870 grams/day) per capita, while Lakshadweep Islands (340 grams/day) generates the least per capita. Per capita waste generation in Delhi, the biggest Union Territory is 650 g/day.

The Census of India classifies cities and towns into 4 classes, Class 1, Class 2, Class 3, and Class 4, depending upon their population (Table 4). Most of the cities studied during this research fell under Class 1. For the purpose of this study, these Class 1 cities were further categorized as Metropolitan, Class A, Class B, etc, until Class H depending upon the population of these cities. This finer classification allowed the author to observe the change in waste generation closer. However, the waste generation rates did not vary significantly between Class A, B, C, D, E, F, G & H cities. They fell in a narrow range of 0.43-0.49 kg/person/day. They generated significantly less MSW per person compared to the six metropolitan cities (0.6 kg/day). The per capita waste generation values of Class 2, 3 and 4 towns calculated in this report are not expected to represent respective classes due to the extremely small data set available. Data for only 6 out of 345 Class 2 cities, 4 out of 947 Class 3 cities and 1 out of 1,167 class 4 towns was available. Despite the lack of data in Class 2, 3, and 4 towns, the 366 cities and towns represent 70% of India's urban population and provide a fair estimation of the average per capita waste generation in Urban India (0.5 kg/day).

Table 4, Per Capita Waste Generation Rate depending upon the Population Size of Cities and Towns

Original Classification	Classification for this Study	Population Range (2001 Census)		No. of Cities	Per Capita kg/day
Class 1	Metropolitan	5,000,000	Above	6	0.605
	Class A	1,000,000	4,999,999	32	0.448
	Class B	700,000	999,999	20	0.464
	Class C	500,000	699,999	19	0.487
	Class D	400,000	499,999	19	0.448
	Class E	300,000	399,999	31	0.436
	Class F	200,000	299,999	58	0.427
	Class G	150,000	199,999	59	0.459
	Class H	100,000	149,999	111	0.445
Class 2		50,000	99,999	6	0.518
Class 3		20,000	49,999	4	0.434
Class 4		10,000	19,999	1	0.342
	TOTAL			**366**	

1.3 MSW GENERATION

Generation of MSW has an obvious relation to the population of the area or city, due to which bigger cities generate more waste. The metropolitan area of Kolkata generates the largest amount of MSW (11,520 TPD or 4.2 million TPY) among Indian cities.

Among the four geographical regions in India, Northern India generates the highest amount of MSW (40,500 TPD or 14.8 million TPY), 30% of all MSW generated in India; and Eastern India (23,500 TPD or 8.6 million TPY) generates the least, only 17% of MSW generated in India. Among states, Maharashtra (22,200 TPD or 8.1 million TPY), West Bengal (15,500 TPD or 5.7 million TPY), Uttar Pradesh (13,000 TPD or 4.75 million TPY), Tamil Nadu (12,000 TPD or 4.3 million TPY) Andhra Pradesh (11,500 TPD or 4.15 million TPY) generate the highest amount of MSW. Among Union Territories, Delhi (11,500 TPD or 4.2 million TPY) generates the highest and Chandigarh (486 TPD or 177,400 TPY) generates the second highest amount of waste.

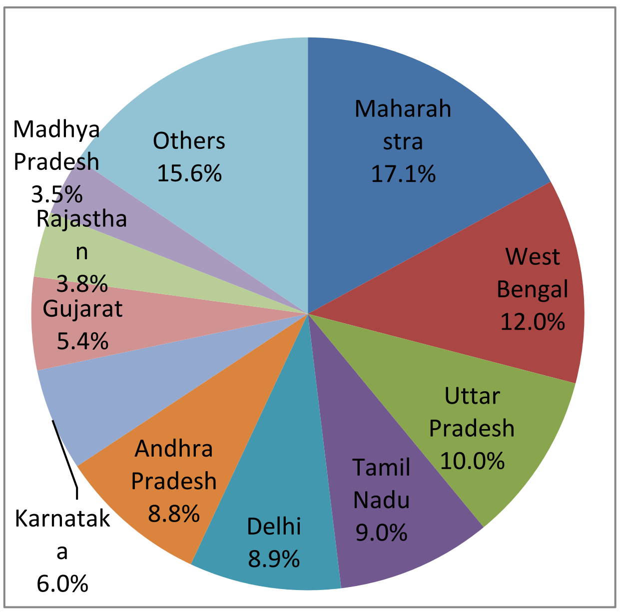


Figure 5, Share of States and Union Territories in Urban MSW Generated

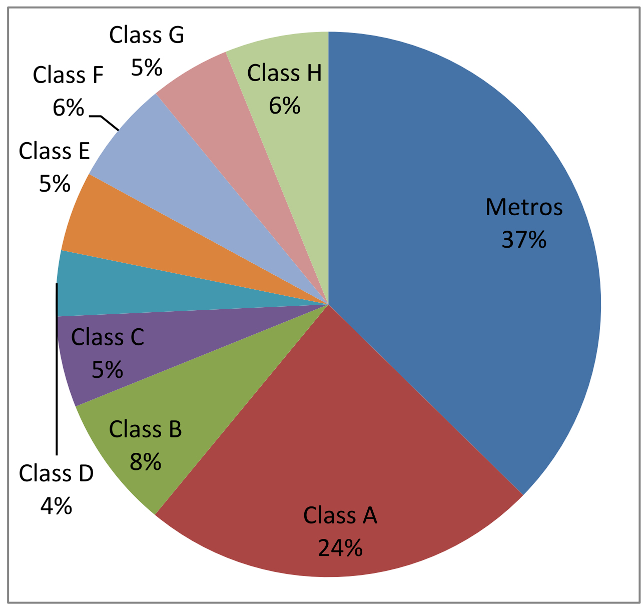


Figure 6, Share of Different Classes of Cities in Urban MSW Generated

1.4 MSW COMPOSITION

Materials in MSW can be broadly categorized into three groups, Compostables, Recyclables and Inerts. Compostables or organic fraction comprises of food waste, vegetable market wastes and yard waste. Recyclables are comprised of paper, plastic, metal and glass. The fraction of MSW which can neither be composted nor recycled into secondary raw materials is called Inerts.

Inerts comprise stones, ash and silt which enter the collection system due to littering on streets and at public places.

Waste composition dictates the waste management strategy to be employed in a particular location. Organics in MSW are putrescible, and are food for pests and insects and hence need to be collected and disposed off on a daily basis. The amount of recyclables like paper and plastic in MSW dictates how often they need to be collected. Recyclables represent an immediate monetary value to the collectors. Organics need controlled biological treatment to be of any value, however due to the general absence of such facilities, organics do not represent any direct value to informal collectors.

Table 5, Components and Waste Materials in MSW

MSW components	Materials
Compostables	Food waste, landscape and tree trimmings
Recyclables	Paper, Cardboard, Plastics, Glass, Metals
Inerts	Stones and silt, bones, and other inorganic materials

1.4.1 COMPOSITION OF URBAN MSW IN INDIA

A major fraction of urban MSW in India is organic matter (51%). Recyclables are 17.5 % of the MSW and the rest 31% is inert waste. The average calorific value of urban MSW is 7.3 MJ/kg (1,751 Kcal/kg) and the average moisture content is 47% (Table 6). It has to be understood that this composition is at the dump and not the composition of the waste generated. The actual percentage of recyclables discarded as waste in India is unknown due to informal picking of waste which is generally not accounted. Accounting wastes collected informally will change the composition of MSW considerably and help estimating the total waste generated by communities.

The large fraction of organic matter in the waste makes it suitable for aerobic and anaerobic digestion. Significant recyclables percentage after informal recycling suggests that efficiency of existing systems should be increased. Recycling and composting efficiency are greatly reduced due to the general absence of source separation. Absence of source separation also strikes centralized aerobic or anaerobic digestion processes off the list. Anaerobic digestion is highly sensitive to feed quality and any impurity can upset the entire plant. Aerobic digestion leads to heavy metals leaching into the final compost due to presence of impurities and makes it unfit for use on agricultural soils. In such a situation the role of waste to energy technologies and sanitary landfilling increases significantly. This is due to the flexibility of waste-to-energy technologies in handling mixed wastes. Sanitary landfilling needs to be practiced to avoid negative impacts of open dumping and open burning of wastes on public health, and on air, water and land resources. Therefore, increasing source separation rates is always the long term priority.

Table 6, Composition of MSW in India and Regional Variation

Region/City	MSW (TPD)	Compostables (%)	Recyclables (%)	Inerts (%)	Moisture (%)	Cal. Value (MJ/kg)	Cal. Value (kcal/kg)
Metros	51,402	50.89	16.28	32.82	46	6.4	1,523
Other cities	2,723	51.91	19.23	28.86	49	8.7	2,084
East India	380	50.41	21.44	28.15	46	9.8	2,341
North India	6,835	52.38	16.78	30.85	49	6.8	1,623
South India	2,343	53.41	17.02	29.57	51	7.6	1,827
West India	380	50.41	21.44	28.15	46	9.8	2,341
Overall Urban India	130,000	51.3	17.48	31.21	47	7.3	1,751

1.4.1.1 PERCENTAGE OF RECYCLABLES AND INFORMAL RECYCLING

A significant amount of recyclables are separated from MSW prior to and after formal collection by the informal recycling sector. The amount of recyclables separated by the informal sector after formal collection is as much as 21% (Appendix 6). The amount of recyclables separated prior to collection is generally not accounted for by the formal sector and could be as much as four times the amount of recyclables separated after formal collection. Comparing the percentage of recyclables in MSW in metro cities with that in smaller cities clearly shows the increased activity of informal sector in metros and other large cities. Increased presence of informal sector in large cities explains the huge difference in recyclables composition between large and small cities, observed by Perinaz Bhada, et al. (15). In metro cities, which generally have a robust presence of informal recycling sector, the amount of recyclables at the dump is 16.28%, whereas in smaller cities where the presence of informal sector is smaller, the composition of recyclables is 19.23%. The difference of 3% in the amount of recyclables at the dump indicates the higher number of waste pickers and their activity in larger cities.

1.5 ECONOMIC GROWTH, CHANGE IN LIFE STYLES AND EFFECT ON MSW

The waste generation rate generally increases with increase in GDP during the initial stages of economic development of a country (16), because increase in GDP increases the purchasing power of a country which in turn causes changes in lifestyle. Even a slight increase in income in urban areas of developing countries can cause a few changes in lifestyle, food habits and living standards and at the same time changes in consumption patterns (16). Therefore, high income countries generate more waste per person compared to low income countries due to the difference in lifestyles.

1.5.1 IMPACT ON MSW GENERATION AND COMPOSITION IN INDIA

Since economic reforms in 1992 – 1993, India has undergone rapid urbanization, which changed material consumption patterns, and increased the per capita waste generation rate. Since 2011, India underwent unprecedented economic growth and the urban per capita waste generation increased from 440 grams/day to 500 grams/day at a decadal per capita waste generation growth rate of 13.6%.

The change in lifestyles has caused considerable change in the composition of MSW generated in India too. Following a trend expected during the economic growth of a country, the percentage of plastics, paper and metal discarded into the waste stream increased significantly and the amount of inerts in the collected waste stream decreased likewise due to changes in collection systems.

From 1973 to 1995, the composition of inerts in MSW decreased by 9%, whereas organic matter increased by 1% and recyclables increased by 8% (Figure 7). However, from 1995 to 2005, inerts decreased by 11%, compostables increased by 10% and recyclables by only 1%. The increase in compostables and recyclables observed (Figure 7) is due to a) increase in recyclable wastes generated due to lifestyle changes, and b) decrease in the overall percentage of inerts due to improvement in collection.

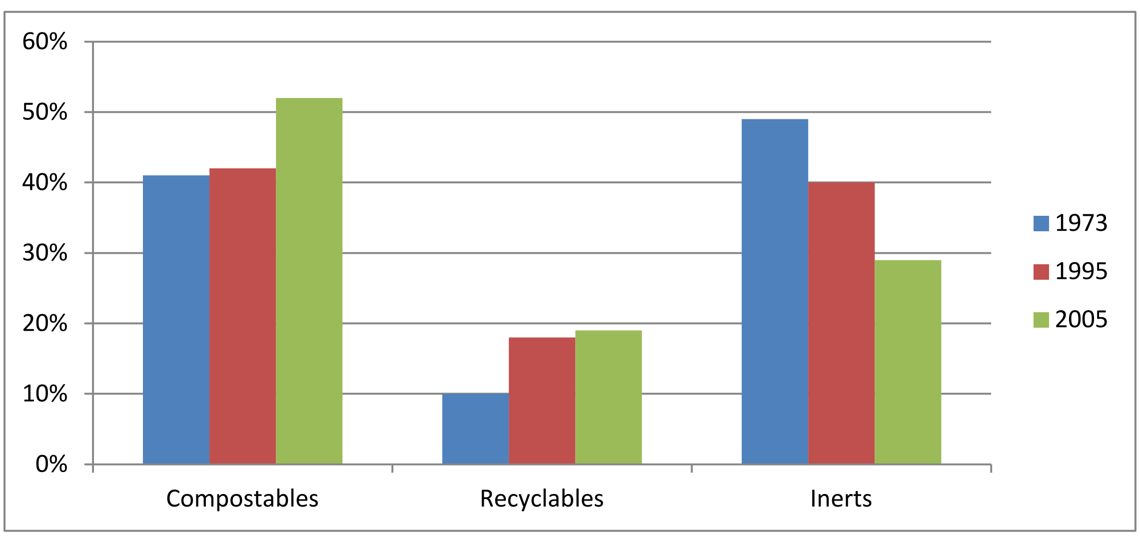


Figure 7, Change in Composition of Indian MSW since 1973, through 1995 and 2005

1.6 POPULATION

India is the second most populous nation on the planet. The Census of 2011 estimates a population of 1.21 billion which is 17.66% of the world population. It is as much as the combined population of USA, Indonesia, Brazil, Pakistan, Bangladesh and Japan. The population of Uttar Pradesh, one among 28 Indian states is greater than that of Brazil, the fifth most populous nation in the world. India's urban population was 285 million in 2001 and increased by 31.8% to 377 million in 2011. Indian urban population is greater than the total population of USA (308.7 million), the third most populous nation.

Appendix 1 lists 366 cities which represent 70% of India's urban population and generate 130,000 TPD or 47.2 million TPY at a per capita waste generation rate of 500 grams/day. This implies the total MSW generated by urban India could be as much as 188,500 TPD or 68.8 million TPY. This number matches the projection (65 million TPY in 2010) by Sunil Kumar, et al. (17). Therefore, this report assumes that the quantum of waste generated by urban India to be 68.8 million TPY. The general consensus on amount of waste generated by urban India is 50 million TPY, which is a very low in comparison to the current findings.

The six metro cities, Kolkata, Mumbai, Delhi, Chennai, Hyderabad and Bengaluru together generate 48,000 TPD (17.5 million TPY) of MSW. Currently, India has 53 cities with populations greater than one million, generating 86,245 TPD (31.5 million TPY), which is about 46 % of the total MSW generated in urban India. The remaining 313 cities studied generate 15.7 million TPY (43,000 TPD), 23% of the total urban MSW, only half of that generated by the 53 cities with million plus population.

1.6.1 POPULATION GROWTH

Indian population increased by more than 181 million during 2001 – 2011, a 17.64% increase in population, since 2001. Even though this was the sharpest decline in population growth rate registered post-Independence the absolute addition during 2001-2011 is almost as much as the population of Brazil, the fifth most populous country in the world.

It is clear that the scale of populations dealt with in case of India and China are entirely different from any other country in the world. The third most populous nation after China and India is US, with a population of 308.7 million, which is only a quarter of India's population. Urban population in India alone, which is 377 million, exceeds this figure. Indian urban population increased by 31.8 % during 2001 – 2011, which implies an annual growth rate of 2.8% during this period.

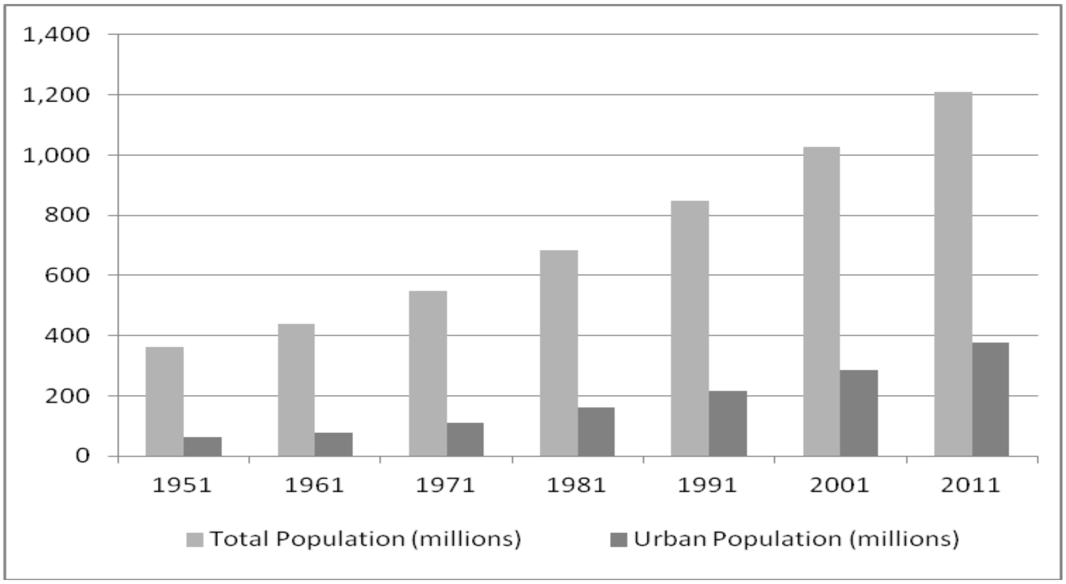


Figure 8, Total Population and Urban Population Growth in India

Urban population growth in India has always been higher than the overall population growth as can be seen in Figure 8, implying a trend of urbanization. Compared to the steady decrease in the percentage of urbanization during 1981 – 2001, the value stabilized during the past two decades, 1991 – 2011 (Figure 9). The urban population growth in the past decade increased the quantum of wastes generated by urban India by 50%.

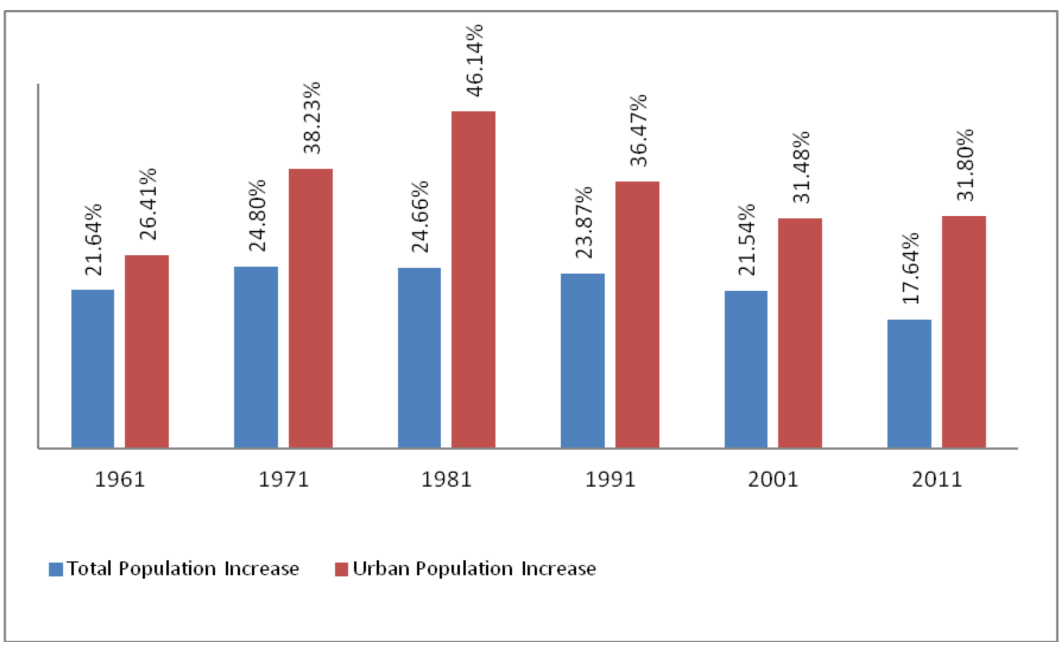


Figure 9, Trend of Urbanization in India

1.6.2 IMPACT ON MSW GENERATION AND DISPOSAL

Population growth and rapid urbanization means bigger and denser cities and increased MSW generation in each city. The data compiled for this report indicate that 366 cities in India were generating 31.6 million tons of waste in 2001 and are currently generating 47.3 million tons, a 50% increase in one decade. It is estimated that these 366 cities will generate 161 million tons of MSW in 2041, a five-fold increase in four decades. At this rate the total urban MSW generated in 2041 would be 230 million TPY (630,000 TPD).

Table 7, Population Growth and Impact on Overall Urban Waste Generation and Future Predictions until 2041

Year	Population (Millions)	Per Capita	Total Waste generation Thousand Tons/year
2001	197.3	0.439	31.63
2011	260.1	0.498	47.30
2021	342.8	0.569	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

MSW Rules 2000 mandate "landfills should always be located away from habitation clusters and other places of social, economic or environmental importance", which implies lands outside the city. Therefore, increase in MSW will have significant impacts in terms of land required for disposing the waste as it gets more difficult to site landfills (7). Farther the landfill gets from the point of waste generation (city), greater will be the waste transportation cost. The solution to reducing these costs and alternatives to landfilling are discussed in detail in further sections.

Table 8, Area of Land Occupied/Required for unsanitary disposal of MSW

Year	Area of Land Occupied/Required for MSW Disposal (sq.km)	City Equivalents
1947 - 2001	240	50% of Mumbai
1947 - 2011	380	90% of Chennai
1947 - 2021	590	Hyderabad
2009 - 2047	1,400	Hyderabad + Mumbai + Chennai

A 1998 study by TERI (The Energy Resources Institute, earlier Tata Energy Research Institute) titled 'Solid Waste Management in India: options and opportunities' calculated the amount of land that was occupied by waste disposed post independence, until 1997. The study compared the land occupied in multiples of the size of a football field and arrived at 71,000 football fields of solid waste, stacked 9 meters high. Based on a business as usual (BAU) scenario of 91% landfilling, the study estimates that the waste generated by 2001 would have occupied 240 sq.km or an area half the size of Mumbai; waste generated by 2011 would have occupied 380 sq.km or about 220,000 football fields or 90% of Chennai, the fourth biggest Indian city area-wise; waste generated by 2021 would need 590 sq.km which is greater than the area of Hyderabad (583 sq.km), the largest Indian city, area-wise (18) (19). The Position Paper on The Solid Waste Management Sector in India, published by Ministry of Finance in 2009, estimates a requirement of more than 1400 sq.km of land for solid waste disposal by the end of 2047 if MSW is not properly handled and is equal to the area of Hyderabad, Mumbai and Chennai together.

2 HIERARCHY OF SUSTAINABLE WASTE MANAGEMENT

The Hierarchy of Sustainable Waste Management (Figure 10) developed by the Earth Engineering Center at Columbia University is widely used as a reference to sustainable solid waste management and disposal. This report is presented in reference to this hierarchy. For the specific purpose of this study, "Unsanitary Landfilling and Open Burning" has been added to the original hierarchy of waste management which ends with sanitary landfills (SLFs). Unsanitary landfilling and open burning will represent the indiscriminate dumping and burning of MSW and represents the general situation of SWM in India and other developing countries.

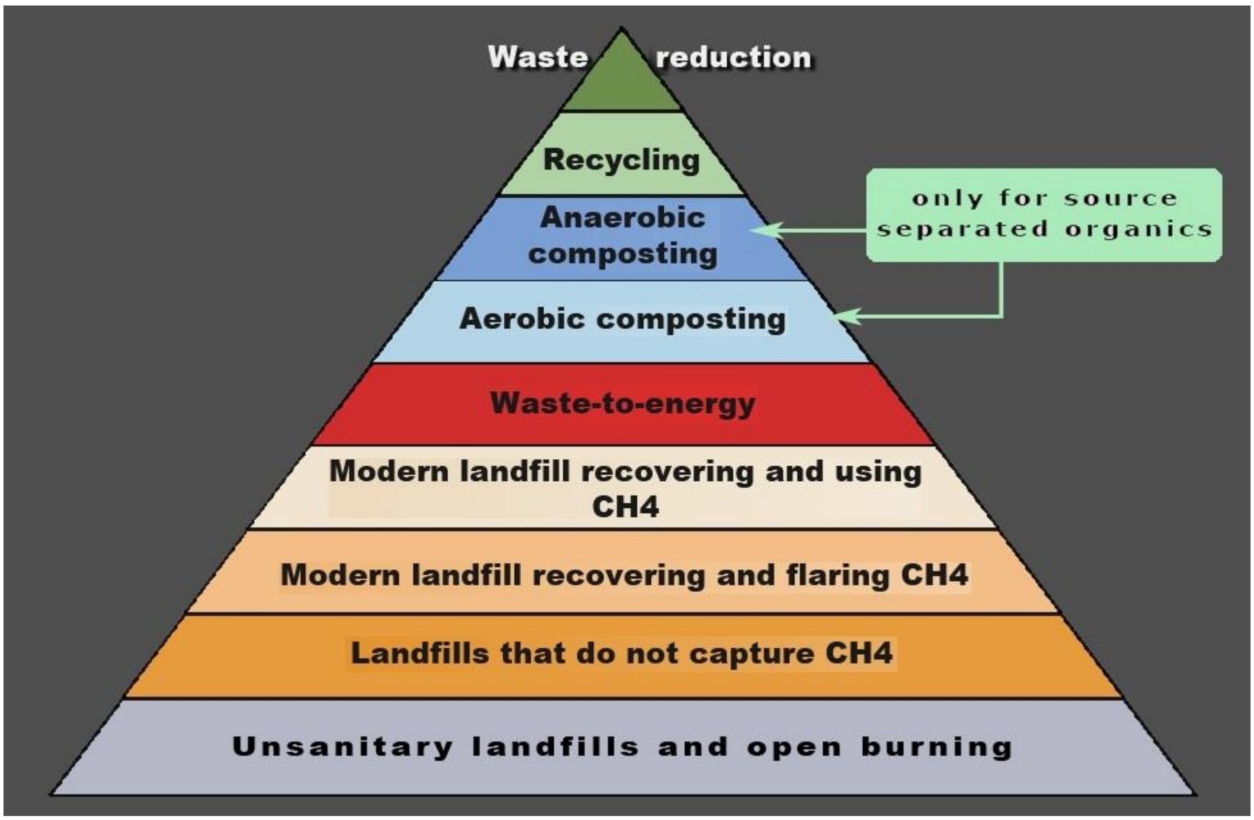


Figure 10, Hierarchy of Sustainable Waste Management

The hierarchy of waste management recognizes that reducing the use of materials and reusing them to be the most environmental friendly. Source reduction begins with reducing the amount of waste generated and reusing materials to prevent them from entering the waste stream (15). Thus, waste is not generated until the end of "reuse" phase. Once the waste is generated, it needs to be collected. Material recovery from waste in the form of recycling and composting is recognized to be the most effective way of handling wastes. Due to technical and economic limitations of recycling; product design; inadequate source separation; and lack of sufficient markets that can use all sorted materials, most of the MSW generated in India ends up in landfills. Local authorities should start working with their partners to promote source separation. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are and will be generated in the future (20). A sustainable solution to handle non-recyclable waste is energy recovery. Energy recovery from wastes falls below material recovery. Landfilling of MSW is equivalent to burying natural resources which could be used as secondary raw materials or as sources of energy. However, in the present society, landfills are required as a small fraction of wastes will have to be landfilled. However, unsanitary landfilling or open dumping of wastes is not considered as an option to handle MSW and is not at all recommended.

2.3 MATERIAL RECOVERY

2.3.1 RECYCLING

Reducing and reusing are the most effective ways to prevent generation of wastes. Once the wastes are generated and collected, the best alternative to handle them would be recycling where the materials generally undergo a chemical transformation. Sometimes, reusing can also happen after collection, in cases where informal traders collect materials of no use from households, reshape or repair them and sell in second-hand markets. Unlike reusing a used material, recycling involves using the waste as raw material to make new products. Recycling thus offsets the use of virgin raw materials.

It is known that as much as 95% of a product's environmental impact occurs before its discarded (21), most of it during its manufacturing and extraction of virgin raw materials. Thus, recycling is pivotal in reducing the overall life cycle impacts of a material on environment and public health. Recycling however requires a separated stream of waste, whether source separated or separated later on (after collection).

Due to the limitations for source separation (See Section 5.6), wastes are collected in a mixed form which is referred to as municipal solid waste (MSW). Once the wastes are mixed it becomes difficult to separate them. Recyclables can still be separated manually to some extent. Such separation and sale of recyclables from mixed wastes provides livelihood to marginalized urban populations in low and middle income countries. High income countries use machines to do the same but they would need the recyclables to be collected as a separate dry stream without mixing with organic food wastes.

The separated stocks of paper, plastic, glass and metal can then be recycled. A hundred percent separation of these materials from MSW is highly energy and time intensive and is generally not carried out. Therefore, mixing of waste will always result in a fraction of residues, which can neither be recycled nor composted and needs to be combusted in RDF or WTE plants to avoid landfilling, and generate energy.

Refer to Section 5.1.1 to check conformance of present recycling system in India with the hierarchy of sustainable waste management.

2.3.2 AEROBIC COMPOSTING

Similar to the recycling of inorganic materials, source separated organic wastes can be composted and the compost obtained can be used as an organic fertilizer on agricultural fields. Organic compost is rich in plant macro nutrients like Nitrogen, Phosphorous and Potassium, and other essential micro nutrients. Advantages of using organic manure in agriculture are well established and are a part of public knowledge.

Box 1, SOURCES OF URBAN ORGANIC WASTES

- Household waste
- Food waste from restaurants, hotels and food joints
- Vegetable market & slaughterhouse waste
- Livestock & poultry waste
- Sewage sludge

United Nations Environment Program (UNEP) defines composting as the biological decomposition of biodegradable solid waste under predominantly aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture. Composting can also be defined as human intervention into the natural process of decomposition as noted by Cornell Waste Management Institute. The biological decomposition accomplished by microbes during the process involves oxidation of carbon present in the organic waste. Energy released during oxidation is the cause for rise in temperatures in windrows during composting. Due to this energy loss, aerobic composting falls below anaerobic composting on the hierarchy of waste management. Anaerobic composting recovers energy and compost and is discussed in detail in Section 2.4.1. Life cycle impacts of extracting virgin raw materials and manufacturing make material recovery options like recycling and composting the most environment friendly methods to handle waste. They are positioned higher on the hierarchy compared to other beneficial waste handling options like energy recovery. However, quality of the compost product depends upon the quality of input waste. Composting mixed wastes results in low quality compost, which is less beneficial and has the potential to introduce heavy metals into human food chain.

Aerobic composting of mixed waste results in a compost contaminated by organic and inorganic materials, mainly heavy metals. Contamination of MSW compost by heavy metals can cause harm to public health and environment and is the major concern leading to its restricted agricultural use (22). Mixed waste composting is therefore not an option for sustainable waste management, but this issue is not a part of public knowledge. Mixed waste composting is widely practiced and is considered better (if not best) (8) in countries like India where more than 91% of MSW is landfilled and there are no other alternatives. It is considered better probably because public health and environmental impacts of unsanitary landfilling are more firmly established by research than those impacts due to heavy metal contamination of MSW compost.

Refer to Section 5.2.1 to check the conformance of aerobic composting and mechanical biological treatment in India with the hierarchy of sustainable waste management.

2.4 ENERGY RECOVERY

Energy requirements of a community can be satiated to some extent by energy recovery from wastes as a better alternative to landfilling. Energy recovery is a method of recovering the chemical energy in MSW. Chemical energy stored in wastes is a fraction of input energy expended in making those materials. Due to the difference in resources (materials/energy) that can be recovered, energy recovery falls below material recovery on the hierarchy of waste management.

2.4.1 ANAEROBIC DIGESTION

The USEPA defines Anaerobic Digestion (AD) as a process where microorganisms break down organic materials, such as food scraps, manure and sewage sludge, in the absence of oxygen. In the context of SWM, anaerobic digestion (also called Anaerobic Composting or Biomethanation) is a method to treat source separated organic waste to recover energy in the form of biogas, and compost in the form of a liquid residual. Biogas consists of methane and carbon dioxide and can be used as fuel or, by using a generator it can be converted to electricity on-site. The liquid slurry can be used as organic fertilizer. The ability to recover energy and compost from organics puts AD above aerobic composting on the hierarchy of waste management.

Similar to aerobic composting, AD needs a feed stream of source separated organic wastes. AD of mixed wastes is not recommended because contaminants in the feed can upset the process. Lack of source separated collection systems, and public awareness and involvement strike off large scale AD from feasible SWM options in India. However, AD on a small scale (called small scale biogas) has emerged as an efficient and decentralized method of renewable energy generation, and waste diversion from landfills. It also reduces green house gas emissions by using methane as an energy source which would otherwise be emitted from landfilling waste.

Refer to Section 5.3 to check the conformance of small scale anaerobic digestion in India with the hierarchy of sustainable waste management.

2.4.2 REFUSE DERIVED FUEL (RDF)

Refuse Derived Fuel refers to the segregated high calorific fraction of processed MSW. RDF can be defined as the final product from waste materials which have been processed to fulfill guideline, regulatory or industry specifications mainly to achieve a high calorific value to be useful as secondary/substitute fuels in the solid fuel industry (23). RDF is mainly used as a substitute to coal (a fossil fuel) in high-energy industrial processes like power production, cement kilns, steel manufacturing, etc, where RDF's use can be optimized to enhance economic performance (23).

The organic fraction (including paper) in RDF is considered to be a bio-fuel and is thus renewable. Since the carbon dioxide released by burning the organic fraction of RDF arises from plant and animal material, the net green house gas (GHG) emissions are zero (Section 4.7). The overall green house emissions from RDF are however not zero. This is due to carbon emissions from burning the plastics fraction left in RDF. The amount of GHG emissions from RDF depends upon the composition or organics and plastics in the MSW stream it is being processed from. Using RDF prevents GHG emissions from landfills, displaces fossil fuels, and reduces the volume of waste that needs to be landfilled, thus increasing their operating life.

On the hierarchy of waste management, RDF is placed below aerobic composting, as a waste to energy technology. It is a slight variant of the waste-to-energy combustion (WTE) technology, which combusts MSW (processed or as it is) to generate electricity. RDF is different because the objective is to increase the calorific value by processing the fuel.

Refer to Section 5.4 to check the conformance of RDF technology in India with the hierarchy of sustainable waste management.

2.4.3 WASTE-TO-ENERGY COMBUSTION (WTE)

Waste-to-Energy combustion (WTE) is defined as a process of controlled combustion, using an enclosed device to thermally breakdown combustible solid waste to an ash residue that contains little or no combustible material and that produces, electricity, steam or other energy as a result (24). Even though both WTE combustion and RDF combust MSW, the objective of WTE combustion is treating MSW to reduce its volume. Generating energy and electricity only adds value to this process.

As discussed in Section 2.4.1, combusting the organic fraction of MSW (a bio-fuel) and releasing carbon dioxide as the end product is a net zero emissions process (Section 4.7). Due to the dominance of organic waste in MSW, MSW is considered as a bio-fuel which can be replenished by agriculture. Also, bio-fuels are renewable. In India, urban MSW contains as much as 60% organic fraction and 10% paper. Therefore, potentially, 70% of energy from WTE plants is renewable energy. Therefore, WTE is recognized as a renewable energy technology by the Government of India (GOI). Australia, Denmark, Japan, Netherlands and the US also recognize WTE as a renewable energy technology (15).

Thermal waste to energy technologies are the only solutions to handling mixed wastes. In whatever way mixed wastes are treated, the impurities in it will pollute air, water and land resources. By aerobically composting mixed wastes, the heavy metals and other impurities leach into the compost and are distributed through the compost supply chain. In contrast, WTE is a point source pollution control technology, where the impurities in the input mixed waste are captured using extensive pollution control technologies (Table 18) and can be handled separately. The bottom ash from WTE combustion contains nothing but inert inorganic materials and minerals which could be used to make bricks and other construction material. The fly ash from WTE contains pollutants from the input stream and needs to be disposed off in sanitary landfills. By controlling the types of materials fed in to the boiler, European and Japanese WTE plants are known to have achieved nearly zero emissions in the fly ash too.

WTE combustion decreases the volume of wastes by up to 90%. Such reduction in volume would prolong the life of a 20 years landfill to 200 years. However, MSW should be combusted after all possible recycling and composting has been done. The input to WTE plants should be the rejects from material recovery and/or composting facilities. Such an integrated system can decrease the amount of wastes landfilled and prolong the life of landfills further. Therefore, WTE combustion is placed below recycling, aerobic and anaerobic digestion on the hierarchy of sustainable waste management.

Refer to Section 5.5 to check the conformance of WTE technology in India with the hierarchy of sustainable waste management.

2.5 SANITARY LANDFILLING

United Nations Environmental Program (UNEP) defines sanitary landfilling as the controlled disposal of wastes on land in such a way that contact between waste and the environment is significantly reduced and wastes are concentrated in a well defined area. Sanitary landfills (SLFs) are built to isolate wastes from the environment and render them innocuous through the biological, chemical and physical processes of nature. UNEP also recognizes three basic conditions to be fulfilled to be designated as an SLF:

a) Compaction of the wastes,
b) Daily covering of wastes (with soil or other material) and
c) Control and prevention of negative impacts on public health and environment.

On the hierarchy of waste management, sanitary landfilling is expanded into three different categories

a) SLFs recovering and using methane (CH_4)
b) SLFs recovering and flaring CH_4
c) SLFs without any CH_4 recovery

SLFs are categorized depending upon their ability to control and prevent negative impacts on environment, from a climate change perspective. They occupy the three positions after WTE technologies on the hierarchy of waste management (Figure 10). Handling CH_4 generated during anaerobic digestion of organics dictates where each type of landfill is placed on the hierarchy of waste management.

Organic waste in landfills undergoes both aerobic and anaerobic digestion depending upon oxygen availability. Majority of the waste on the top undergoes aerobic digestion due to greater oxygen availability. Waste which is inside SLFs undergoes anaerobic digestion due to reduced oxygen availability. The final gaseous product of aerobic digestion is CO_2, which results in a net zero emission (Section 4.7). However, the final gaseous product of anaerobic digestion is CH_4, which if captured can be used as a fuel, generating renewable energy and converting the carbon in CH_4 to CO_2, thus resulting in a net zero emissions.

In a business as usual scenario (BAU) in India and elsewhere, the CH_4 is let out into the atmosphere and not captured. CH_4 is a green house gas (GHG), with twenty one (21) times more global warming potential than CO_2 (over a long time period). Therefore, every CH_4 molecule released from a landfill has 21 times the potential to warm the planet than CO_2. Thus, capturing and flaring CH_4 is environmentally preferred to sanitary landfilling without capturing CH_4.

However, landfilling of materials should be the last option considered for disposing wastes in an integrated waste management system. Also, "currently, the implementation and practice of sanitary landfilling are severely constrained in economically developing countries (like India) by the lack of reliable information specific to these countries" (25).

2.6 UNSANITARY LANDFILLING AND OPEN DUMPING

There is no specific definition for unsanitary landfilling. However, it is generally characterized by open dumping of wastes, lack of monitoring of the site, stray animals and birds feeding on the wastes, absence of leachate or methane collection systems and wastes exposed to natural elements.

The direct implications of landfilling include burying materials which were extracted by energy and infrastructure intensive and in most cases environmentally harmful methods and in turn depleting earth's natural resources. From an energy recovery perspective, landfilling is equivalent to burying barrels of oil. Apart from these moral implications, landfilling causes extensive public health and environmental damage. Landfills create unsanitary conditions in the surroundings, attract pests and directly impact human health. Unsanitary landfills also contaminate ground and surface water resources when the leachate produced percolates to the water table or is washed as runoff during rains. Unmonitored landfills catch fires due to methane generation and heat and result in uncontrolled combustion of wastes, releasing harmful gases like carbon monoxide, hydrocarbons and particulate matter into low level atmosphere. In addition to these harmful impacts, unsanitary landfills contribute to Climate Change by releasing methane, a green house gas (GHG) with 21 times more global warming potential than carbon dioxide (in the first year of release, methane is 71 times more potent than carbon dioxide as a GHG).

3 STATUS OF CURRENT WASTE HANDLING PRACTICES IN INDIA

Table 9, Status of Present Waste Handling Techniques in India

S.No	City	MSW Generated (TPD)	*Composting*	*RDF/ WTE*	*LFG recovery*	*Sanitary Landfill*	*Earth Cover*	*Alignment/ Compaction*	*Uncontrolled Dumping*	*Biomethanation*
1	Greater Kolkata	12,060	700	NO	NO	NO	YES	NO	YES	NO
2	Greater Mumbai	11,645	370	80*	YES	NO	YES	YES	YES	YES
3	Delhi	11,558	825	NO	NO	NO	NO	YES	YES	YES
4	Chennai	6,404	YES	NO	NO	NO	YES	NO	YES	NO
5	Greater Hyderabad	5,154	40*	700*	NO	NO	NO	YES	YES	NO
6	Greater Bengaluru	3,501	450	NO	NO	NO	NO	NO	YES	NO
7	Pune	2,724	600	NO	YES	YES	YES	YES	YES	YES
8	Ahmadabad	2,636	YES	NO	NO	YES	YES	YES	YES	NO
9	Kanpur	1,839	YES	NO	NO	NO	YES	NO	YES	NO
10	Surat	1,815	YES	NO	NO	YES	YES	YES	YES	NO
11	Kochi	1,431	YES	NO	NO	NO	NO	NO	YES	20**
12	Jaipur	1,426	NO	500	NO	NO	YES	YES	YES	NO
13	Coimbatore	1,311	YES	NO	NO	NO	YES	NO	YES	NO
14	Greater Visakhapatnam	1,250	NO	NO	NO	NO	NO	YES	YES	NO
15	Ludhiana	1,167	NO	NO	NO	NO	NO	NO	YES	NO
16	Agra	1,069	NO	NO	YES	NO	NO	YES	YES	NO
17	Patna	989	YES	NO	NO	NO	NO	NO	YES	NO
18	Bhopal	919	100	NO	NO	NO	NO	YES	YES	NO
19	Indore	908	YES	NO	NO	NO	NO	YES	YES	NO
20	Allahabad	853	NO	NO	NO	NO	YES	YES	YES	YES
21	Meerut	841	NO	NO	NO	NO	NO	NO	YES	NO
22	Nagpur	838	YES	NO	NO	NO	NO	NO	YES	NO
23	Jodhpur	825	216	NO	NO	YES	YES	YES	YES	NO
24	Lucknow	778	YES	NO	NO	NO	NO	YES	YES	YES*
25	Srinagar	747	YES	NO	NO	NO	NO	NO	YES	NO
26	Varanasi	739	NO	NO	NO	NO	NO	NO	YES	NO
27	Vijayawada	720	YES	225*	NO	NO	NO	YES	YES	YES
28	Amritsar	711	NO	NO	NO	NO	YES	YES	YES	NO
29	Aurangabad	702	YES	NO	NO	NO	NO	NO	YES	NO
30	Faridabad	698	NO	NO	NO	NO	NO	NO	YES	NO
31	Vadodara	634	YES	NO	NO	NO	YES	NO	YES	NO

S.No	City	MSW Generated (TPD)	*Composting*	*RDF/ WTE*	*LFG recovery*	*Sanitary Landfill*	*Earth Cover*	*Alignment/ Compaction*	*Uncontrolled Dumping*	*Biomethanation*
32	Mysore	578	YES	NO	NO	NO	NO	NO	YES	NO
33	Madurai	568	NO	NO	NO	NO	NO	NO	YES	NO
34	Pimpri Chinchwad	567	YES	NO	NO	NO	NO	NO	YES	NO
35	Jammu	559	NO	NO	NO	NO	NO	NO	YES	NO
36	Jalandhar	554	350	NO	NO	NO	NO	NO	YES	NO
37	Jamshedpur	539	40	NO	NO	NO	YES	YES	YES	NO
38	Chandigarh	509	YES	500	NO	YES	YES	YES	YES	YES
39	Bhiwandi	489	YES	NO	NO	NO	NO	NO	YES	NO
40	Gwalior	477	120	NO	NO	NO	NO	NO	YES	NO
41	Tiruppur	462	YES	NO	NO	NO	NO	NO	YES	NO
42	Navi Mumbai	455	NO	NO	NO	YES	YES	YES	YES	NO
43	Mangalore	424	NO	NO	NO	YES	YES	YES	YES	NO
44	Jabalpur	398	NO	NO	NO	NO	NO	NO	YES	NO
45	Bhubaneswar	373	NO	NO	NO	NO	NO	NO	YES	NO
46	Nashik	345	300	NO	NO	YES	YES	YES	YES	NO
47	Ranchi	340	NO	NO	NO	NO	NO	NO	YES	NO
48	Rajkot	332	YES	300*	NO	NO	YES	NO	YES	NO
49	Raipur	331	YES	NO	NO	NO	NO	NO	YES	NO
50	Thiruvananthapuram	322	150	NO	NO	NO	YES	YES	YES	20 **
51	Guntur	313	NO	275*	NO	NO	NO	NO	YES	NO
52	Kolhapur	305	YES	NO	NO	NO	NO	NO	YES	NO
53	Bhavnagar	266	YES	NO	NO	NO	NO	NO	YES	NO
54	Udaipur	264	YES	NO	NO	NO	NO	NO	YES	NO
55	Dehradun	259	NO	NO	NO	NO	YES	YES	YES	NO
56	Guwahati	258	NO	NO	NO	NO	NO	YES	YES	NO
57	Jalgaon	208	100	NO	NO	NO	NO	NO	YES	NO
	TOTAL TONNAGE	**64,845**	4,361	1,680						
	Count		38	6	3	8	21	24	59	9

This report has updated the "Status of Cities and state capitals in implementation of MSW (Management and Handling) Rules, 2000", jointly published by the Central Pollution Control Board (CPCB) and the National Environmental Engineering Research Institute (NEERI), with respect to waste disposal options. The original table was published by Sunil Kumar, et al. in the paper "Assessment of the Status of Municipal Solid Waste Management in Metro Cities, State Capitals, Class I Cities and Class II Towns in India: An Insight" (1). This updated table contains only those cities which generate MSW greater than 200 TPD and have taken significant steps towards proper SWM.

Informal recycling has not been included in this table. Most of the recyclable waste is collected by the informal recycling sector in India before it is collected by the formal system. It is assumed that informal waste picking happens in all Indian cities to some extent (Kochi is an exception due to labor laws which prohibit waste picking). Also, the exact percentage of recycling in each of these cities is unknown. However, it is estimated that the informal sector recycles as much as 56% of recyclables generated in large cities and metros, (See Section 5.1.1). The recycling percentage is lower in smaller cities as was observed by Perinaz Bhada, et al (15).

3.1 COMPOSTING OR MECHANICAL BIOLOGICAL TREATMENT (MBT)

On an average, 6% of MSW collected is composted in mechanical biological treatment (MBT) plants across India. MBT is the most widely employed technology to handle MSW in India. Currently, there are more than 70 composting plants in India treating mixed MSW, most of them located in the states of Maharashtra (19), Himachal Pradesh (11), Chhattisgarh (9) and Orissa (7) (Appendix 8). More than 26 new plants are proposed in different cities and towns across India. The first 10 MBT plants built in India are however not in operation anymore.

Out of the 57 cities which generate MSW above 200 TPD, 38 cities have composting plants, which treat more than 4,361 TPD of MSW. Table 9 is therefore the first such effort which accounts for about 40% of the current MSW composting capacity in India.

Almost all composting/MBT facilities handle mixed wastes. The only known plants which handle source separated organic wastes are in Vijayawada and Suryapet (26). Since almost all these plants handle mixed solid wastes, the percentage of rejects which go to the landfill is very high. During the author's research visit in India, it was observed that only 6-7% of the input MSW is converted into compost. Accounting for moisture and material losses, the remaining 60% which cannot be composted any further is landfilled despite its high energy content (See Section 5.2.4)

3.2 REFUSE DERIVED FUEL (RDF)

There are 6 RDF plants in India, near Hyderabad, Vijayawada, Jaipur, Chandigarh, Mumbai and Rajkot. The plant in Vijayawada used to serve the city of Guntur too. The Hyderabad and Vijayawada plants handled 700 TPD and 500 TPD of MSW to generate 6 MW of electricity respectively. RDF produced in these plants was combusted in specifically designed WTE boilers. The author visited one of these plants and found out that both these facilities are currently not in operation.

The RDF plants near Jaipur and Chandigarh combust the RDF produced in cement kilns to replace fossil fuels. They handle 500 TPD of MSW each. The author visited the plant in Jaipur and found that it is not operated regularly. The plant in Chandigarh is known to have been dormant too, but it is being retrofitted with MSW drying systems to reduce moisture in the final RDF.

The RDF plant in Rajkot handles 300 TPD of waste. Other than this information, there is not much known about this plant; its present operational status is unknown too. It is the same case with the small scale RDF plant in Mumbai, which produces RDF pellets by processing 80 TPD of MSW (See Section 5.4).

3.3 WASTE-TO-ENERGY COMBUSTION (WTE)

There are no WTE mass burn combustion plants currently in operation in India. Only two such plants were built in India until now. The latest one among them has finished construction on the Okhla landfill site, New Delhi and is about to start operations. An earlier WTE plant, which was built in Timarpur, New Delhi is not in operation anymore. The two WTE plants in Hyderabad and Vijayawada are not mass burn combustion. They combust RDF produced after considerable processing of MSW, and addition of secondary biomass fuels like rice husk. Therefore they are RDF-WTE plants.

3.4 SANITARY LANDFILLS

On comparing Table 9 with the original publication (Comparison in Appendix 3), it was observed that the number of SLFs is gradually increasing. Eight cities now have SLFs as compared to zero SLFs out of 74 cities studied. The eight cities with SLFs are Pune, Ahmadabad, Surat, Jodhpur, Chandigarh, Navi Mumbai, Mangalore and Nashik. The author visited the landfill facility at Nashik and observed that there were no precautions taken to handle landfill fires, which were found to be common at the facility (See Section 4.2). In addition to the 8 cities with SLFs, an additional 13 (total 21) cities apply earth cover over the wastes dumped and an additional 15 cities (total 24) compact or align the wastes. The frequency of applying earth cover on wastes is not known.

LFG recovery from landfills has also been attempted at landfills in Mumbai and Pune. A study by USEPA's Methane to Markets program found methane recovery from only 7 landfills (in 4 cities) to be economically feasible (Table 10).

UNEP recommends "[sanitary landfilling] is well suited to developing countries (like India) as a means of managing the disposal of wastes because of the flexibility and relative simplicity of the technology". This recommendation does not take into consideration the high maintaining and operating costs of SLFs and the need for SWM projects to sustain themselves. Most sanitary landfills built in developing nations eventually fail due to high operating costs. A system where majority of the waste generated is planned to reach the landfill will lack robust cost recovery mechanisms. In such a case, the only cost recovery mechanism possible would be tipping fees, which will require increasing or levying user charges/taxes, which many ULBs cannot implement. Sanitary landfilling systems should be designed as an addition to recycling, composting or WTE facilities, which sustain themselves financially.

Table 10, Landfill Gas Recovery Feasibility in Indian Landfills; Source: Methane to Markets

Dumpsite Name	City	LFG Feasibility	Total Waste (million tons)	Area	Waste depth (m)	
					Minimum	**Maximum**
Okhla	Delhi	Yes	680,000	54	20	30
Karuvadikuppam	Pondicherry	No	637,732	7		
Deonar	Mumbai	Yes	12,700,000	120	3	22
Pirana	Ahmadabad	Yes	9,300,000	55	22.5	
Autonagar	Hyderabad	No	1,200,000	18.2	5	10
Uruli Devachi	Pune	No	280,000	22.5	5	12.5
Gorai	Mumbai	Yes	2,340,000	24	10.2	
Shadra	Agra	No	473,457	5	12	
Barikalan Dubagga	Lucknow	No	287,100	2.78	12.9	
Moti Jheel	Lucknow	No	288,500	3.3	8.8	
Bhalswa	Delhi	Yes	6,900,000	22.3	18	
Dhapa	Kolkata	Yes	11,000,000	31.5		30
Gazipur	New Delhi	Yes	10,000,000	25	25.5	
Count: 13	**9**	**7**				

4 IMPROPER SOLID WASTE MANAGEMENT (WASTE DISPOSAL)

ULBs spend about $10 – 30 (INR 500 – 1,500) per ton on SWM. About 60-70% of this amount is spent on collection, 20-30% on transportation. No financial resources are allotted for scientific disposal of waste (6) (7). Despite the fairly high expenditure, the present level of service in many urban areas is so low as to be a potential threat to the public health and environmental quality (4).

A guidance note titled " Municipal Solid Waste Management on a Regional Basis", by the Ministry of Urban Development (MOUD), Government of India (GOI) observes that "Compliance with the MSW Rules 2000 requires that appropriate systems and infrastructure facilities be put in place to undertake scientific collection, management, processing and disposal of MSW. However, authorities are unable to implement and sustain separate and independent projects to enable scientific collection, management, processing and disposal of MSW. This is mainly due to lack of financial and technical expertise and scarcity of resources, such as land and manpower."

Improper solid waste management deteriorates public health, degrades quality of life, and pollutes local air, water and land resources. It also causes global warming and climate change and impacts the entire planet. Improper waste management is also identified as a

BOX 2, IMPACTS OF IMPROPER SOLID WASTE MANAGEMENT

Sources: (21), CPCB

1. Improper solid waste management causes
    a. Air Pollution,
    b. Water Pollution and
    c. Soil Pollution.
2. MSW clogs drains, creating
    a. stagnant water for insect breeding and
    b. floods during rainy seasons
3. Greenhouse gases are generated from the decomposition of organic wastes in landfills.
4. Insect and rodent vectors are attracted to the waste and can spread diseases such as cholera and dengue fever.
5. Some Health Problems linked to improper solid waste management are,
    a. Nose & throat infections,
    b. Lung infection,
    c. Breathing problems,
    d. Infection, Inflammation,
    e. High PM10 exposure,
    f. High pollution load,
    g. Bacterial infections,
    h. Obstruction in airways,
    i. Elevated mucus production,
    j. Covert lung hemorrhage,
    k. Chromosome break,
    l. Anemia,
    m. Cardiovascular risk,
    n. Altered immunity,
    o. Allergy, asthma and
    p. Other infections.

cause of 22 human diseases (21) and results in numerous premature deaths every year.

Indiscriminate dumping of wastes and leachate from landfills contaminates surface and groundwater supplies and the surrounding land resources. It also clogs sewers and drains and leads to floods. Mumbai experienced a flood in 2006 which was partly due to clogged sewers. Insect and rodent vectors are attracted to MSW and can spread diseases such as cholera, dengue fever and plague. Using water polluted by solid waste for bathing, food irrigation, and as drinking water can also expose individuals to disease organisms and other contaminants (21). The city Surat has experienced a city-wide bubonic plague epidemic in 1994 due to improper SWM.

Open burning of MSW on streets and at landfills, along with landfill fires emit 22,000 tons of pollutants into the lower atmosphere of Mumbai city, every year. The pollutants identified in Mumbai due to uncontrolled burning of wastes are carbon monoxide (CO), carcinogenic hydro carbons (HC) (includes dioxins and furans), particulate matter (PM), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) (5).

MSW dumped in landfills also generates green house gases like methane, which has 21 times more global warming potential than carbon dioxide. Improper SWM contributes to 6% of India's methane emissions and is the third largest emitter of methane in India. This is much higher than the global average of 3% methane emissions from solid waste. It currently produces 16 million tons of CO_2 equivalents per year and this number is expected to rise to 20 million tons of CO_2 equivalents by 2020 (27).

The world is moving towards calling wastes as "resources". Due to the inability to manage these resources in the next decade, India will landfill 6.7 million tons of recyclables (or secondary raw materials); 9.6 million tons of compost (or organic fertilizer); and resources equivalent to 57.2 million barrels of oil.

Efforts towards proper SWM were made by ULBs equipped with financial and managerial capacity to improve waste management practices in response to MSW Rules 2000 (9). Despite these efforts to manage wastes, more than 91% of MSW collected is still landfilled or dumped on open lands and dumps (7), impacting public health, deteriorating quality of life and causing environmental pollution. It is estimated that about 2% of the uncollected wastes are burnt openly on the streets; and about 10% of the collected MSW is openly burnt in landfills or is caught in landfill fires (5) (See Section 4.2). The MSW collection efficiency in major metro cities still ranges between 70 - 90% of waste generated, whereas smaller cities and towns collect less than 50% of waste generated (6).

4.1 UNSANITARY LANDFILLING (DUMPING)

Figure 11, Open Dump near Jaipur: Half of Jaipur City's MSW Reaches this Site

Majority of the MSW collected in India is disposed off on open land or in unsanitary landfills (Figure 11). This is in addition to the irregular and incomplete waste collection and transportation in many cities, which leaves MSW on the streets. Many municipalities in India have not yet identified landfill sites in accordance with MSW Rules 2000. In several municipalities, existing landfill sites have been exhausted and the respective local bodies do not have resources to acquire new land. Such a lack of landfill sites decreases MSW collection efficiency (7). Unsanitary landfilling pollutes ground and surface waters, emits green house gases and other organic aerosols and pollutes the air. Pests and other vectors feeding on improperly disposed solid wastes is a nuisance and above that a breeding ground for disease causing organisms.

For land requirements to landfill MSW, see Section 4.4.

4.2 OPEN BURNING, LANDFILL FIRES & AIR QUALITY DETERIORATION

Open burning is the burning of any matter in such a manner that products of combustion resulting from the burning are emitted directly into the ambient (surrounding outside) air without passing through an adequate stack, duct or chimney (5). Open burning of wastes is practiced all over India due to reasons like

a) open burning by waste-pickers for recovery of metals from mixed wastes;
b) open burning in bins by municipal workers or residents to empty MSW collection bins(Figure 12);
c) open burning of plastic wastes by street dwellers for warmth at night (Figure 14).

In addition to open burning of wastes, landfill fires are also common at every landfill in India (Figure 13). Landfill fires were observed at Pimpri-Chinchwad (unsanitary), Nashik and Vishakhapatnam (unsanitary) landfills. They are caused due to the build-up of heat inside waste beds due to decomposing (aerobic or anaerobic) organic matter. Sometimes, these fires continue for weeks at a stretch, even after long showers.

Figure 12, Open Burning of MSW Inside a Garbage Bin on the Street in a High Density Residential Area in Hyderabad

Figure 13, Landfill Fire at a Sanitary Landfill in India

Figure 14, Waste Picker Burning Refuse for Warmth at Night, Chandini Chowk, Delhi

The author observed refuse being used as a fuel by street dwellers to keep warm during nights (Figure 14). Lit refuse fires were observed frequently in Delhi while author was touring the streets in late January, 2011. Refuse and other biomass burning have been on the rise, as large slum populations do not have adequate kerosene and LPG supply at affordable costs. Slum dwellers use all kind of combustible refuse for burning (5).

4.2.1 AIR EMISSIONS FROM OPEN BURNING AND LANDFILL FIRES

A 2010 study by NEERI, "Air Quality Assessment, Emissions Inventory and Source Apportionment Studies: Mumbai" found out that open burning and landfill fires are a major source of air pollution in Mumbai. The study found that about 2% of the total MSW generated in Mumbai is openly burnt on the streets and 10% of the total MSW generated is burnt in landfills by humans or due to landfill fires.

In Mumbai, open burning of MSW is (Appendix 4, Table 11, Figure 16, Figure 17, Figure 18, Figure 19)

1. the largest emitter of carbon monoxide (CO), particulate matter (PM), carcinogenic hydrocarbons (HC) and nitrous oxides (NO_x), among activities that do not add to the economy of the city;
2. the second largest emitter of hydrocarbons (HC);
3. the second largest emitter of particulate matter (PM);
4. the fourth largest emitter of carbon monoxide compared to all emissions sources in Mumbai; and
5. the third largest emitter of CO, PM and HC combined together in comparison to all emission sources in the city .

Open burning contributes to 19% of air pollution due to CO, PM and HC in Mumbai (Figure 19). More than twice as much particulate matter is emitted by open burning of MSW as compared to emissions from road transportation in Mumbai. Also, a quarter of volatile hydrocarbons entering the atmosphere in Mumbai are a result of such activity.

MSW is combusted on the streets, exposing millions of urban Indians directly to these emissions every day. MSW burning in the landfill happens in areas with lesser population but the activity emits pollutants into the lower atmosphere, where the dispersion of pollutants is very low, increasing the risk of exposure to these harmful emissions.

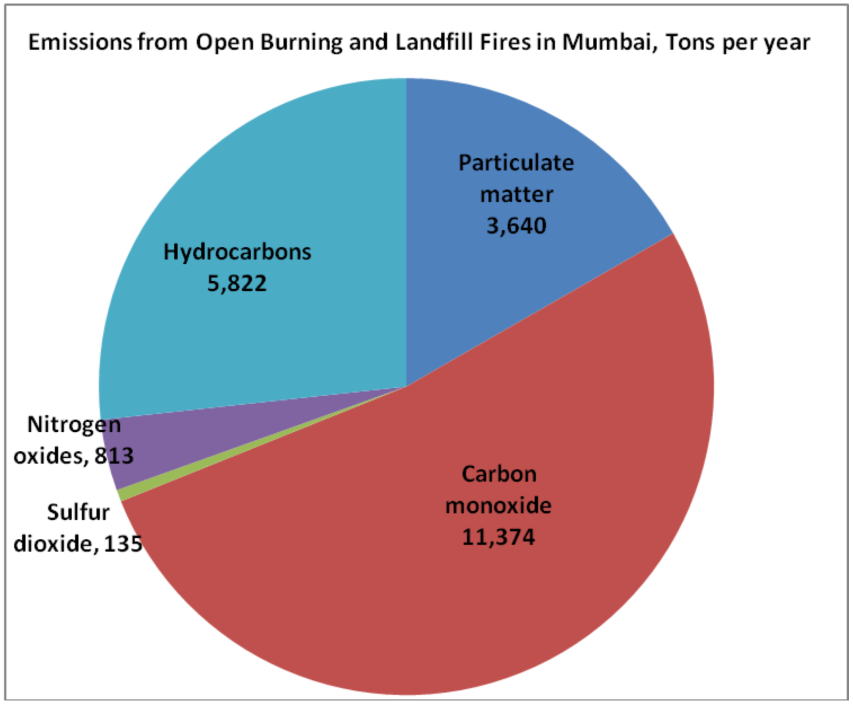


Figure 15, Open Burning of MSW Releases 22,000 tons per year of CO, HCs, PM, NOx, and SO2 into Mumbai's Lower Atmosphere

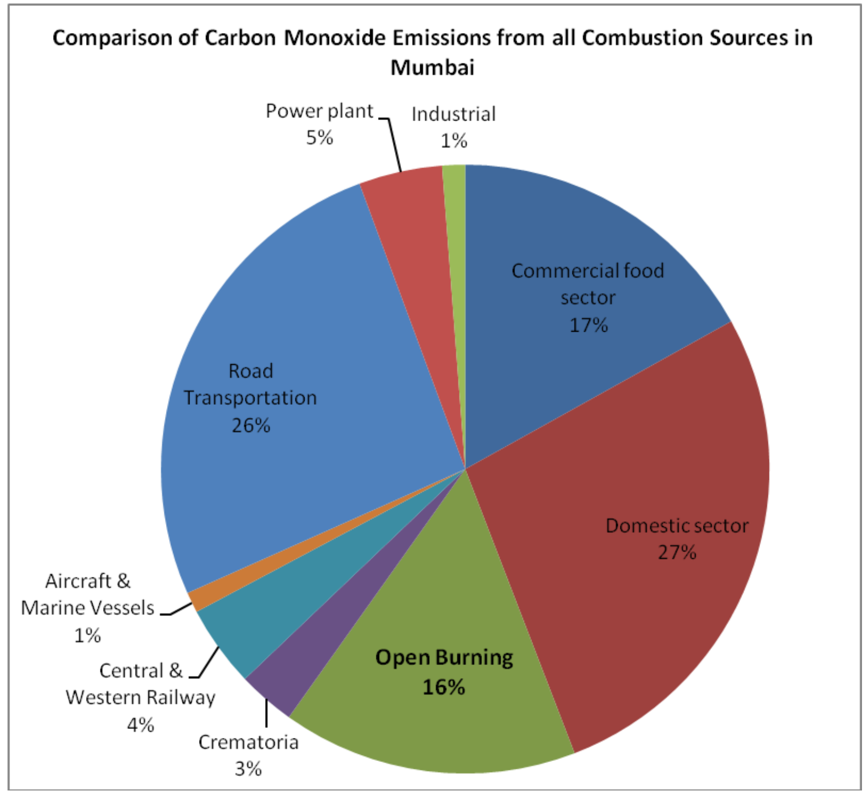


Figure 16, Open burning is a Major Contributor to Carbon Monoxide Pollution in Mumbai

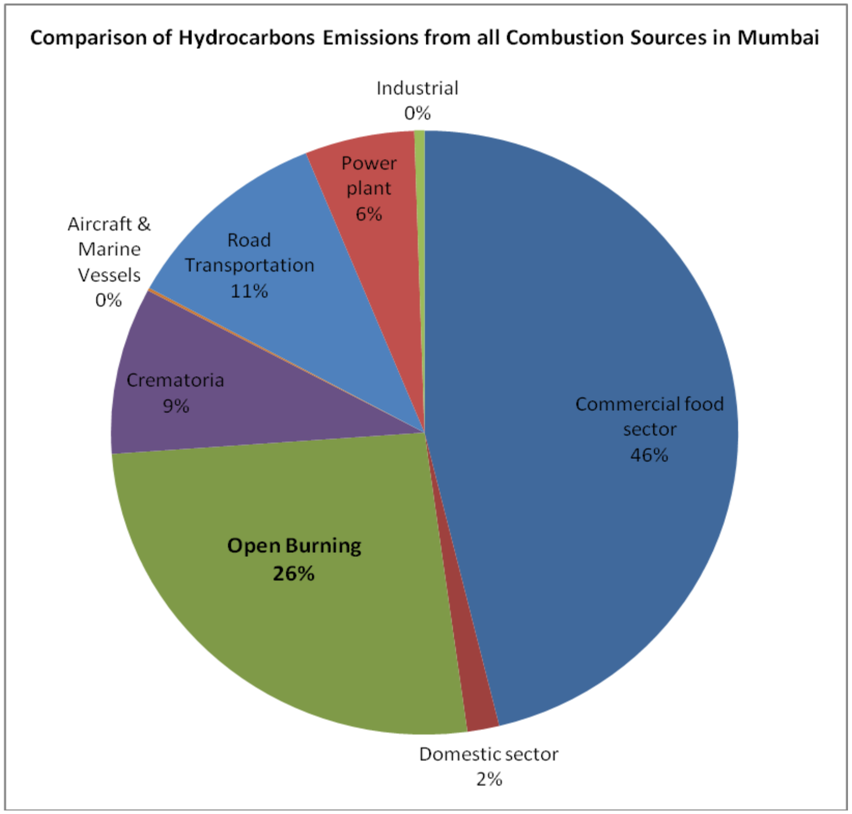


Figure 17, Open burning is the second largest contributor of Hydrocarbons in Mumbai's atmosphere

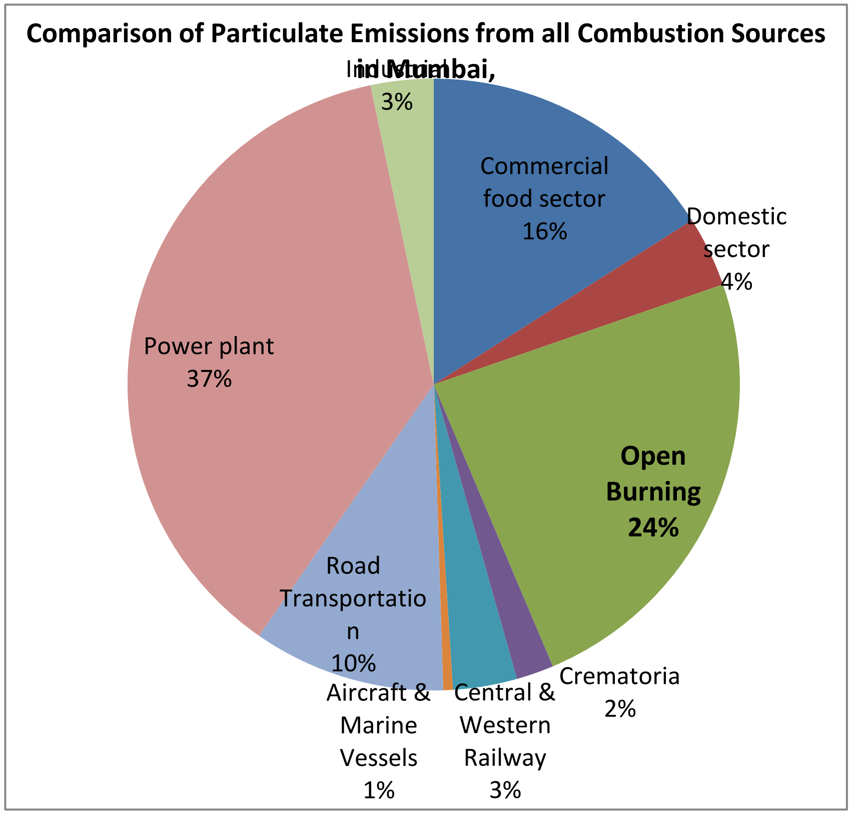


Figure 18, Open burning of MSW is the Second Largest Source of Particulate Matter Emissions in Mumbai, greater than Road Transportation

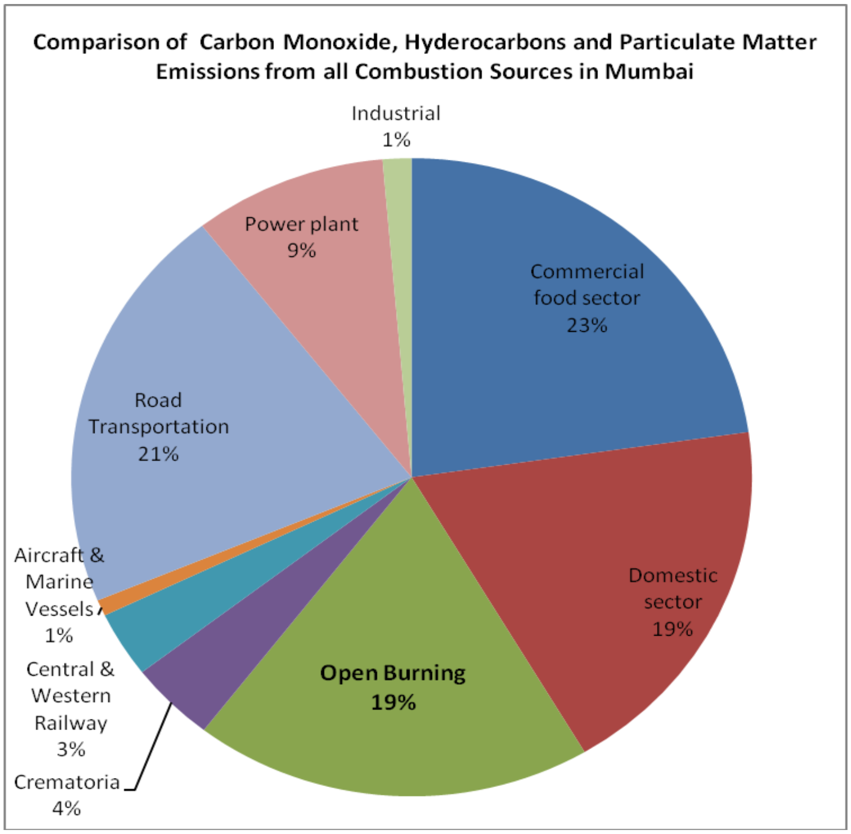


Figure 19, Open burning contributes to 19% of Mumbai's Air Pollution due to Carbon Monoxide, Hydrocarbons and Particulate Matter

Table 11, Air Emissions Inventory from Open burning and Other Combustion Sources in Mumbai; Source: CPCB, NEERI

Source of Emission	Emissions (tons/year)					
	PM	**CO**	**SO2**	**NOx**	**HC**	**Total**
Commercial food sector	2,429.3	12,271.1	315.4	628.5	10,312.9	**25,957**
Domestic sector	564.9	19,723.7	1,262.0	9,946.9	368.1	**31,866**
Open Burning	**3640**	**11374**	**135**	**813**	**5822**	**21,784**
Crematoria	300.7	2,213.0	7.9	44.4	1,991.9	**4,558**
Central & Western Railway	514.0	3,147.0	1,449.0	19,708.0		**24,818**
Aircraft & Marine Vessels	77.4	791.7	96.7	1,003.4	33.8	**2,003**
Road Transportation	1,544.8	18,856.2	606.4	13,203.1	2,427.1	**36,638**
Power plant	5,628.3	3,215.7	24,473.3	28,944.5	1,266.6	**63,528**
Industrial	503.7	879.7	28,510.2	8,435.2	116.8	**38,446**

The study identifies that open burning of MSW on streets and landfill sites need to be stopped immediately to increase air quality in Mumbai and points out the need for credible solutions to this problem. The study has calculated that 50% reduction in open burning and a 100% reduction in landfill fires are required to reduce PM pollution in Mumbai by 98%, along with many other initiatives.

4.2.2 DIOXINS/FURANS EMISSIONS

Open burning of MSW and landfill fires emit 10,000 grams of dioxins/furans into Mumbai's lower atmosphere every year (5) (28) (Appendix 14).

Dioxins and Furans are known carcinogenic agents; they can cause cancer in case of long term exposure. The risk of exposure to dioxins/furans is considerably increased due to the fact that MSW is burnt on the streets and landfills which are at ground level, releasing them into directly into ambient surroundings. Also, open burning is a frequent occurrence in some communities, and Landfill fires, once started, go on for weeks at a stretch, increasing human exposure further. During health studies conducted in Kolkata, waste pickers who are regularly exposed to landfill fire emissions for longer periods were found to have a "Chromosome Break" incidence which was 12 times higher than the control population. Chromosome Break often leads to cancer. Municipality workers were also found to have higher incidence of Chromosome Break compared to control population, but less than that of waste pickers.

Health and environmental impacts of open burning are less known to the public and environmental organizations also often ignore open burning as a source of dioxins/furans emissions.

4.3 WATER POLLUTION

Unsanitary landfills can contaminate ground and surface water resources when the leachate produced percolates through the soil strata into the groundwater underneath or is washed as runoff during rains. Leachate is generally a strong reducing liquid formed under methanogenic (anaerobic) conditions. The characteristics of leachate depend on the content of various constituents in the dumped waste (4).

"Studies on Environmental Quality in and around Municipal Solid Waste Dumpsite" in Kolkata, by Biswas A.K., et al. found moderately high concentrations of heavy metal in groundwater surround the dumpsite. The study found out that the groundwater quality has been significantly affected by leachate percolation.

Leachate generally contains organic chemicals formed by anaerobic digestion of organic wastes and heavy metals leached from inorganic wastes. The heavy metals generally observed in leachate are Lead (Pb), Cadmium (Cd), Chromium (Cr) and Nickel (Ni). All these heavy metals are characterized as toxic for drinking water. Due to the reducing property of leachate, during percolation through soil strata, it reacts with Iron (Fe) and Manganese (Mn) species underground and reduces them into more soluble species, thus increasing their concentrations in groundwater (4). Such reactions when they occur, pose a serious drinking water toxic risk. These predictions are substantiated by studies which found high concentrations of Cr, Cd and Mn in groundwater due to leachate percolation. Nitrates present in the environment can also be reduced to nitrites due to leachate. Nitrites consumed through drinking water can oxidize haemoglobin (Hb) in the blood to methaemoglobin (met Hb), thereby inhibiting the transportation of oxygen around the body (4).

The study clearly establishes that unsanitary landfills in India and elsewhere are potential sources of heavy metals contamination in groundwater sources adjoining the landfills. It also points out that there is an urgent need to adopt credible solutions to control water pollution due to indiscriminate dumping of wastes.

4.4 LAND DEGRADATION AND SCARCITY

Landfilling of municipal solid waste (MSW) is a common waste management practice and one of the cheapest methods for organized waste management in many parts of the world (4). This practice of unsanitary landfilling not only occupies precious land resources near urban areas; it also degrades the quality of land and soil in the site. Presence of plastics and heavy metals in the soils make it unfit for agriculture and emissions of methane and structural instability of the land make it unfit for construction activities. It would require massive remediation efforts which are time and infrastructure intensive, to make the land useful.

Landfilling occupies vast amount of lands near urban areas. A 1998 study by TERI (The Energy Resources Institute, earlier Tata Energy Research Institute) titled 'Solid Waste Management in India: options and opportunities' calculated the amount of land that was occupied by all the waste that was generated in India post-Independence until 1997. The study compared the land occupied in multiples of the size of a football field and arrived at 71,000 football fields of solid waste, stacked 9 meters high.

Based on a business as usual (BAU) scenario of 91% landfilling, the study estimates that the waste generated

1. by 2001 has occupied 237.4 sq.km or an area half the size of Mumbai;
2. by 2011 would have occupied 379.6 sq.km or more than 218,000 football fields or 90% of Chennai, the fourth largest Indian city area-wise;

3. by 2021 would need 590.1 sq.km which is greater than the area of Hyderabad (583 sq.km), the largest Indian city area-wise (18) (19).

The Position Paper on The Solid Waste Management Sector in India, published by Ministry of Finance in 2009, estimates a requirement of more than 1400 sq.km of land for solid waste disposal by the end of 2047 if MSW is not properly handled. This area is equal to the area of Hyderabad, Mumbai and Chennai together.

17 cities out of 59 surveyed by Central Pollution Control Board, CPCB have proposed new sites for landfills (Appendix 9). 24 cities (23.4 million TPY) use 34 landfills for dumping their waste, covering an area of 1,900 hectares (Table 12).

Table 12, Area Occupied by Known Landfills in India; Source: CPCB

Name of city	No. of landfill sites	Area of landfill (ha)
Chennai	2	465.5
Coimbatore	2	292
Surat	1	200
Greater Mumbai	3	140
Greater Hyderabad	1	121.5
Ahmadabad	1	84
Delhi	3	66.4
Jabalpur	1	60.7
Indore	1	59.5
Madurai	1	48.6
Greater Bengaluru	2	40.7
Greater Visakhapatnam	1	40.5
Ludhiana	1	40.4
Nashik	1	34.4
Jaipur	3	31.4
Srinagar	1	30.4
Kanpur	1	27
Kolkata	1	24.7
Chandigarh	1	18
Ranchi	1	15
Raipur	1	14.6
Meerut	2	14.2
Guwahati	1	13.2
Thiruvananthapuram	1	12.15
Total		**1894.85**

The concept of regional landfills used in western countries is very relevant to India to overcome the challenges of siting new landfills, lack of financial and human resources in every ULB. The state of Gujarat has identified many regional landfills. The first attempt at developing a regional facility in India was by Ahmadabad Urban Development Authority (AUDA), in 2007, to address the SWM requirements of 11 towns in its (then) jurisdiction. Located at the village Fatehwadi, the facility integrated composting facilities for approximately 150 TPD (9).

Each regional landfill will act as a common dumping site for MSW from a cluster of ULBs. Regional landfills make it easy to share financial and human resources between ULBs and facilitates proper sanitary landfill disposal of wastes. Sanitary landfills which are otherwise very costly to be built and maintained by individual ULBs are made economical by scaling up landfill operations.

4.5 PUBLIC HEALTH CRISIS

The present level of SWM service in urban areas is a potential threat to public health and environment (4). Inhalation of bioaerosols, and of smoke and fumes produced by open burning of waste, can cause health problems. Also, the exposure to air-borne bacteria is infectious. Toxic materials present in solid waste are determinants for respiratory and dermatological problems, eye infections and low life expectancy (16). The carbonaceous fractions and toxic elements like Cr, Pb, Zn, etc. dominate the fine particle range. As most of the fine particles can possibly enter the human respiratory systems, their potency for health damage is high. Also, these fine particles from open burning which constitute higher fractions of toxics are mostly released at ground level (5). On comparing emissions from open burning to the concentrations and composition of emissions causing indoor air pollution due to bio-fuel burning inside homes (28), it can be concluded that emissions from open burning also cause numerous premature deaths in the populations exposed, but there is no data available on this subject.

A less observed side effect of improper SWM in India is the introduction of heavy metals into the food chain. Compost from mixed waste composting plants is highly contaminated with heavy metals. Using this compost on agricultural fields will result in contamination of the agricultural soil with heavy metals. Food crops grown on contaminated agricultural soils when consumed will introduce the heavy metals into the food chain and lead to a phenomenon called "biomaginification". Biomaginification is defined by United States Geological Survey (USGS) as the process whereby the tissue concentrations of a contaminant (heavy metals) increases as it passes up the food chain through two or more trophic levels (plants and humans or plants, cattle and humans). Heavy metals generally found in mixed waste composts are Zinc (Zn), Copper (Cu), Cadmium (Cd), Lead (Pb), Nickel (Ni) and Chromium (Cr).

Long-term exposure to these heavy metals through food can cause severe health damage. Heavy metals in human body are known to cause damage to the central nervous system and circulatory system, liver and kidney dysfunction, anemia, stomach and intestinal irritation and psychological and developmental changes in young children. However additional research is required to properly understand the transport pathways of heavy metals into human bodies through different agricultural crops and meat products. Heavy metal contamination of groundwater due to leachate percolation below unsanitary landfills can also cause biomaginification of heavy metals in humans who drink water from those sources.

Long term exposure of populations surrounding dumpsites to open waste disposal can lead to health problems (Box 2). Ill health of municipal workers and waste pickers means a threat to public health. Also, contagious diseases can spread rapidly in densely populated Indian cities posing a bigger threat to public health.

Diseases caused due to stray animals, pests and insects attracted to wastes is a threat to public health too. Sewers and drains clogged by solid waste are breeding grounds for mosquitoes. Improper SWM in the city Surat caused a city-wide bubonic plague epidemic in 1994, which later transformed Surat into one of the cleanliest cities in India. Stray animals and insects carry other diseases like cholera and dengue fever (21).

4.6 QUALITY OF LIFE (QOL)

The Global Development Research Center, GDRC defines Quality of Life (QOL) as the product of the interplay among social, health, economic and environmental conditions which affect human and social development. QOL reflects the gap between the hopes and expectations of a person or population and their present experience.

In a country like India, which aspires to be a global economic giant, public health and quality of life are degrading everyday with the increasing gap between services required and those provided. India is also considered a sacred nation by the majority of its inhabitants but the streets and open lands in Indian cities are filled with untreated and rotting garbage.

The present citizens of India are living at a time of unprecedented economic growth and changing lifestyles. Unsanitary conditions on the streets and air pollution in the cities will widen the gap between their expectations due to the rapidly changing perception of their “being” and “where they belong” and the prevailing conditions, resulting in plummeting quality of life.

Improper SWM is an everyday nuisance to urban Indians. Uncollected waste on the streets, acts as a breeding ground for street dogs, stray animals and other disease vectors. Urban Indians have to deal with stench on the streets as soon as they leave their homes and have to walk by or drive by open bins and MSW dumps every day. During the rainy season, many urban Indians come across the unpleasant experience of having to walk in ankle height waters mixed with rotting MSW. The author during his research visits in India observed dry solid waste flying with wind, in the streets of Chennai. Living with children in such conditions adds to the trauma of adults that their children have to get exposed to such living conditions. These experiences are very unpleasant and unsettling and they develop a downgraded image of themselves to the citizens. There is a danger that such conditions for a prolonged time impact the sense of community between individuals and encourages indifference to any initiatives taken towards the betterment of the situation (29).

Figure 20, Improper SWM is an Everyday Nuisance to Urban Indians

Such conditions and experiences cause decrease in the work efficiency and disease. The high disease burden due to improper SWM will result in a degraded QOL and in turn disrupts the citizen's sense of well being. These cumulatively impact the economy of the urban centers negatively.

4.7 IMPACT ON CLIMATE CHANGE

Solid waste management is the third largest emitter of anthropogenic methane in the world, contributing to 3% of the world's overall green house gas emissions. In India, SWM is the second largest anthropogenic methane emitter and the largest green house gas emitter among activities which do not add to the economical growth of the country. They contribute 6% to the overall green house gas emissions of 2.4 Giga tons of CO_2 equivalents generated by India (27). Presently, an insignificant fraction of methane emitted from solid waste dumpsites is captured in India, rest of it is left into the atmosphere, not captured and unused. Control of GHGs from SWM is considered an achievable goal in the short term, among many other efforts to avert climate change.

Anoxic conditions inside landfills result in the anaerobic digestion of organic wastes which produces methane as the final gaseous product. Due to anaerobic reactions, landfills emit methane throughout their life time and also for several years after closure. Methane has high energy content and if captured economically can act as a renewable energy source. In case of unsanitary landfills which do not have methane capture mechanisms installed, the methane is released into the atmosphere.

The organic fraction of MSW is made photosynthetically by plants using carbon dioxide absorbed from the atmosphere. Therefore, at the end of their life cycle, carbon dioxide emissions from organic wastes mean a 'net zero emission'. However, since methane has 21 times more global warming potential as compared to CO_2, methane emissions from organic wastes mean 'net positive emissions'. One ton of methane equals 21 tons of CO_2 equivalents over a long period of time. In short time periods, CH_4 is much more potent than CO_2. During the first year of release, CH_4 is 71 times more potent than CO_2. Therefore, net positive emissions of GHGs in the form of methane warm the planet faster and contribute to global warming and in turn climate change.

However, SWM is very infrastructure intensive and expensive and cannot be afforded by all developing nations. Climate change is a problem that will affect every country on this planet and hence it requires concerted efforts. Our planet has reached a position where it is more economical to achieve GHG emission reductions in developing nations as compared to developed nations. This situation has lead to the creation of Clean Development Mechanism (CDM) under the Kyoto Protocol. The countries which have signed the Kyoto Protocol agree to reduce their GHG emissions below certain standards. CDM provides an avenue to developed nations to achieve these standards, by making it easy to buy carbon credits from developing nations. This mechanism therefore has dual benefits of reducing the overall GHG emissions of the planet and also helps improve the facilities in developing nations.

5 CONFORMANCE WITH THE HIERARCHY OF SUSTAINABLE WASTE MANAGEMENT

Comparison of SWM in India with the hierarchy of sustainable waste management does not show a very bright situation. It indicates a developing country with a huge population and growing economy and scattered but ongoing efforts towards SWM. There is also a definite awareness among local bodies as well as policy makers on SWM. The SWM sector in India has progressed in the right direction during the last few years (7), specifically after the introduction of Jawaharlal Nehru National Urban Renewal Mission (JnNURM) by the Government of India (GOI). However, it still suffers due to lack of managerial and financial resources and public awareness on the issue. The sector has a long way to go. Changes expected in disposal of MSW in the near future are

a. more extensive integration of informal waste sector into the formal systems,
b. further increase in the construction of composting facilities,
c. new RDF, WTE and sanitary landfill facilities and
d. capping of some landfills for landfill gas (LFG) recovery

Further financial and technical assistance from GOI is expected. Academic and scientific research institutions are also expected to increasingly focus on this sector.

5.1 RECYCLING

Recycling of resources from MSW in India is mostly undertaken by the informal sector. The formal recycling set-up in India in a minor fraction and is only in its initial stages, experimenting different models. Informal recycling in developing nations like India is a consequence of the increased gap in waste service provision (16) and the resultant ease of access to secondary raw materials which have immediate economic value.

5.1.1 INFORMAL SECTOR

All recycling in India is entirely undertaken by the informal sector. The informal sector comprises of waste pickers (WPs), itinerant waste buyers, dealers and recycling units. WPs constitute the largest population in the informal sector.

Generally, recyclables are collected in two ways; paper, glass and metal are collected before they enter the MSW stream from households on an instant payment basis, by a special group of people called 'Kabariwala' (from here on referred to as itinerant waste buyers) and plastics are generally collected by waste-pickers from litter on streets or from heaps of waste in landfills (30). Shopkeepers sell recyclable items, such as newspaper, cardboard, glass containers, tin cans etc. to itinerant waste buyers too. Waste pickers retrieve recyclable materials like milk bags, plastic cups and containers, glass, etc from what is discarded by households, commercial establishments and industries. Larger commercial establishments and industries sell the recyclable waste (source separated or otherwise) to waste dealers in bulk, who then sell it to recycling units (31).

BOX 3, INFORMAL WASTE MANAGEMENT IN INDIA

Source: (36)

The informal recycling sector in India and elsewhere

1. supplements the formal system and subsidizes it in financial terms
2. provides employment to a significant proportion of the population
3. operates competitively and with high levels of efficiency
4. operates profitably generating surplus
5. links up with formal economy at some point in the recycling chain
6. Offsets carbon emissions by making recycling possible and thus reducing the extraction and use of virgin raw materials

The recyclables collected are separated by pickers and collectors on a daily basis and transferred to small, medium and large dealers (Figure 21, Figure 22, Figure 23, Figure 24). Usually, the pickers and collectors sell to small dealers in the slums, near their residence. The small dealers sell the waste to medium or large dealers and finally the waste will be sold to the recycling units (16). There are 1,777 known plastic recycling units in India (32). Most of these known units are located in Tamil Nadu (588), Gujarat (365), Karnataka (302), Kerala (193) and Madhya Pradesh (179). The total number of plastic recycling units (will be much higher) and the capacity of each of these units is unknown.

Most of the recyclable waste is collected by the informal recycling sector in India before it is collected by the formal system. The informal sector recycles some percentage of formally collected waste too from transfer stations and dumps. This report estimates that the informal sector recycles 20.7% of recyclables from the formal system (Appendix 4), which compares fairly well with the best recycling percentages achieved around the world. It has to be observed that this number excludes the amount of wastes this sector recycles from MSW prior to collection, which is generally not accounted for and can be as much as four times the quantity recycled from formally collected waste (Appendix 4). This implies an estimated overall recycling percentage of 56% of recyclable wastes generated. This is a very high percentage, considering that the recycling percentages achieved by many infrastructure-intensive centralized waste management systems in Europe and US are only about 30%.

Figure 21, First Stage of Separation of Recyclables into Plastics, Metals and Glass, after Collection by Waste Pickers

Figure 22, Second Stage of Separation of Plastics into Different Types

Figure 23, Plastic Bottles after Second Stage of Separation

Figure 24, Sorted Metal after Second Stage of Separation

5.1.1.1 COMMUNITY GAIN, CHEAP SERVICE

Waste-pickers and scrap-dealers provide a low-cost service to the community. In Delhi, the informal sector collects and transports about 1,088 TPD of recyclables (33) which would otherwise be the responsibility of the municipality. In doing so, they save $ 17.8 million (INR 795 million) per year in collection and transportation costs to the Municipal Corporation of Delhi (MCD) (33) (34) (35). Similarly, a study named “Recycling Livelihoods”, made by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, earlier GTZ), SNDT Women’s University and Chintan Environmental Research and Action Group (Chintan) has found that, the informal sector effectively subsidizes the formal waste sector to the extent of USD 4.08 million (INR 200.6 million) per year in waste handling costs in Pune city (36).

Figure 25, Secondary Separation of Waste Paper at a Bulk Waste Paper Dealer Shop

In addition to subsidizing the formal sector and in turn the tax payer's money, the informal sector also provides an essential service to the community by clearing the streets off waste and augments the collection efficiency of formal systems. The informal recycling sector in Pune is known to handle up to one-thirds of the MSW handled by the formal system (36). Informal recycling also helps reduce the overall life-cycle impacts of materials by helping to recycle them, reducing the need for extraction of virgin raw materials and manufacturing.

Recovery of recyclable materials by the informal system is up to 56% (GIZ estimates 89% in Pune (36); other sources and general consensus suggest 70% (37) as compared to the formal sector where no recovery takes place. The sector also provides livelihood to the marginalized populations among urban poor by providing twice as many jobs as the formal system. In Pune city alone, the informal system operates at a net profit of USD 12.7 million (INR 621 million) per year (36). Even though these revenues are not distributed evenly amongst the populations involved in this sector, the average earnings of the least well-off exceed the statutory minimum wage. This sector achieves such high profits by enhancing “the value of a unit of plastic (as an example) by 750% before it is even reprocessed” (36).

5.1.1.2 ENVIRONMENTAL GAIN, CARBON OFFSETS

In addition to providing a cheap service to the community, the informal recycling sector also contributes towards reducing the global warming effect, since recycling has an obvious greenhouse gas (GHG) emissions reduction. Another study by Chintan in 2009, “Cooling Agents” estimates that the informal sector avoids 1 million tons of CO_2 equivalents of GHG emissions in Delhi alone, by collecting 476 TPD of mixed paper, 510 TPD of mixed plastics, 17 TPD of metals and 85 TPD of glass (Total 1,088 TPD of MSW) (33).

Informal recycling also helps reduce the overall life-cycle impacts of materials by helping to recycle them, reducing the need for extraction of virgin raw materials and manufacturing. Recovery of recyclable materials by the informal system is up to 56%.

The monetized environmental benefit on account of the informal system is higher than the environmental costs of the formal system. The use of non renewable energy resources in the informal system is minimal.

5.1.1.3 INADEQUACY & UNPREDICTABILITY

The existence of the informal recycling sector in Indian cities is useful to municipal corporations and beneficial to the community and environment. However, at the same time waste pickers are known to burn wastes at landfills (38) in order to recover metals or to keep warm at night. Open burning of wastes by waste-pickers and other people in addition to intentionally or accidentally set landfill fires are a major source of air pollution in Indian cities, emitting particulates, carbon monoxide and organic compounds including toxic dioxins (5). Waste-pickers are constantly exposed to emissions, have unhealthy living conditions and are prone to injuries and diseases, all of which decrease their overall life expectancy. The ill-health of waste pickers is a public health problem and even though they are generally not in contact with the public, it poses a threat to the overall health of the community.

Informal recycling is only a part of the solution to the MSWM crisis in India. At maximum potential, the informal sector can handle about only 20 - 30% of the generated wastes and also it is absent in cities like Kochi where labor unions do not allow people to work without a membership, which is denied to waste pickers. Though complete absence of the informal recycling is not the case everywhere, this sector is small in many cities. Significant informal recycling occurs in only the largest cities of a state or region. Also, waste-picking at landfills is difficult because of the height/depth of waste heaps. Mixed wastes are dumped in heaps at landfills and limit foraging to the top layers of the heap, leaving those at the bottom untouched. In summary, the Informal recycling sector in its present state is inadequate and unreliable in solving the SWM crisis.

Box 4, HURDLES IN ORGANIZING WASTE PICKERS; UNPREDICTABILITY & UNRELIABILITY

Source: (36)

- WP organizations are not very extensive geographically across India. Almost all organizations work in only metros and other large cities;
- WPs are dispersed, argumentative and arrogant at times, street wise and street smart and willing to challenge and ask questions simply because they have nothing to lose being where they are;
- WPs tend to be migrants who return to their villages during specific periods in the year. Therefore, all organizing and formal work has to take into account this demographic trend, which is very challenging, given the demands of formal service provision;
- Given the informal nature of work, WPs enjoy flexibility in work schedules. Organizing them becomes additionally challenging as there is no fixed routine within which to intervene and make time for organizing activities;
- The degree to which a particular material will be recycled depends on income levels; the existence of local and national markets; the need for secondary raw materials; the level of financial and regulatory governmental intervention; prices of virgin materials and the international trade in secondary raw materials and relevant treaties (16) , therefore all recyclables need not necessarily be recycled by the sector and are thus MSW of no value is left on streets or burnt openly.

5.1.1.4 HEALTH RISK ASSESSMENT OF WASTE-PICKERS

The working conditions for pickers and collectors are unhygienic and safety equipment such as gloves and boots are unaffordable for waste pickers. Thus, the health risks for WPs are high.

Due to the lack of safety equipment, (36)

a. 68% of the WPs in Delhi injure themselves regularly,
b. 21% injure themselves often

"They (WPs) are constantly exposed to stench produced by rotting waste and the smoke and fumes produced by open burning of waste. They are also exposed to air-borne bacteria as well as infectious or toxic materials present in solid waste are determinants for respiratory and dermatological problems, eye infections and low life expectancy." (16)

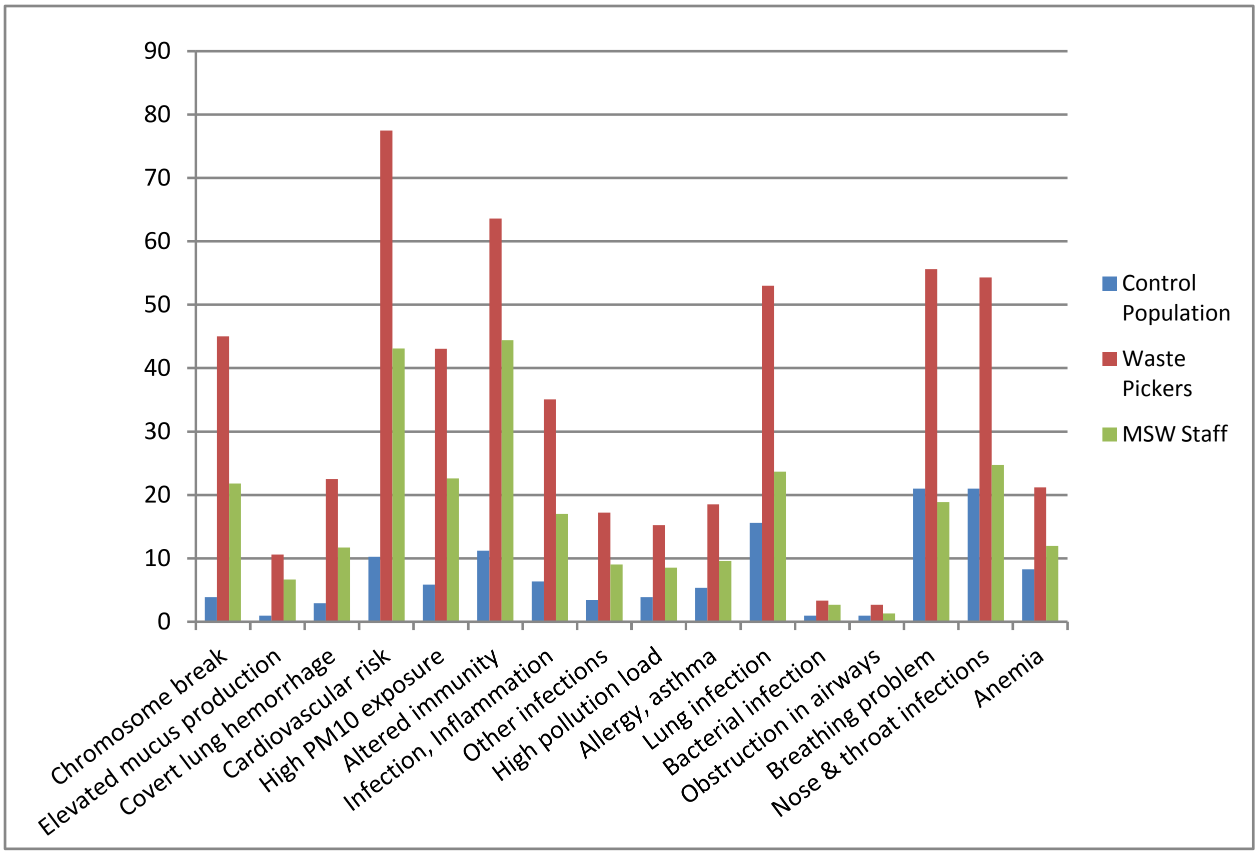


Figure 26, Higher Incidence of all Diseases tested for in waste pickers; Appendix 10

WPs were also found to be suffering from occupation related musculo-skeletal problems, respiratory and gastro-intestinal ailments. 82% of the women waste pickers studied in a health study were found to be severely anemic. This could be not only as a result of malnutrition, but also due to exposure to toxics, particularly heavy metals (36). During a clinical examination of municipal workers, waste pickers and controls conducted in Kolkata, it was found that waste pickers had a higher incidence of all 16 health problems tested for, compared to the control population (CP) and MSW staff (Figure 26). The five most prevalent health problems observed in waste pickers' were Cardiovascular risk (77%, around 8 times that of CP), Altered immunity (64%, around 6 times that of CP), Breathing problem (56%, around 3 times that of CP), Nose and throat infections (54%, around 3 times that of CP) and Lung infections (53%, around 3 times that of CP).

The increased risk of ailments due to direct exposure to MSW is important to know. The five health problems with increased risk of incidence in WPs are Chromosome break (around 12 times that of CP), Elevated mucus production (11 times that of CP), Covert lung hemorrhage (around 8 times that of CP), Cardiovascular risk and High PM_{10} exposure (around 7 times that of CP). There is a clear decrease in the incidence and prevalence of health problems among MSW staff workers, as they use better protective wear, take precautions and can easily access other facilities due to the formal nature of their employment. The prevalence of health problems in MSW staff workers is also high compared to the control population and strict measures should be taken by ULBs to improve their health and thus the overall health of the city.

5.1.1.5 RECOGNITION AND INTEGRATION, ORGANIZING THE INFORMAL SECTOR

The informal recycling sector in India is in fact well-structured and has a huge presence, especially in mega cities. This sector is responsible for the recycling of around 70% of plastic waste (37) and up to 56% of all recyclable waste generated in India. On the basis of all information collected during this visit, the author estimates that the informal sector recycles about 10 million tons of recyclable waste per year.

The high percentage of recycling the informal sector is able to achieve is the cumulative effort of large numbers of WPs on the streets, at the bins and dumpsites. For example, the informal sector in Delhi employs about 150,000 people who are 0.9 % of the population of Delhi (16.75 million) (3) (33) (39). Equally large populations of waste-pickers are estimated in Mumbai, Kolkata and Chennai. Other cities, such as Bengaluru, Hyderabad and Ahmadabad have slightly lower populations of waste-pickers. Based on information collected during this trip, the author estimates the total number of people involved in informal recycling in India to be 2.86 million, i.e. 0.75% of the urban population (377 million) or 0.23 % of the total population of India (1,210 million). Numerically waste pickers in India possibly outnumber those in any single country in the world (36). Coordinating such a large work force will be a heavy burden on ULBs due to the lack of necessary managerial resources.

> **Box 5: INTEGRATING THE INFORMAL SECTOR INTO FORMAL WASTE MANAGEMENT SYSTEMS**
> **Source:** (36)
>
> To transform the aesthetics of waste handling by the informal sector, it has to be
>
> a) assisted to provide professionalized and efficient waste collection services;
> b) encouraged to introduce value added services;
> c) convinced about the importance of service level benchmarks and monitoring;
> d) made aware of the importance of maintaining work ethic and discipline; and
> e) trained according to their work, depending on whether they are waste pickers, itinerant buyers, sorters or graders.

Public policies towards the informal waste sector are largely negative in most parts of the world. It is either because of embarrassment at the presence of waste pickers or 'concern' for their inhuman and unhygienic working and living conditions and has led to police harassment as in Colombia; to neglect as in parts of West Africa; to collusion, where waste pickers are tolerated in return for either bribes or support to political parties as in Mexico City (40). In case of developed economies, they have allowed their informal recycling systems to disappear and as a result are now struggling to re-establish systems to rebuild recycling percentages to former levels and meet the ever-increasing recycling targets (40). But, the Government of India has clearly held a different path with an informed perspective. Blind eye towards waste-picking until now has been largely due to the sector's unreliability and inadequacy in managing enormous quantities of urban wastes. Their absorption into formal systems is also hindered by their lack of accountability unlike formal systems which are accountable to the public.

5.1.1.6 CHANGE IN PERCEPTION

The role of informal sector in recycling resources was recognized in the latest Plastic Waste (Management and Handling) Rules, 2011 that were regulated by the Ministry of Environment and Forests (MOEF). These rules make municipal authorities responsible for coordination of all stake holders involved in waste management, including waste pickers. Such laws are necessary in inching towards sustainable waste management and need support in the form of relevant policy changes at the national level.

Institutionalizing the informal sector can overcome the issue of unreliability. This was evident in the case of road sweeping in Hyderabad, where the contracts were awarded to organized groups of informal waste pickers and workers. Also, employing self-help groups of waste pickers in door-to-door collection has proven successful nationwide; individuals in these groups have much better working conditions compared to earlier (41). Thus, the focus should be on institutionalizing the informal sector. Considering the ongoing widespread privatization of the MSWM sector, it is very important to frame policies that make the employment of waste-pickers in the corporate sector easier. Once employed, the minimum wage requirements, labor laws and operational health and safety regulations will ensure their welfare. However, solving intricacies which arise due to such regulations will be a formidable challenge to policy makers.

Further analysis and studies on the sector’s impact on a) diverting waste from landfills and thus b) reducing need for transportation, along with c) waste characteristics before and after waste-picking will help involving informal sector in MSWM plans further.

5.2 COMPOSTING

Composting is the biological decomposition of the biodegradable organic fraction of MSW under controlled conditions to a state sufficiently stable for nuisance-free storage and handling and for safe use in land applications (42). Composting is the most widely employed MSWM technique in India, with above 70 composting plants (Appendix 8); most of these composting facilities handle between 100 – 1000 TPD of MSW. It is estimated that up to 6% of MSW collected is composted (7) which makes it the only major waste handling technology employed in India. India has an estimated potential of producing about 4.3 million tons of compost each year from MSW, which could help reducing the wide gap between availability and requirement of organic manure for soils in India (26).

Composting is successful because it is a low cost and low infrastructure set-up and also produces compost, which is a marketable byproduct. In addition to making a positive contribution to agriculture, the sale of organic wastes reduces the amount of waste to be collected and disposed of by municipal authorities (43).

Composting of MSW is undertaken by either of the two methods, a) Windrow composting or b) Vermicomposting. Landfill mining and bioremediation are other ways of extracting compost among other resources from landfills. Even though these two processes are different, they’ll be used interchangeably in this report to indicate the process of emptying a landfill while recovering resources from it.

Box 6, HISTORY OF COMPOSTING AND REASONS FOR INITIAL FAILURES
Sources: (43) **and** (71)

The first MBT plants in India were built in early 1970s with government intervention to promote its practice. Ten semi-mechanized composting plants (MBTs) were set up in Ahmadabad, Bombay, Bangalore, Baroda, Delhi, Calcutta, Jodhpur, Jaipur, Kanpur and Vijayawada in 1975-76 (71).The process included removal of big pieces, pulverization, forced aeration with augers and sieving. Almost all the plants have stopped working as there were many problems, which include:

- Semi-mechanized machinery was imported and a minor mechanical fault usually led to breakdown due to non-availability of spare parts,
- Mixed nature of waste was a major difficulty. Pulverizers got frequently clogged with pieces of rags, plastic and rubber etc. and blades of which were broken down due to metal and glass pieces present in the waste. Amount of soil mixed into the waste also caused problem in the process, in addition to the lowering of the quality produced.
- Lack of continuous power supply was another problem.
- The process could not be continued in rainy season.
- The actual capacity turned out to be far less than the designed capacity.
- Lack of market for the finished product was another problem. As a result the enterprise could not become self sustained.

During research visits in India, the author observed that vermicomposting was employed by towns or small cities generating MSW < 100 TPD, whereas larger cities employed mechanical windrow composting. Mechanical composting facilities optimize MSW processing and minimize manual handling of wastes. These composting plants which use mechanical and biological operations to handle mixed wastes are called Mechanical Biological Treatment plants (MBT). MBT and composting will be used interchangeably because almost all windrow composting plants in India operate as MBTs.

The capital investment for building a composting plant is $ 4,500 per ton (INR 200,000) of waste processed (44) and the compost is being sold at $ 45 – 50 per ton (INR 2,000 – 2,200) (45). Availability of government aid and rising entrepreneurial interest resulted in an upsurge in the number of composting facilities nationwide. Among 74 cities examined for their present waste handling techniques, only 22 cities had composting facilities in 2008, whereas by 2010, the number of cities employing composting grew to 40. At present, there are a total of 70 cities which employ MSW composting and 22 new projects are proposed.

In addition to the reasons cited for the failures of composting facilities in Box 6, another important but overlooked factor is the contamination of end product (43) by heavy metals, glass and plastic.

5.2.1 WINDROW COMPOSTING OR MECHANICAL BIOLOGICAL TREATMENT (MBT)

Windrow composting is the most common method of composting in India; it involves the stabilization of organic solid waste through aerobic decomposition. Windrow composting facilities can efficiently handle large quantities of waste in comparison to vermicomposting. For example, plants in Bengaluru, Pimpri and Nashik handle 100 TPD, 500 TPD and 300 TPD of MSW respectively (45) as compared to a vermicomposting plant in Suryapet which handles 40 TPD. During the MBT process, recyclables are separated from the mixed wastes, baled and sold to a nearby recycling company at a cost of $78 (INR 3,500) per ton of plastics and $56 (INR 2,500) per ton of paper (46).

5.2.1.1 COMPOSTING PROCESS

At MBT facilities, mixed wastes are first dried, shredded and sieved into 70 mm and 35 mm fractions. Only the -35 mm fraction undergoes composting; rest is compost rejects and goes to the landfill. -35 mm material is arranged in rows, 2 m tall, 3 m wide and 11 m long (Figure 27). A bacterial-slurry prepared inside the facility is then sprayed on these windrows to accelerate decomposition of the organic material. The windrows are turned once every week continuously for 8 weeks. At the end of the 8th week, the waste is shredded and sieved in multiple stages into +16 mm and -16 mm fractions. -16 mm is the precursor to compost which should be “cured” for another 2 – 3 weeks before being sold. It was observed that the demand for compost was higher than the supply from these facilities.

On the basis of all information collected during this trip, the author estimates that only 6-7% of the input mixed waste (12 – 15 % of organic waste input) can be recovered as compost (Figure 28). Rest of the MSW, 60% (on wet basis) is landfilled as compost rejects (See Section5.2.4).

Figure 27, Windrow Composting of mixed solid wastes is the most successful waste management technology in India

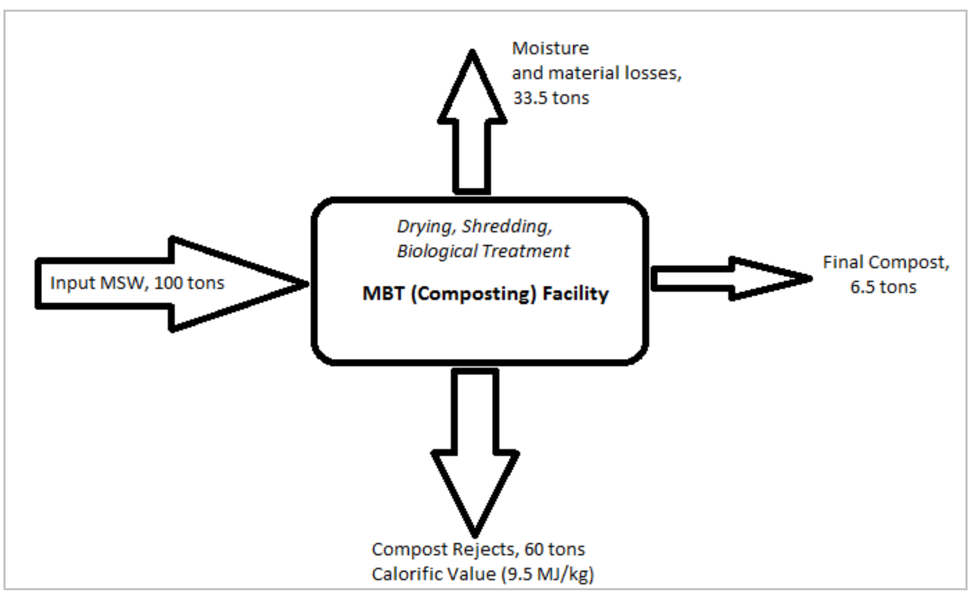


Figure 28, Material Balance Flowchart of MBT Process, with Calorific Values of Different Fractions of Composting Rejects: Source: Ramky Enviro Engineers

5.2.2 LANDFILL MINING AND BIOREMEDIATION OF LANDFILLS

Landfill mining and bioremediation are very similar to each other and are both related to microbial digestion of organic wastes. The only difference is landfill mining is carried out after natural decomposition of organic wastes in a landfill and bioremediation is carried out by humans to accelerate the decomposition process.

5.2.2.1 LANDFILL MINING

Landfill mining is a process of recovering valuable materials from landfilled MSW. The process involves excavation, processing and reuse of landfilled materials with the objectives of conservation of landfill space; reuse of materials; reduction of landfill footprint; and elimination of potential contamination source and rehabilitation of dumpsite (47). Processing of the materials involves primary separation of materials and sieving; reuse of the recovered materials includes both energy and material recovery. The prime objective of landfill mining is space clearance for incoming waste or reclaiming land. A study of fourteen successful landfill mining operations outside India (Appendix 7) indicates eight of them were carried out with the prime motive of land reclamation, six of them for material and energy recovery, four to avoid long term contamination of groundwater and two of them were carried out as demonstration projects.

MSW in landfills decomposes in two stages, a) aerobic decomposition and b) anaerobic decomposition (48). The products of such decomposition were observed to be chunks of compost mingled with plastic, paper and rags during the author's research visit to the Autonagar landfill in Hyderabad. The mining operations in this landfill were being carried out in a small scale.

5.2.2.2 LANDFILL MINING PROJECTS

Landfill mining in India was observed in cities with closed or overflowing landfills. The author visited the closed landfill in Autonagar, Hyderabad, which was being mined for compost by excavating and sieving the landfilled material. The compost is sold to organic fertilizer companies to be used in agriculture as a supplement to chemical fertilizer according to the Integrated Plant Nutrient Management policy. This process involves loosening, spraying a bio-culture and regularly turning the waste beds. It is then followed by sieving and packing.

By 2007, landfill mining was carried out seven times in five different cities, namely Nashik (in 2003), Madurai, Mumbai (in 2004), Hyderabad (in 2004, 2007) and Pune (in 2006, 2007). These seven projects together cleared more than 60 hectares of landfill area, emptying more than 5 million cubic meters of waste. This corresponds to about 3 million tons of MSW considering a bulk density of 0.5 tons/m^3.

5.2.2.3 BIOREMEDIATION

Bioremediation with respect to MSW landfills can be defined as a "cleanup" technology employing biological options, generally bacteria to stabilize landfilled organic wastes through aerobic decomposition.

The utility in such stabilization is

a. avoidance of anaerobic digestion of organics and resultant methane emissions
b. avoidance of leaching and resultant water pollution
c. value addition to landfilled MSW by making it easier to mine them (for landfill mining)

Bioremediation of landfills can also be used to help landfill mining. In this process which is very similar to windrow composting, bacterial slurry is sprayed on mixed waste and the heaps are turned regularly to produce compost which can then be mined. MSW over a hectare of land in Gorai dumpsite was stabilized/bio-remediated and the compost formed was mined along with recovery of recyclables. 9 m tall waste beds over this area were cleared in 3 months with low investment and infrastructure which is affordable by most Class I and Class II cities in India.

Table 13, Bioremediation Projects Undertaken in India Until 2007; Source: Almitra Patel

Open Dumps Bio-Remediated by the Year 2007							
Year	**Location**	**Area cleared (ha)**	**Area cleared (m^2)**	**Waste Height (m)**	**Waste Volume (m^3)**	**Total Cost (INR Millions)**	**Cost/cu.m**
2003	Nasik	11.6	116000	5	580,000	6.4	11.03448
2004	Madurai	12	120000	2	240,000	0.75	3.125
2004	Mumbai	1	10000	10	100,000	1	10
2004	Hyderabad	3	30000	20	600,000	-	-
2007	Hyderabad	19	190000	20	3,800,000	-	-
2006	Pune (Demo)	1	10000	10	100,000	-	-
TOTAL		**47.6**	**476000**		**5,420,000**		

5.2.2.4 PROSPECTS FOR LANDFILL MINING AND BIOREMEDIATION IN INDIA

Even though landfill mining and bioremediation are similar processes to windrow composting, they have a higher carbon foot print as they are generally carried out in landfills consisting MSW which would have already emitted some (or all) methane due to anaerobic digestion. These process have a potential to earn CDM credits of $ 11 – 17 (INR 500 – 800) per ton of compost recovered (49). They also have the potential to provide an alternate solution to permanent landfills. Further, they avoid long term methane emissions from landfills and recover materials.

The time period and costs to clear the landfills by these methods are impressive. However, the possibility of high heavy metal concentration in the compost looms large. The compost from such an activity will not be suitable for food crops. It can however be used in gardening or for cash crops. The major motive of landfill mining and bioremediation should be clearing the landfills rather than trying to sell the by-product compost. Before any decision can be taken on the usage of such compost, detailed studies are required.

5.2.3 COMPOST QUALITY AND HEAVY METAL CONTAMINATION

A less observed side effect of improper SWM in India is the introduction of heavy metals into human food chain. Compost from mixed waste composting plants is highly contaminated with heavy metals. Using this compost on agricultural fields will result in contamination of the agricultural soil with heavy metals. Food crops grown on contaminated agricultural soils when consumed will introduce the heavy metals into the food chain and lead to a phenomenon called “biomaginification” (50) (51). Biomaginification is defined by United States Geological Survey (USGS) as the process whereby the tissue concentrations of a contaminant (heavy metals) increases as it passes up the food chain through two or more trophic levels (plants and humans or plants, cattle and humans). Heavy metals generally found in mixed waste composts are Zinc (Zn), Copper (Cu), Cadmium (Cd), Lead (Pb), Nickel (Ni) and Chromium (Cr).

A study conducted by the Indian Institute of Soil Science (IISS), Bhopal found that compost produced from MSW in India is low grade, with high heavy metal concentrations and low nutrient value (26). Figure 29 shows the range of concentration of heavy metals Zinc (Zn), Copper (Cu), Cadmium (Cd), Lead (Pb), Nickel (Ni) and Chromium (Cr) in MSW composts from 29 cities. Compost from only two cities out of twenty nine passed the statutory guidelines by European countries (except Netherlands) for high quality composts. The two cities are Suryapet and Vijayawada where MSW collection is source separated.

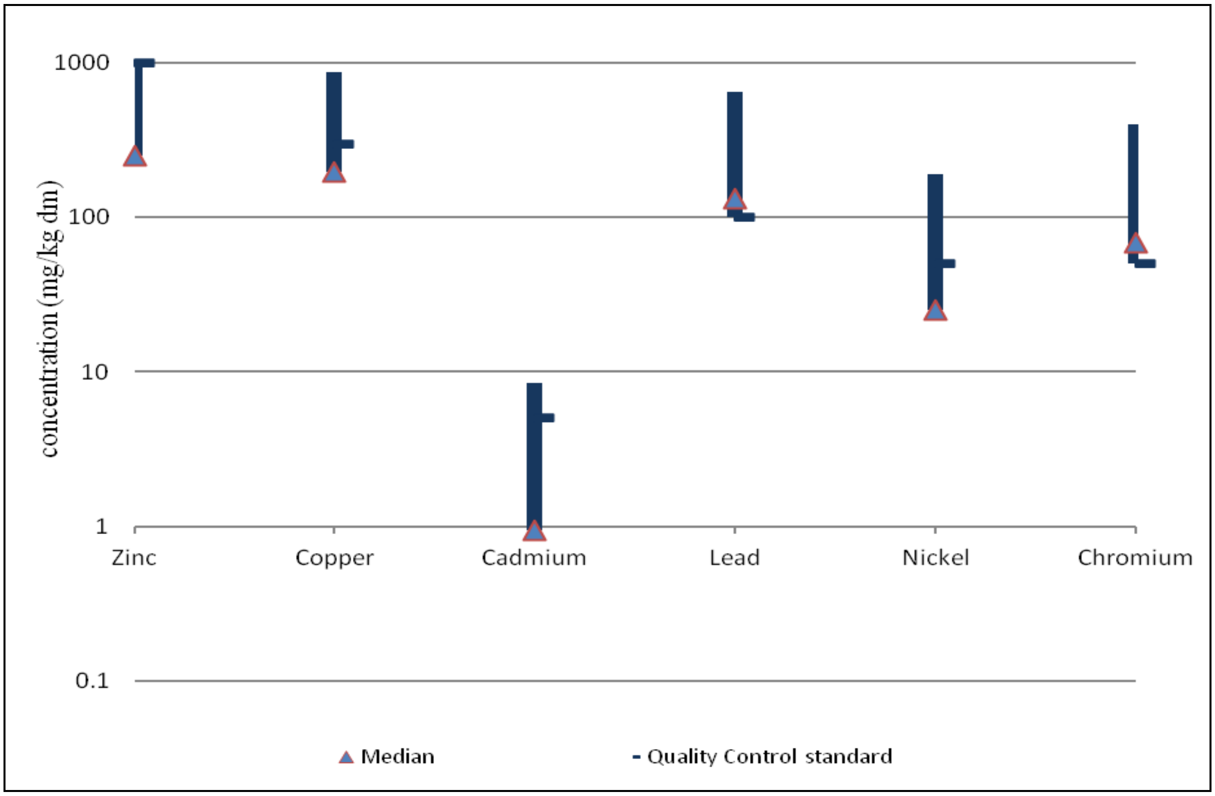


Figure 29, Heavy Metals Concentration in Mixed Solid Waste Compost in Comparison to Quality Control Standards

Majority of the samples do not comply with Indian quality control standards (Figure 30, Appendix 12) for total potassium, total organic carbon, total phosphorus and moisture content; and exceeded the quality control limits for heavy metals contamination by Lead (Pb) and Chromium (Cr). The study also found that incidence of heavy metals in MSW compost from cities (population < 1 million) is less than half of that from bigger cities; but the compost still doesn't clear the quality control standards in all instances. If all MSW generated in India in the next decade is composted as mixed waste and used for agriculture, it would introduce 73,000 tons of heavy metals into agricultural soils (Appendix 13).

Contamination of MSW compost by heavy metals can cause harm to public health and environment and is the major concern leading to its restricted agricultural use (22). Mixed waste composting is therefore not an option for sustainable waste management. In countries like India where more than 91% of MSW is landfilled and there are no other alternatives available, mixed waste composting is widely practiced and considered better (if not the best) than landfilling (8). For health impacts of heavy metals, see Section 5.2.3.

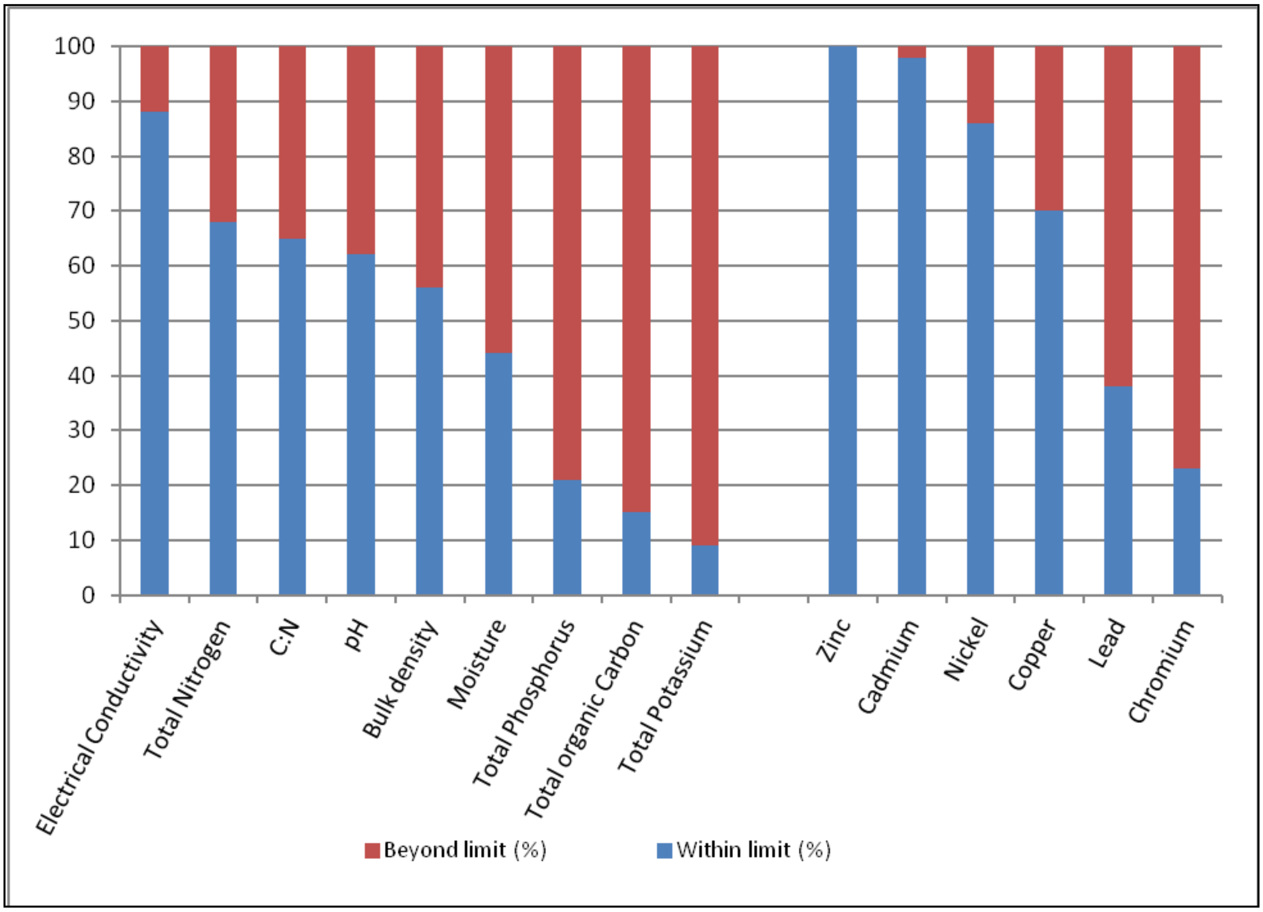


Figure 30, Heavy Metal Concentration beyond Quality Control Standards in Mixed Solid Waste Compost from 29 Indian Cities, (26)

Authorities should make sure they are not ignoring future health costs by choosing economic (cheaper) technologies today and creating a bigger public health crisis in the form of bioaccumulation of heavy metals. Usage of MSW compost for food crops should be regulated; simultaneous research on the risk of bioaccumulation due to usage of MSW compost should be conducted to account for public health, and environmental costs in decision making.

5.2.4 COMPOST YIELD

Lack of actual performance data of MSW composting facilities was a major concern during initial research, thus an important finding during research visits is that the compost yield from mixed waste composting facilities (MBTs) is only 6-7%. Rest of the MSW, up to 60% of the input waste (accounting for moisture loss and material loss during decomposition) is discarded as composting rejects and landfilled (Appendix 15).

Figure 31, Rejects from the composting plant at Pimpri Chinchwad

Rejects from composting plants in Bengaluru, Nashik and Pimpri were observed to contain a high percentage of plastics, mainly plastic bags (Figure 31, Figure 32). Composting treats only 11% of dry solids in MSW, the rest of it, i.e., about 90% of waste (on a dry basis, or 60% on a wet basis) ends up in unsanitary landfills in case of no further treatment (45). However, mixed waste composting still avoids landfilling of MSW and increases the operating life of a landfill by 2.5 years in every 20 years.

Compost rejects at Pimpri composting facility were divided into four distinct fractions, (+) 70mm rejects (overflow from 70 mm sieve), (+) 35mm rejects (overflow from 35 mm sieve), (+) 16mm rejects (overflow from 16 mm sieve) and (+) 4mm rejects (overflow from 4 mm sieve). The number of fractions the rejects are divided into depends upon the facility's design. Analysis of these rejects showed that overall lower calorific value of composting rejects was 9.5 MJ/kg

(2,300 kcal/kg). The lower calorific value of these fractions was found to be as high as 11.6 MJ/kg (2,800 kcal/kg).

Table 14, Composition of Various Fractions of MSW during Mechanical Biological Treatment (MBT); Source: Ramky Enviro Engineers Ltd.

	Moisture	Ash	Volatile Matter	Fixed Carbon	LHV (MJ/kg)
Input MSW	16.05	34.36	45.91	3.68	7.3
70mm rejects	5.74	12.31	77.99	3.96	11.6
35mm rejects	5.25	14.72	75.17	4.86	10.8
16mm rejects	26.74	20.12	41.57	11.57	10.0
4mm rejects	10.25	54.01	29.87	5.87	4.7
compost, after 4 weeks	14.01	22	59.23	4.76	8.8

Figure 32, Composting Rejects are up to 60% of Input MSW and have a Calorific Value as high as 11.6 MJ/kg

The calorific value of input MSW at the Pimpri facility is 7.3 MJ/kg (1,750 kcal/kg). It is identical to the average calorific value of urban MSW in India which is also 7.3 MJ/kg. If MSW from all cities is treated in MBT facilities, the calorific value of compost rejects will be different from those from the Pimpri facility. However, since MSW generated in many cities has higher calorific value than the input MSW at Pimpri, we will assume composting rejects from MBT facilities in India have an average lower calorific value of 9.5 MJ/kg.

5.3 SMALL SCALE ANAEROBIC DIGESTION (BIOGAS)

Figure 33, A Small Scale Biogas Unit Developed by Biotech, Kerala; Capacity: 2 kg/day of Organic Waste

Anaerobic digestion of kitchen waste to produce biogas and liquid slurry on a small scale has been very successful in India, especially in parts of South and West India, where the region's temperate weather conditions favor the process yearlong. Many households have such biogas units installed. Total number of units installed in cities is unknown due to numerous companies offering them and the units are installed in both urban and rural areas. In order to have a closer look at this technology, the author identified a private company called Biotech with its office in Thiruvananthapuram, Kerala as a case study for small scale biogas. This company alone installed twenty thousand (20,000) units of small scale biogas (Figure 33) in Thiruvananthapuram and Kochi, combined. Units installed by Biotech divert about 40 tons of waste from landfills, which is 7% of the organic waste generated in both cities together. It also implies avoidance of about 5% of collection and transportation costs and resulting GHG emissions.

5.3.1 CAPACITY AND COST

The units are smaller in size, flexible with feed and operation when compared to its counterparts. They cost $ 470 (INR 21,000) per unit and almost half of this cost is subsidized in different ways. Each unit can handle kitchen waste from a household with 3 – 5 members and can generate one cubic meter of biogas every day. Biogas mainly constitutes methane and carbon dioxide and the unit can be connected directly to a cooking stove. Per capita organic waste generation in Thiruvananthapuram and Kochi is 0.17 kg/day and 0.38 kg/day respectively. A single household in Thiruvananthapuram and Kochi produce 0.5 – 0.85 kg/day and 1.1 – 2 kg/day respectively (depending on the number of persons in the house). Thus, the capacity of these biogas units is enough for households in these two cities and each unit occupies only 1.25 m^2 of space.

The technology was successfully scaled-up by the company to handle 300 kg of organic wastes every day. Space required per kg of waste treated increases with the scale due to increase in the number of single-units used and piping involved. More than 200 institutional units were installed at different hotels and canteens, hospitals, schools, markets and slaughter houses. Biogas from such institutional units is converted to electricity using a generator and is used for street lighting. One cubic meter of gas can produce 1.5 KW of electricity.

5.3.2 COMPARISON

Small scale biogas is a decentralized technology and the most environmentally friendly technology to recover energy from organic wastes. It can be successfully deployed in South India where the temperatures favor the process yearlong. The company Biotech is researching ways to introduce this into other regions of India which are colder. However looking at the public investment and integrated waste management perspective, it takes many such single units to address organic waste from a single community and the technology would be able to address only 50% of the waste stream in Thiruvananthapuram or Kochi. Also, the public investment into the technology is comparatively much higher (Table 15) and the units produce organic slurry which needs to be properly utilized. Table 15 is a comparison between small scale biogas and WTE combustion as waste to energy solutions to the SWM crisis in Chennai. The values used in these calculations are generation of 6,464 TPD of MSW (in year 2005), organic waste percentage of 41% and calorific value of 10.9 MJ/kg.

Table 15, Comparison of small scale biogas and WTE Combustion as options for SWM in Chennai (cost in USD); Source: Biotech, (15)

*Costs calculated for the society as a whole					
	Small Scale Biogas (INR)	**USD**	**WTE Combustion (INR)**	**USD**	Comparison
Capital Cost*	27,827,520,000	622,818,263	10,773,333,333	241,122,053	
Operational +Transportation Cost* (20 yrs)	0	0	10,841,484,756	242,647,376	
Expenses to society	27,827,520,000	622,818,263	21,614,818,089	483,769,429	1.3
Potential to avoid Landfilling (%)	41%		85%		2.1
Electric Energy Produced (MWh/day/ton)	0.75		0.76		
Total Energy produced in 20 yrs (MWh)	25,915,311		63,793,335		2.5
Potential to Avoid Pollution due to Transportation (%)	41%		0		41
Residue Disposal	Use for agriculture			Sanitary Landfill	Additional Cost for WTE

The difference in total costs is because of the difference in scale of the technologies compared and the difference in total energy produced is because the feed for small scale biogas is only organic waste whereas feed for WTE includes rest of the MSW fraction too which are an extra 40 - 50% and have higher calorific value. Despite these differences, small scale anaerobic digestion would be the most sustainable way to treat source separated organic wastes considering the avoidance of emissions from transportation. Since anaerobic digestion works only for source separated organics as is the case with small scale biogas plants, it is not at all an option for mixed solid wastes. As source separation is not practiced in India, it is difficult to collect separated organic wastes on a large scale. That also explains why large scale biomethanation which could have been an option otherwise is not a part of this report.

5.4 REFUSE DERIVED FUEL

Refused Derived Fuel is MSW which has been processed to fulfill guidelines, regulatory or industry specifications mainly to achieve a high calorific value. Other refuse derived fuels include residues from industrial/trade waste, sewage sludge, industrial hazardous waste, biomass waste, etc (52). Industry specifications the RDF has to meet generally include specifications for boiler feed or emissions control.

In developing countries like India with MSW which has a low calorific value (7.3 MJ/kg compared to values greater than 10 MJ/kg in Europe, Japan and US) and high percentage of inerts, processing of waste is necessary to make it suitable as a fuel. This makes RDF an important alternative to WTE combustion. One of the less expensive and well-established technologies to produce RDF from MSW is mechanical biological treatment (MBT). An MBT plant separates out metals and inert materials, screens out organic fractions (for stabilization using composting processes), and separates out high-calorific fractions for RDF. RDF can also result from a 'dry stabilization process' in which residual waste (after separating out metals and inert materials) is dried through a composting process leaving the residual mass with a higher calorific value (23). The RDF thus produced is either used directly as floc/fluff or is compressed to make pellets. RDF fluff (as it is called in India) can be directly combusted in dedicated WTE plants whereas making RDF pellets increases the marketability of the product as they can be used for co-combustion in various solid fuel industries like cement kilns, coal fired power plants, etc.

RDF is an alternative to WTE and is a potential waste management technology. It needs lesser capital and can make use of existing infrastructure, compared to WTE. To make RDF (or fluff as it is called in India to differentiate it from RDF pellets), mixed solid wastes are processed through stages of shredding, sieving, drying and compaction. RDF plants which make fluff are located near Hyderabad, Vijayawada, Jaipur and Chandigarh. RDF produced at Hyderabad and Vijayawada is taken to dedicated WTE plants for electricity generation, (Figure 34), whereas RDF from Jaipur and Chandigarh plants is transported to cement plants to be used in place of coal. Hyderabad and Vijayawada had the first RDF facilities in India which served as demonstration projects. The administration of Nashik composting plant is testing the feasibility of using composting rejects as RDF in a cement plant; similar attempts are being made at Pimpri composting facility too.

Box 7, SOLID FUEL INDUSTRY IN INDIA

Sources: (74) , (73), (72), www.indexmundi.com

The solid fuel industry is well established in India. The major users of solid fuels are power plants, steel plants, cement manufacturing plants, alumina refineries, etc. The solid fuel generally used is coal.

The demand for solid fuel is very high. India consumed more than 600 billion tons of coal consumption in 2009 and is one of the major users of coal worldwide. Solid fuels are the second largest source of electricity after hydro power. Coal accounted for 53% of India's energy consumption in 2007. Usage of coal will double by the end of 2030 and increase domestic production and imports. In addition to rising environmental awareness and changing regulations, coal shortages, soaring coal prices and resulting frequent plant shutdowns have also increased the necessity for alternative sources of solid fuels.

The coal used by Alumina refineries is of F and G grades, having a useful heat value ranging from 16 MJ/kg (3800 k.cal/kg) to 18 MH/kg (4300 k.cal/kg) and ash content ranging from 35% to 50%. In comparison, the lower calorific value of rejects from composting plants is as high as 11.6 MJ/kg and has very low ash content. Therefore, Rejects from composting can be further processed to cater to the needs of the huge and well established solid fuel industry. RDF from Jaipur and Chandigarh facilities is already being used as fuel in cement plants.

5.4.1 RDF FOR SOLID FUEL INDUSTRY

High percentage of rejects from MBT facilities (60%), having a high calorific value (9.5 MJ/kg) opens a huge opportunity for RDF and WTE. Assuming 6% of all MSW generated in India is treated in MBT facilities, out of which, 60% is compost rejects which could be used as refuse derived fuel (RDF), India is currently generating 2.48 million TPY of RDF. Such a huge source of energy is being generated and landfilled every year. This is equivalent to landfilling nearly 4 million barrels of oil because there are no facilities which could use them. This RDF can be used in the already well established solid fuel industry in India (Box 7). India would have landfilled 58 million barrels of oil in the form of RDF alone by 2041 if there were no RDF co-combustion or WTE facilities to generate energy out of it.

Coal is the major source of energy for India's solid fuel industry, which includes thermal power plants, steel plants, cement kilns, aluminum refineries, etc. Coal shortage due to increasing consumption by China and other developing nations is driving its prices high and is also stalling the operations of many industries. In early 2011, many thermal power plants were operated below capacity due to low reserves of coal, threatening India's energy security. RDF can become an important alternative to coal in these industries. It is much cheaper considered to coal and readily available from existing MBT and RDF plants. Proper regulations and monitoring of co-combustion facilities are required to avoid environmental pollution due to RDF combustion. Pollution control equipment used in modern WTE facilities should be adopted by these co-combustion facilities.

5.4.2 EXISTING PROJECTS AND THEIR PERFORMANCE

The prospects of RDF in India were recognized very early after MSW Rules 2000 were passed. Two plants to produce and combust RDF were built near Hyderabad and Vijayawada in 2003 (3 years after MSW Rules 2000). These two plants built with assistance from government agencies like Andhra Pradesh Technology Development Corporation (APTDC) served as demonstration projects for the technology. Two other RDF making plants were built in Jaipur and Chandigarh which use RDF as fuel in cement plants to reduce the amount of coal used.

Totally, there are 6 RDF plants in India, near Hyderabad, Vijayawada, Jaipur, Chandigarh, Mumbai and Rajkot. The RDF plant in Vijayawada serves two cities, Vijayawada and Guntur. The Hyderabad and Vijayawada RDF plants were the first RDF plants to be built in India and each handle 700 TPD and 500 TPD of MSW to generate 6 MW of electricity respectively. The author visited one of these plants and found out that they're both not in operation, currently. The RDF plants near Jaipur and Chandigarh can be considered as the second generation of RDF plants which combust the RDF produced in cement kilns to replace fossil fuels. They handle 500 TPD of MSW each. The author visited the plant in Jaipur and found that it is not operated regularly. The plant in Chandigarh is known to have been dormant too, but it is being retrofitted with systems to reduce moisture in the MSW while processing. The RDF plant in Rajkot handles 300 TPD of waste. Other than this, there is not much information available about this plant; its present operations status is not known either. It's the same case with the small scale RDF plant in Mumbai, which produces RDF pellets by processing 80 TPD of MSW.

5.4.3 ANALYSIS OF RDF PLANTS IN INDIA

The analysis of RDF plants presented in this section is based on the author's field visits and meetings with professionals who were involved in building and operating these plants.

5.4.3.1 EARLY FAILURES

Similar to earlier waste management technologies experimented in India, RDF plants also met with initial failures. Out of the six well known RDF facilities in India, two are now out of operation, another two are not operated regularly and the status of the remaining two is unknown. Reasons for these failures are discussed in the sections below. A common observation was that the investors in RDF facilities overestimated the supply of wastes and the fraction that can be recovered as RDF. Simultaneously, only capital costs were considered and long term maintenance costs were either ignored or were severely underestimated. These issues need to be addressed in future RDF projects and relevant changes are required in existing projects.

5.4.3.1.1 HYDERABAD AND VIJAYAWADA (RDF WTE)

The four plants in India can be divided into two categories for analysis, the first two at Hyderabad and Vijayawada are RDF combustion facilities and are similar in design, and the next two at Jaipur and Chandigarh send their waste to co-combustion facilities and are similar to each other in design. While plants in Hyderabad, Jaipur and Chandigarh serve only the city that is mentioned, the plant at Vijayawada is built to handle wastes from Vijayawada and Guntur (40 km apart) each with a current population of 1.4 million and 678,000 respectively. Vijayawada and Guntur generate about 700 TPD and 300 TPD of MSW respectively.

The RDF combustion plant for Hyderabad is built 50 km away in a village called Elikatta in the district of Mahabubnagar and receives RDF from the processing facility inside the city, whereas the combustion facility at Vijayawada receives half of the RDF from the processing plant situated nearby and the other half from the plant in Guntur, 40 km away. Both these combustion plants are designed to handle 700 TPD of RDF and supplementary biomass to produce 6 MW of electricity.

The author visited the plant at Hyderabad in which the waste is dumped at ground level and fed into a traveling grate, stoker fired boiler by inclined conveyors (Figure 34). Both facilities generated above 6.6 MW (more than design power) during their initial years of operation. Even though the plant at Hyderabad is not running, the boiler is still working and is operated twice every month to maintain the machinery.

The reasons for the failure to operate the plant are mechanical problems in the condenser (Figure 35) and leaks in the piping, which if replaced will get the plant running. A condenser is a common component in process industries and is not unique to WTE plants. In addition to failure of condenser, it is believed that the plant had problems with continuous waste supply. Vijayawada plant is believed to have problems with the supply of waste to the facility and it could operate for only about 6 years (53).

Figure 34, Conveyor Belt for Feeding RDF into the WTE Boiler, Hyderabad RDF-WTE Plant, Elikatta

A common observation in all these failures is the lack of institutional framework and legal agreements between the a) municipalities, b) plant owners and the c) electricity boards. The technology did well but with additional fuel like rice husk as is the case in Hyderabad, where 20 - 25% by weight of the feed to boiler is rice husk, which has a calorific value of 13 MJ/kg (54). By adding 25% (weight %) of rice husk to RDF which has a calorific value of 11.7 MJ/kg (55), we get a mixed fuel with calorific value of 12 MJ/kg which is sufficient for self sustained combustion. If additional biomass fuel like rice husk or bagasse is considered during design of the plant, the price fluctuations of such fuel have to be considered too, which did not seem to happen in case of Hyderabad plant. Procuring these additional biomass fuels was not economical at times and there was no continuous supply of these fuels.

Figure 35, Condensers of Hyderabad RDF-WTE Plant, Elikatta

5.4.3.1.2 JAIPUR AND CHANDIGARH

The RDF facility at Jaipur is situated 17 km away from the city and can handle 500 TPD of MSW, however it has been running at only 70% capacity, handling 350 TPD. The facility was not in operation during the author's visit and the last time it was operated was on February 14, 2011 (as on 05th March, 2011). The facility operates with a RDF recovery percentage of 7 – 8 % depending upon the requirement of 'fluff' at a cement plant located 350 km away. With an efficiency of recovering only 7 – 8% of wastes, RDF technology can increase a landfill's lifetime by only 1.5 years in every 20 years. As the facility at Jaipur is not operating every day, the waste that is not accepted is dumped at the nearby landfill along with rejects (above 90% of the input) and construction and demolition debris. The facility employs two shredders, both imported, a trommel screen, a vibrating screen and a magnetic separator. One of the shredders used at the facility was observed to undergo severe wear and tear and was replaced at least four times since initial installation of the facility. Chandigarh facility was also known to have been facing problems and that its frequency of operation is low. It is currently undergoing technology upgradation and is expected to resume full scale operation soon.

5.4.4 HIGH PERCENTAGE OF REJECTS

During research visits in India, it was observed that the output from RDF plants was only 5-7%. Rest of the MSW, up to 95% is landfilled. In most occasions, the RDF plant rejects are not accepted at landfills or it becomes expensive for the operator to transport such huge quantity of rejects to a landfill. Therefore, these rejects can be seen dumped around the facilities. The operators at these facilities complained that the presence of construction and demolition (C & D) waste decreased the overall RDF output. Presence of C & D wastes not only increased the inerts percentage but it also makes separation of high calorific value fraction difficult. Primary shredders employed in these facilities also had difficulty dealing with high percentage of C & D wastes.

Use of RDF for co-combustion in cement plants also faces significant problems in India. Cement plants needed RDF as a fuel only when coal and other biomass fuels became expensive or were not available. RDF has lesser calorific value compared to coal and therefore is not a priority choice in cement plants. Due to the lack of continuous demand for RDF at respective cement plants, the MSW which reaches the RDF plant everyday is not always processed and is dumped along with the inerts around the plant or in landfills.

5.5 WASTE-TO-ENERGY COMBUSTION

Waste-to-Energy combustion is a proven mixed waste handling technology across the developed world. Comparatively it is less successful in countries like the US when compared to Europe and Japan. This is due to different reasons, the most prevalent one being cheaper landfilling in the US due to larger land availability. But in the case of New York, New York pays just $60 per ton as a tipping fee for MSW that is thermally treated at a WTE plant in Newark, NJ, while paying over $100 per ton of several million tons of trash it generates that are hauled to remote landfills in South Carolina, Ohio, and elsewhere (56). The probability of WTE becoming economically cheaper than landfilling in India is low due to loosely implemented regulations. However, with an increasing middle class, increase in public health awareness and generation of mixed waste (due to lack of source separation), WTE will become an important part of integrated solid waste management in India. Due to the lack of source separation all MSW generated and collected is mixed waste.

WTE is the only technological solution which could recover the maximum energy and materials from mixed waste. WTE boilers are specifically designed to be flexible with feed in order to be able to handle highly heterogeneous mixed solid wastes.

WTE is recognized as a renewable energy technology by the Government of India (GOI). Australia, Denmark, Japan, Netherlands and the US are some more countries which recognize WTE as a renewable energy technology (15). Due to the dominance of organic waste in MSW, it is considered as a bio-fuel which can be replenished by agriculture. In India, urban MSW contains as much as 60% organic fraction and 10% paper. Therefore, potentially, 70% of energy from WTE plants is renewable energy.

The activity in the WTE sector has increased considerably within only one year since author's first research visit in January, 2010. A WTE plant is under construction at Okhla, New Delhi; two RDF-WTE plants are under construction at Bibinagar (Hyderabad) and Karimnagar; and a WTE plant is being planned for Pimpri. Apart from these new projects, there are already two RDF-WTE plants in India, one in Hyderabad and the other in Vijayawada (See Section 5.4.3.1.1). They employ similar technology and design parameters. They use refused derived fuel mixed with agro wastes as feed into traveling grate, stoker fired boilers to generate 6.6 MW power.

Only two WTE plants and two RDF-WTE plants were built in India until now. The latest one among them has finished construction on the Okhla landfill site, New Delhi and is about to start operations. The first WTE incinerator in India was installed at Timarpur, Delhi in 1985. It was designed to produce 3.75 MW of electricity, based on imported technology at the cost of $ 9.1 million (INR 410 million) (53). It failed to operate on a daily basis and was on a trial run until 1990 when it was closed (57). The two RDF-WTE plants built at Hyderabad and Vijayawada are not working either (See Section 5.4.3.1).

The track record of WTE in India is acting as its biggest obstacle for further development. Past failures can act as lessons to forth coming WTE projects but will not be valid arguments against new facilities. This is because the reasons identified for past failures are a) improper design to handle Indian wastes and b) inadequate solid waste collection systems. Improper design includes mismatch of the quality of incoming refuse with the plant design calorific value (57), high percentage of inerts and having to handle refuse manually (58). The failures are due to bad planning, lack of inter-institutional cooperation, and lose implementation of contracts and laws. The WTE boiler installed in Hyderabad ran successfully and produced more power than designed capacity (6.6 MW) until its condenser stopped working due to air and water leakages. Also, since the first WTE in India in 1985, India has undergone two decades of unprecedented economic growth which changed the lifestyles, which in turn changed the nature of waste and increased its quantity. The change in nature of MSW resulted in higher percentage of recyclables and increase in calorific value of wastes; improvement in collection of MSW decreased the fraction of inerts that end up in the MSW stream. During the same time, WTE industry has also undergone a revolution in pollution control worldwide (59).

5.5.1 POWER POTENTIAL FROM URBAN MSW

Table 16, Potential for Energy Generation from MSW and Fossil Fuel (Coal) Displacement

S.No.	City	MSW Generated (TPD)	Calorific Value (MJ/kg)	Power Production Potential (MW)	Coal substituted (TPY)
1	Greater Kolkata	11,520	5.0	129.9	1,445,194
2	Greater Mumbai	11,124	7.5	186.6	2,075,263
3	Delhi	11,040	7.5	186.8	2,078,043
4	Chennai	6,118	10.9	149.0	1,657,716
5	Greater Hyderabad	4,923	8.2	91.0	1,012,526
6	Greater Bengaluru	3,344	10.0	74.9	833,427
7	Pune	2,602	10.6	61.8	687,908
8	Ahmadabad	2,518	4.9	27.9	310,362
9	Kanpur	1,756	6.6	25.9	288,159
10	Surat	1,734	4.1	16.1	179,314
11	Kochi	1,366	2.5	7.6	84,327
12	Jaipur	1,362	3.5	10.7	118,652
13	Coimbatore	1,253	10.0	28.0	311,631
14	Greater Visakhapatnam	1,194	6.7	18.0	199,801
15	Ludhiana	1,115	10.7	26.8	298,041
16	Agra	1,021	2.2	5.0	55,457
17	Patna	945	3.4	7.3	80,844
18	Bhopal	877	5.9	11.7	130,174
19	Indore	867	6.0	11.7	130,139
20	Allahabad	815	4.9	9.0	100,455
21	Meerut	804	4.6	8.2	91,457
22	Nagpur	801	11.0	19.8	220,216
23	Lucknow	743	6.5	10.9	120,839
24	Srinagar	713	5.3	8.5	94,139
25	Asansol	706	4.8	7.7	85,250
26	Varanasi	706	3.4	5.3	59,291
27	Vijayawada	688	8.0	12.3	137,263
28	Amritsar	679	7.7	11.7	130,219

S.No.	City	MSW Generated (TPD)	Calorific Value (MJ/kg)	Power production Potential (MW)	Coal substituted (TPY)
29	Faridabad	667	5.5	8.3	91,897
30	Dhanbad	625	2.5	3.5	38,583
31	Vadodara	606	7.5	10.1	112,737
32	Madurai	543	7.6	9.2	102,832
33	Jammu	534	7.5	8.9	99,398
34	Jamshedpur	515	4.2	4.9	54,279
35	Chandigarh	486	5.9	6.4	71,478
36	Pondicherry	449	7.7	7.8	86,578
37	Jabalpur	380	8.6	7.3	81,410
38	Bhubaneswar	356	3.1	2.5	27,592
39	Nashik	329	11.6	8.5	94,918
40	Ranchi	325	4.4	3.2	35,985
41	Rajkot	317	2.9	2.0	22,748
42	Raipur	316	5.3	3.8	42,019
43	Thiruvananthapuram	308	10.0	6.9	76,506
44	Dehradun	247	10.2	5.7	63,082
45	Guwahati	246	6.4	3.5	39,032
46	Shillong	137	11.5	3.5	39,153
47	Agartala	114	10.2	2.6	28,901
48	Port Blair	114	6.2	1.6	17,552
49	Aizwal	86	15.8	3.0	33,831
50	Panaji	81	9.3	1.7	18,707
51	Imphal	72	15.8	2.5	28,323
52	Gandhinagar	65	2.9	0.4	4,739
53	Shimla	59	10.8	1.4	15,851
54	Daman	23	10.8	0.6	6,218
55	Kohima	20	11.9	0.5	5,941
56	Gangtok	19	5.2	0.2	2,449
57	Itanagar	18	14.3	0.6	6,419
58	Silvassa	11	5.4	0.1	1,472
59	Kavarati	5	9.4	0.1	1,171
	TOTAL	**81,407**		**1,292**	**14,367,909**

The overall power potential from MSW in India is estimated to be 3,650 MW and 5,200 MW by 2012 and 2017 respectively (60). Power potential from MSW from 59 cities was found out to be 1,292 MW. Generation of energy from MSW can displace 14.5 million TPY of low grade coal every year. Delhi has the highest potential for power generation from MSW (186.8 MW), followed by Mumbai (186.6 MW), Chennai (149 MW), and Hyderabad (91 MW). MSW generated in Chennai (6,118 TPD) is only about half of the waste generated in Kolkata (11,520 TPD) but it has a higher calorific value (10.9 MJ/kg), more than twice of that of MSW in Kolkata (5 MJ/kg). Chennai has the highest calorific value of MSW compared to other cities generating MSW > 1,000 TPD, followed by Ludhiana (10.7 MJ/kg), Pune (10.6 MJ/kg), and Bengaluru and Coimbatore (10 MJ/kg).

WTE is a large scale technology. Most WTE plants are built with a capacity to handle 1,000 TPD of waste. The concept of regional landfills should be adopted to build regional WTE facilities to serve two or more cities, each of which landfill less than 1,000 TPD of MSW after recycling and composting.

5.5.2 COST

Modern WTE combustion facilities are designed according to Maximum Available Control Technology (MACT) regulations, requiring investment of majority of the capital in building a WTE plant in its pollution control technology (Table 18). The economics of a WTE plant depends upon the type of energy output from it. Energy generation from MSW can be in the form of electricity and/or steam. WTE plants which generate only steam as the final product are less capital expensive. Some WTE plants generate electricity and low pressure steam, which increases their overall energy efficiency and revenues. However, the generation of steam requires the presence of industries which can utilize a continuous supply of process steam or facilities which need district heating (and cooling). WTE plants in Europe and US provide steam for district heating and cooling. Perinaz Bhada, et al., recommends a WTE facility selling only electricity for India due to the current absence of district heating (and cooling) infrastructure in Mumbai and elsewhere. However, Investors in Indian WTE market should consider the possibility of industrial steam utilization to achieve better efficiency and economy.

Electricity generation from WTE would require a steam turbine in addition to the combustion facility and therefore is more expensive compared to a facility which generates only steam. The capital cost of building such a WTE plant is USD 51,000 (INR 2,300,000) per ton of waste processed (62) (63). In comparison to windrow composting which costs only $ 4,500 (INR 200,000) per ton of organic waste processed (1), WTE is expensive. However, electricity produced from WTE plants has better product demand and no marketing issues like compost. It can be sold to the grid directly. Also, WTE will provide better pollution control compared to mixed-waste composting, which disperses the pollutants in to agricultural fields and later into environment.

Cost per kilowatt hour of electricity generated by MSW, is slightly costlier than other biomass fuels, wind and small hydro (15). It is very cheap compared to solar photovoltaic, which is currently highly subsidized by GOI. While comparing WTE to other waste management techniques, its potential to generate energy and handle mixed wastes with least/no harm to environment and public health should be considered. While comparing it to other renewable energy options, benefits of waste management, energy and metal recovery, and reduction of green house gases should be considered (15). Compared to other sources of energy, energy generation from MSW is imperative, which would otherwise cause serious public health and environmental damage (61).

5.5.3 OKHLA WASTE-TO-ENERGY PROJECT, NEW DELHI

The WTE plant built at Okhla, New Delhi is scheduled to start operations in 2011. Okhla plant will be the first modern WTE combustion plant in India, it is designed to handle 1350 TPD of MSW and generate 16 MW of power. This WTE facility will provide energy to 600,000 households and will treat MSW generated by nearly 800,000 households. Its success in operation and in monitoring emissions will have a strong influence on the future of WTE industry in India. It is built on an old dumpsite. It is facing public protests because of the increase in truck traffic in adjoining communities, once the operations begin. Okhla area has a landfill operating since 1994 and receiving 1200 TPD MSW. Some of this MSW used to be dumped at the present WTE facility's site. It is unknown how much waste was dumped here to compare the increase in truck traffic. In case of increase in truck traffic, one way of reducing it would be to employ trucks with larger capacities.

5.5.4 EMISSIONS

Incinerators had a long history of pollution. They were one of the major sources of pollution in western countries where municipal, medical and hazardous wastes were burnt in incinerators. They were recognized as sources of pollution and due to rise in environmental awareness and decrease in air quality in cities, most of them were shut down. Stringent air quality regulations made by respective governments led to less polluting technology. Since then, the pollution control equipment has advanced so rapidly that the US EPA regards it as "a clean, reliable, renewable source of energy," and one that has "less environmental impact than almost any other source of electricity" (15). WTE also provides point source pollution control, where pollutants from the MSW which would otherwise get dispersed in nature can be captured and handled accordingly.

Table 17, Low Emissions Achieved by German WTE Facilities; Source: EEC

Emissions	Emissions Standards (mg/m^3)	Emissions Achieved (mg/m^3)
Particulate Matter	10	0.3
Sulfur Dioxide (SO_2)	50	1.35
Nitrous Oxides (NO_x)	200	28.8
Total Organic Carbon	10	0.2
Carbon Monoxide (CO)	50	6.05
Mercury (Hg)	0.03	0.001
Heavy Metals	0.51	0.0162
Dioxins (ng/Nm^3)	0.11	0.00058

The advent of pollution control technology has dramatically reduced dioxins and furans emissions from WTE plants. A comprehensive study of all available literature by National Research Council (NRC), USA published as 'Waste Incineration and Public Health' found no correlation between WTE plants and public health impacts. A study conducted by Chinese Academy of Sciences and Stanford University found that emissions from all Chinese WTE facilities were in compliance with Chinese standards.

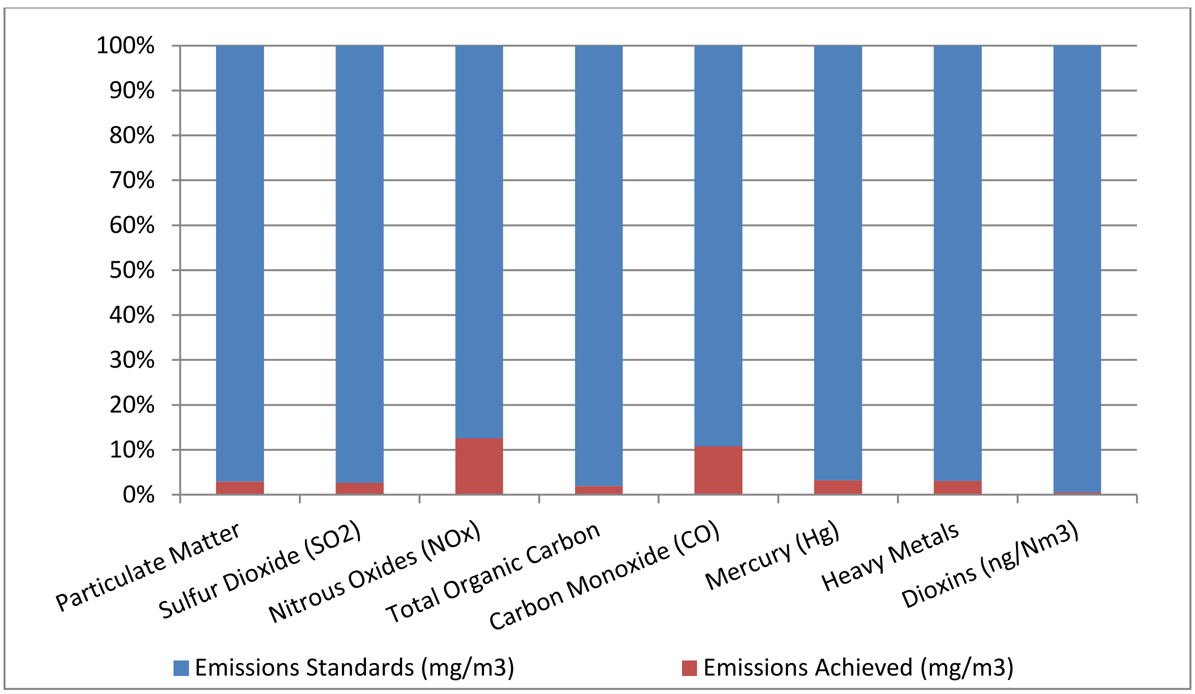


Figure 36, Comparison of German Emissions Standards and Emissions achieved by German WTE facilities

All 84 WTE plants in US together release less than 12 g/year of dioxins combined. The average dioxins emissions from all small and large WTE plants in France are 0.003 ng/Nm^3 and 0.017

ng/Nm^3 respectively. These emissions are 33 times and 5 times lower than the EU and French standard for dioxin emissions (0.1 ng/Nm^3), which is one of the most stringent regulation for dioxins in the world. Other emissions from WTE facilities are also very low. Lowest emissions from German WTE facilities are provided in Table 17. Figure 36 shows that these facilities emit much lower than the most stringent standards for pollutant emissions in the world.

Large WTE facilities in China which adopted best available air pollution control technology could even meet European standards. The study found small concentration of dioxins in agricultural soils in the vicinity of a WTE plant, the major sources for which were found out to be open burning of wastes, traffic and nearby hot water boilers (62).

5.5.5 EMISSIONS CONTROL TECHNOLOGY

Table 18, WTE Air Emissions, Emission Sources and Causes, and Control Technology

Emission	Source	Major Cause	Control Mechanism/technology
Carbon Monoxide (CO)	Carbon in fuel	Incomplete combustion	Boiler and grate design to enhance combustion and turbulence, auxiliary burners
Particulate Matter (PM)	Carbon and minerals in fuel	Incomplete combustion and	Boiler and grate design to enhance combustion and turbulence, auxiliary burners, fabric filters
Nitrogen Oxides (NOx)	Nitrogen in fuel and primary air	High temperature conditions	Flue gas recirculation, selective non-catalytic reduction
Sulfur Dioxide (SO2)	Sulfur in fuel	Product of Oxidation	Packed bed absorption with alkaline scrubbing liquid
Hydrogen Chloride (HCl)	Chlorine in fuel	Product of Halogenation,	Dry lime injection, packed bed absorption with acidic scrubbing liquid
Dioxins and Furans	Organic chlorine in fuel	Incomplete combustion and temperatures between 140 - 149 ^{o}C	Auxiliary burners, high temperature oxidizing conditions, rapid gas cooling, adsorption by activated carbon injection
Mercury (Hg)	Hg in waste stream		Adsorption by activated carbon injection
Lead (Pb)	Pb in waste stream		Fabric filters
Trace organic compounds	Carbon and hydrogen in fuel	Incomplete combustion	High temperature oxidizing conditions
Fugitive Emissions	Initial waste handling		Negative pressure buildings and use as primary air for combustion

Modern WTE facilities employ extensive pollution control technologies which comply with MACT regulations (Maximum Available Control Technology) of USEPA. Some pollution control mechanisms and technologies employed include, flue gas recirculation, selective non-catalytic reduction, activated carbon injection, packed bed absorbers, fabric filters, etc. (Table 18)

Source separated collection is also an important method to control pollution. Source separation of MSW allows for more precise control of combustion conditions. For example, removal of chlorine containing metals and plastics from the MSW stream reduces reactions due to metal catalysts inside the plant and can significantly decrease dioxins formation in incineration (62). Source separation also helps increasing the recycling and composting rates and ensures the combustion of only the non-recyclable and non-compostable fraction of MSW.

5.5.6 OPPOSITION TO WTE

WTE is opposed in India due to the failure of Timarpur plant in 1985. The failure of the Timarpur plant was the eleventh among waste management facilities which failed to work in India, the first ten being composting (MBT) plants. The reasons of this failure are improper planning and import of foreign equipment which cannot be repaired in India, which are the same for the failure of composting plants. The opposition to only WTE arises because of the high cost of building one such plant. Most of the opposition to WTE in India is inherited from the opposition to polluting incinerators in the West around the 1980s.

It is an ironic situation for WTE all around the world because it is targeted for opposition despite its effectiveness in managing wastes. This situation demands better knowledge about the concept of waste-to-energy and also a deeper analysis of existing data. It also pushes academicians into supporting WTE, which they do not have to do with other effective SWM techniques like recycling and composting. Often in extreme situations, WTE gets more opposition than landfilling!

The main objective of WTE is to manage wastes, reduce the volume of waste landfilled and recover resources. Energy generation adds value to the waste and makes proper waste management economically feasible. Composting and biomethanation work on the same principle too.

5.5.7 ON COMPETITION WITH RECYCLING

One of the arguments against WTE which needs clarification is its competition with recycling. Opponents of WTE claim that installing WTE facilities decreases recycling in the community. However, the ladder of sustainable waste management (Figure 37) prepared by the Earth Engineering Center at Columbia University shows that recycling and WTE go hand in hand in reducing the amount of wastes landfilled.

Countries which recycle most of their wastes also employ more WTE combustion and vice versa. Employing combustion for waste management indicates a high level of environmental awareness of a country. Netherlands for example is employing the most sustainable waste management strategy. The strategy they employ includes a combination of recycling, composting and WTE to the extent that the MSW landfilled in Netherlands is nearly zero. As can be observed in other sustainable countries, WTE is an important aspect of an integrated waste management system in addition to recycling and composting.

The argument of 'competition with recycling' is extrapolated further in developing nations by some organizations and it is claimed that installing WTE facilities not only reduces recycling but also displaces waste pickers. This might happen if the municipal authority shuts WPs from the formally collected waste. But, a closer look at the numbers shows a different situation.

For example (Appendix 6), 7,000 WPs in Pune collect and help recycle up to 56% of recyclables generated every year. However, the amount of recyclables recycled from formally collected wastes is only 21%, which is only 4% of the total wastes collected formally. It has to be understood that informal recycling already works very efficiently and this percentage of recycling is achieved by WPs collecting 34 kg/day each (Chintan estimates 60 kg/person/day is collected by WPs). Despite the huge number of WPs working efficiently every day, the amount of wastes recycled are only 4%. The rest, about 330,000 TPY of MSW is still landfilled. WTE facilities if planned will be designed to handle only fraction of these wastes which have already been foraged for recyclables. The efficiency of WPs can be further increased by providing waste transfer stations or material recovery facilities (MRFs) to them. But, the rise in efficiency of recycling achievable in near future does not assure complete waste management. It indeed leaves thousands of tons of MSW to be landfilled every year. Therefore, even if a WTE facility with 210,000 TPY MSW handling capacity (similar to Hyderabad and Vijayawada) is built, it would not interfere with the recyclable collection by WPs. However, it has to be made sure that MSW input to WTE facilities comes from the rejects of MRF facilities where all recoverable recyclables are separated. This can be made possible by integrating the informal sector into the overall waste management system of the city.

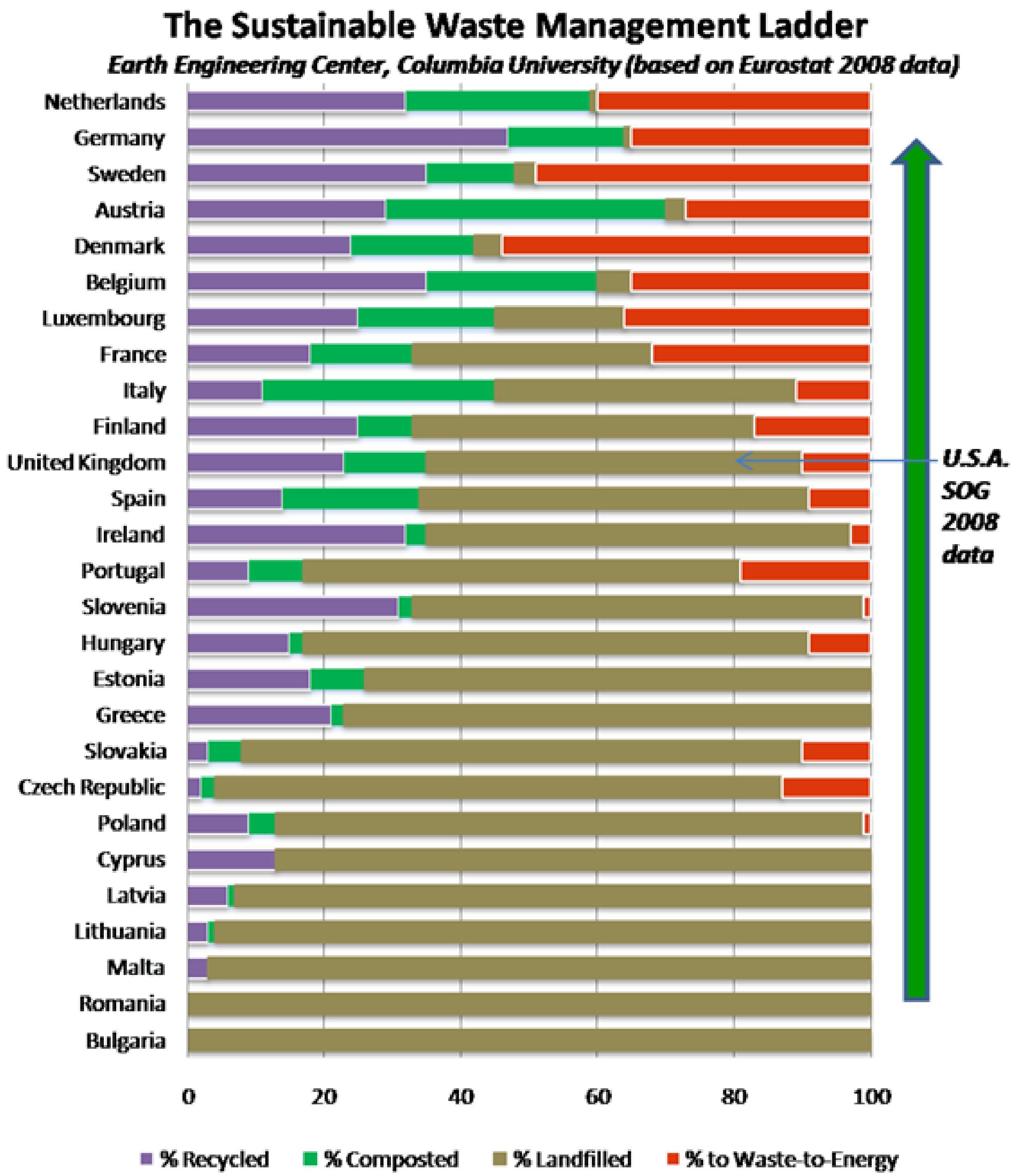


Figure 37, Sustainability ladder of SWM in Europe, Source: EEC

5.6 SOURCE SEPARATION

Proper SWM requires separate collection of different wastes, called source-separated waste collection. Source separated collection is common in high income regions of the world like Europe, North America and Japan where the infrastructure to transport separate waste streams exists. Most centralized municipal systems in low income countries like India collect solid wastes in a mixed form because source separate collection systems are non-existent. Source separated collection of waste is limited by infrastructure, personnel and public awareness. In India only paper is separately collected from the source by itinerant waste buyers present all over cities. Small scale biodigestion also uses source separated kitchen waste.

Table 19, Effect of Source Separation on Heavy Metals in MSW Compost; Source: IISS

Heavy Metals	Concentration in compost (mg/kg)		
	Mixed Waste	*Partially Separated*	*Source Separated*
Zinc	414	303	153
Copper	370	292	81
Cadmium*	230	90	80
Lead	252	183	41
Nickel	41	44	21
Chromium	142	88	53
Cadmium Concentration Units: mg/100 kg*			

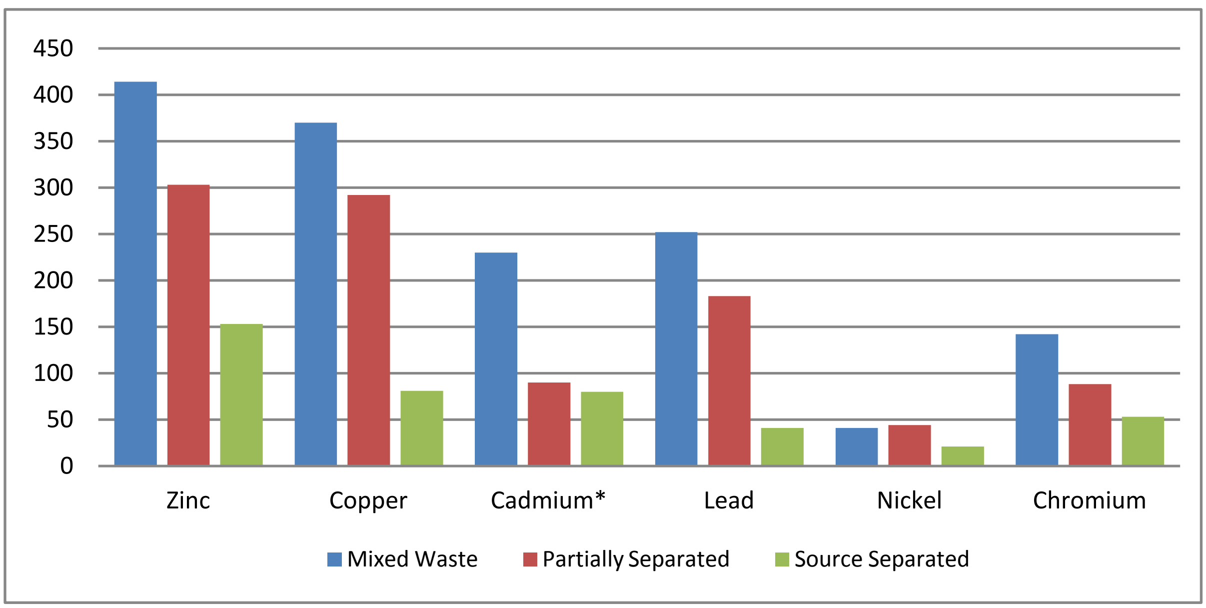


Figure 38, Impact of Source Separation on Heavy Metals Concentration in MSW Compost

Efficiency of recycling and composting is greatly reduced due to the general absence of source separation. Absence of source separation strikes centralized aerobic or anaerobic digestion processes off the list. Anaerobic digestion is very sensitive to the feed quality and thus biomethanation systems get easily upset due to impurities in the feed. This was the reason for the failure of a large scale biomethanation plant in Lucknow. Aerobic Composting requires source separated organic materials too, to avoid impurities and heavy metals in the final compost (Table 19, Figure 38). The only known composting plants which handle source separated organic wastes are in Vijayawada and Suryapet (26).

Increasing source separation would increase the overall material and energy recovery rates from MSW. It also helps control pollution in WTE plants. For example, removal of chlorine containing metals and plastics from the MSW stream reduces reactions due to metal catalysts inside the plant and can significantly decrease dioxins formation in incineration (62). Source separation also ensures the combustion of only the non-recyclable and non-compostable fraction of MSW.

Box 8 GOVERNMENT POLICY
Source: (9)

The Government of India (GOI) recognizes that the existing state of MSW management systems in the country is also raising serious public health concerns and sanitation issues that need to be addressed in the public interest.

The responsibility for SWM management lies with the respective Urban Local Bodies (ULBs), consisting of municipal corporations, municipalities, nagar panchayats, etc., (collectively referred to as the 'Authorities'). The Municipal Solid Waste (Management and Handling) Rules, 2000 (the 'MSW Rules'), issued by the Ministry of Environment and Forests, Government of India, under the Environment (Protection) Act, 1986, prescribe the manner in which the Authorities have to undertake collection, segregation, storage, transportation, processing and disposal of the municipal solid waste (the 'MSW') generated within their jurisdiction under their respective governing legislation.

Compliance with the MSW Rules requires that appropriate systems and infrastructure facilities be put in place to undertake scientific collection, management, processing and disposal of MSW. However, it has increasingly come to the attention of the national (and state) government that, the Authorities are unable to implement and sustain projects to enable scientific collection, management, processing and disposal of MSW.

Government of India through its various wings has implemented or sponsored numerous workshops for municipal officials and conferences for businesses and academia on SWM. Apart from such encouragement, it introduced schemes like Jawaharlal Nehru National Urban Renewal Mission (JnNURM) to develop urban areas and included proper SWM as one of its main objectives. Under JnNURM, GOI sponsored 42 SWM projects worth USD 500 million (INR 22.5 billion) between 2006 and 2009 (GOI's average share is around 20%) (Table 20). It has successfully joined hands with the private sector to form "Public Private Partnerships (PPP)".

Table 20, JnNURM Projects Undertaken, and Government Share, Source: CPCB

S.No.	City	Year Sanctioned	Total Cost (INR Lakhs)	Total Cost (USD Million)	Government Contribution (USD Million)	Govt. Share (%)
1	Agra	2007	3,083.99	6.85	1.71	25.0
2	Ahmadabad	2009	11,885.84	26.41	2.31	8.7
3	Allahabad	2008	3,041.49	6.76	0.84	12.5
4	Amritsar	2009	7,249.00	16.11	2.01	12.5
5	Asansol	2007	4,357.27	9.68	2.42	25.0
6	Chennai	2007	25,532.00	56.74	4.96	8.8
7	Chennai	2008	4,421.25	9.83	0.86	8.7
8	Coimbatore	2007	9,651.00	21.45	8.04	37.5
9	Dehradun	2008	2,460.00	5.47	1.09	20.0
10	Dhanbad	2009	5,585.90	12.41	1.55	12.5
11	Faridabad	2007	7,650.00	17.00	2.13	12.5
12	Guwahati	2007	3,561.71	7.91	3.52	44.4
13	Haridwar	2009	1,671.53	3.71	0.74	20.0
14	Imphal	2007	2,580.71	5.73	1.29	22.5
15	Indore	2007	4,324.66	9.61	3.60	37.5
16	Itanagar	2007	1,194.38	2.65	1.19	45.0
17	Jaipur	2006	1,319.74	2.93	1.10	37.5
18	Kanpur	2007	5,623.79	12.50	3.12	25.0
19	Kochi	2007	8,812.00	19.58	4.89	25.0
20	Kolkata	2007	5,658.53	12.57	3.30	26.2
21	Kolkata	2009	11,196.52	24.88	2.18	8.8
22	Lucknow	2007	4,292.37	9.54	1.19	12.5
23	Madurai	2007	7,429.00	16.51	6.19	37.5
24	Mathura	2006	991.60	2.20	0.88	40.0
25	Meerut	2006	2,259.40	5.02	1.26	25.0
26	Mumbai	2009	4,986.86	11.08	0.97	8.7
27	Mumbai	2007	17,879.00	39.73	3.48	8.7
28	Mysore	2008	2,998.00	6.66	1.33	20.0
29	Nainital	2010	931.00	2.07	0.41	20.0
30	Nasik	2006	5,999.23	13.33	5.00	37.5
31	Patna	2008	1,155.81	2.57	0.32	12.5
32	Patna	2007	3,695.40	8.21	1.03	12.5
33	Pondicherry	2009	4,966.00	11.04	2.21	20.0
34	Pune	2006	7,044.81	15.66	3.91	25.0
35	Rajkot	2006	867.00	1.93	0.96	50.0

S.No.	City	Year Sanctioned	Total Cost (INR Lakhs)	Total Cost (USD Million)	Government Contribution (USD Million)	Govt. Share (%)
36	Ranchi	2009	5,139.43	11.42	2.28	20.0
37	Shimla	2007	1,604.00	3.56	0.71	20.0
38	Surat	2007	5,249.72	11.67	2.92	25.0
39	Thiruvananthapuram	2008	2,456.00	5.46	1.09	20.0
40	Vadodara	2007	3,098.54	6.89	3.44	50.0
41	Varanasi	2007	4,867.73	10.82	1.35	12.5
42	Vijayawada	2008	5,805.00	12.90	1.61	12.5
	TOTAL/AVERAGE		**224,577.21**	**499.06**	**95.44**	**19.1**

Box 9, JAWAHARLAL NEHRU NATIONAL URBAN RENEWAL MISSION (JnNURM)

Sources: (52)**,** (7)

JnNURM should be credited for the shift in the way Indian cities have started to manage their wastes. Even though Clean Development Mechanism (CDM) revenues were applicable to almost all SWM projects in India, the paradigm shift observed now has started only after the introduction of JnNURM. This "Urban Renewal Mission" was launched by the Government of India in December 2005 in response to challenges faced by urban Indians. An overall investment of over USD 22 billion (INR 100,000 crores) is envisaged over a period of 7 years from 2005-2012 in 65 "priority cities". Central Government would contribute USD 13 billion and the rest will be contributed by State Governments and respective Urban Local Bodies (ULBs). By 2023, it is expected to benefit 150 million urban Indians.

An important objective of JnNURM is to Improve SWM as a basic service. SWM projects initiated under JnNURM cover improving primary collection, waste transportation and waste disposal. Introduction of JnNURM has provided opportunities for expanding PPPs in all the above areas of SWM. Among the 42 SWM projects undertaken through JnNURM funds (Table 20), 34 cities proposed to start door to door collection. Rest of the cities are undertaking projects for sanitary landfill facilities and composting facilities.

7 OTHER SOURCES OF INFORMATION

The scope of this study is limited to comparing different waste management technologies and their public health and environmental impacts and has consciously kept away from repeating information which is already published. The volume of research on SWM in less considering the need for such, however, good quality manuals, papers and guidelines do exist. This section cites those sources of information which could help get a wholesome idea of the entire solid waste management sector in India. Many other publications are available on www.WTERT.org and will also be made available on the website of WTERT – India, which is under construction.

To get an overall idea of the theoretical aspects, specifications, law and government policy, please refer to Solid Waste Management Manual, published by the Ministry of Urban Development (MOUD), Government of India (GOI). This publication covers topics ranging from MSW collection, technology specifications, waste handling techniques and the law and government policy among many other topics (BOX 10).

BOX 10, SELECTED CONTENTS IN MINISTRY OF URBAN DEVELOPMENT'S SOLID WASTE MANAGEMENT MANUAL

Sources: MOUD, GOI

1. Principles of Solid Waste Management
2. Sorting and Material Recovery
3. Primary Collection of Waste
4. Waste Storage Depots
5. Transportation of Waste
6. Composting
7. Energy Recovery from MSW
8. Emerging Technologies
9. Landfills
10. Institutional Aspects
11. Economic and Financial Considerations
12. Management Information System
13. Legal Aspects
14. Policy Guidelines

The Guidance Note published by MOUD, GOI on Municipal Solid Waste Management on a Regional Basis is an excellent source of information on specifications and feasibility of regional landfills and a good collection of such case studies.

The National Master Plan for Development of Waste-to-Energy in India published by the Ministry of New and Renewable Energy (MNRE), GOI is a very good source of information on the theoretical aspects, opportunities and specifications of waste to energy technologies that could be adopted in India. The need for a feasibility study of a WTE plant, the rationale behind WTE and the need for WTE are covered in EEC's publication Feasibility Analysis of Waste-to-Energy as a Key Component of Integrated Solid Waste Management in Mumbai, India.

Recycling Livelihoods: Integration of the Informal Recycling Sector in Solid Waste Management in India published by SNDT Women's University, Chintan and GIZ presents a clear picture of the role of informal recycling sector in solid waste management in India and the issues and methods of integrating informal recycling sector into the overall waste management system of a city.

Toolkit for Public Private Partnership frameworks in Municipal Solid Waste Management published by MOUD, Ministry of Finance Department of Economic Affairs, GOI and Asian Development Bank (ADB) presents the frame work, process and opportunities for public private partnerships (PPP) in the solid waste management sector in India.

8 CONCLUSIONS

Two decades of economic growth since 1990 has changed the composition of Indian wastes. The quantity of MSW generated in India is increasing rapidly due to increasing population and change in lifestyles. Land is scarce and public health and environmental resources are precious. The current SWM crisis in India should be approached holistically; while planning for long term solutions, focus on the solving the present problems should be maintained.

The Government of India and local authorities should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future (20). State Governments should take a proactive role in leveraging their power to optimize resources.

Improving SWM in India is imperative. Improper SWM presents imminent danger to public health, India's environment and the quality of life of Indians. Materials and energy recovery from wastes is an important aspect of improving SWM in India. It not only adds value to SWM projects and makes them economically feasible but is also more sustainable. Diverting MSW from landfills and especially from unsanitary landfills in India to any extent will contribute to the cause. India should choose those options or a combination of them, which will

a. best address the issue of overall solid waste management,
b. have the least/no impact on public health and environment,
c. consume minimal resources and
d. be economically feasible.

Recycling, composting and waste-to-energy are integral parts of the solution and they are all required; none of them can solve the India's SWM crisis alone. Policy to include waste-pickers in the private sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations. MBT for windrow composting of mixed wastes should be used to separate wastes. Such separation at a later stage allows for managing the wastes better. Compost from such a facility should be used for cash crops/ or lawns or as landfill cover instead of for food crops. Rejects from composting should be combusted to produce energy and reduce their volume. Only the ash from the WTE plants or co-combustion facilities should be landfilled. Such a scenario would divert 93.7% of MSW from landfilling.

If Indian WTE industry can exhibit self-responsibility in emissions control with constant emissions monitoring, and reporting and can feedback the results into a loop of self-improvement, it will lead the way for reforms in implementation of regulations across all other industries. It would have also established itself as a solution to a crisis and a source of comfort to more than a billion people and inspiration to a huge industrial sector, rather than being perceived by some as another problem to fight against.

The success of recycling in India depends upon leveraging the advantage India has in the form of informal recycling sector. There is a world-wide consensus that the need of recycled materials will spike in the next decade. The informal sector should be ready to meet this demand. This also increases opportunities for private companies which can aggregate large amounts of waste to supply in bulk. Prevalence of one of these or co-existence depends upon the quality of the product and the quantity (bulk) they can supply.

- Informal Sector should be integrated into formal system;
- Compost from MBT should be used as landfill cover/ cash crops/ lawns;
- RDF and WTE for the rest of the waste from MBT plants; and
- Majority source separation should be the target of Municipal corporations

Solid Waste Management, its impacts on public health and environment, and prospects for the future should be further researched. The findings should be disseminated into the public knowledge domain more effectively.

PART II, WASTE-TO-ENERGY RESEARCH AND TECHNOLOGY COUNCIL IN INDIA (WTERT - INDIA)

9 WTERT – INDIA

In order to address the rising interest, increasing investments and to funnel important decisions related to MSWM in India in the right direction, the Earth Engineering Center at Columbia University and National Environmental Engineering Research Institute have decided to set-up Waste-to-Energy Research and Technology Council (WTERT) in India; and included it in WTERT's global charter where it would function as India's window to the world on the entire spectrum of SWM issues. WTERT – India is set-up with the same guiding principle as WTERT's global charter that "responsible management of wastes must be based on science and best available technology and not on ideology and economics that exclude environmental costs and seem to be inexpensive now but can be very costly in the future". All sister organizations in WTERT's global charter understand that solutions vary from region to region and work together towards better waste management around the world. WTERT – India is set-up with the understanding that solutions to SWM in India will be different compared to other countries and is committed to researching locally available resources. WTERT – India will represent the changing times in the country where attempts are being made to conserve every natural resource and reclaim them if possible. It also expects wastefulness of resources will decline and optimum recovery of materials and energy from wastes will be achieved.

Some activities planned for WTERT-India are

- Brainstorming Workshop on SWM in general and WTE in particular to be held in India involving major stakeholders (PCBs, NGOs, Municipal Corporation and Private Companies) in early 2012, to identify niche research areas in SWM;
- International conference on SWM in Mumbai, India in 2012;
- Manuals on applicability of various MSW processing technologies to India;
- Providing internships for graduate students on research projects;

Setting up WTERT-India was an integral part of this research. It included bringing together the Earth Engineering Center (EEC) at Columbia University, the parent organization of Waste-to-Energy Research and Technology Council (WTERT) and the leading research organization on material and energy recovery from wastes in the world; and National Environmental Engineering Research Institute (NEERI), a prime research organization set up by the Government of India. WTERT – India is EEC's response to the lack of research and research organizations in India, specific to materials and energy recovery from wastes. EEC and NEERI have signed a Memorandum of Understanding to start collaboration (Annexure I) and have published a press release to this extent (Annexure III).

9.3 EARTH ENGINEERING CENTER (EEC)

For nearly two decades, the Earth Engineering Center (EEC) of Columbia University has conducted research on the generation and disposition of used materials and products in the U.S. and globally. This research has engaged many researchers on all aspects of waste management. Since 2000, EEC has produced thirty M.S. and Ph.D. theses and published nearly one hundred technical papers. In 2002, EEC co-founded, with the U.S. Energy Recovery Council (ERC; www.wte.org), the Waste-to-Energy Research and Technology Council (WTERT), which is by now the foremost research organization on the recovery of energy and metals from solid wastes in the U.S. For more information on EEC's work and publications on waste management, please visit www.WTERT.org.

9.4 NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE (NEERI)

The National Environmental Engineering Research Institute (NEERI) headquartered at Nagpur and with five other branches in Chennai, Delhi, Hyderabad, Kolkata and Mumbai is a prime research institute in India. It is a forerunner in research on SWM with a dedicated R & D division, and researchers. Research conducted by NEERI in 2005 on SWM in fifty nine cities is one of the most comprehensive studies on this issue. Other important studies on SWM include India's Initial National Communication to the United Nations Framework Convention on Climate Change and the work related to Landfill Gas Use as LNG in transport sector as well as new LFG models development that is in progress with Texas Transportation Institute, US. The researchers engaged in solid waste management at NEERI are recognized internationally. For more information on NEERI's work in India, please visit www.NEERI.res.in.

9.5 GLOBAL WTERT COUNCIL

WTERT – India will be the latest addition to the Global WTERT Council which is already operating in the U.S., Canada, Greece, China, Germany, Japan, Brazil, France, U.K. and Italy. The mission of this council is to identify the best available technologies for the treatment of various waste materials, conduct additional academic research as required, and disseminate this information by means of publications, the WTERT web pages, and periodic meetings. In particular, WTERT strives to increase the global recovery of materials and energy from used solids, by means of recycling, composting, waste-to-energy, and, sanitary landfilling with LFG utilization.

10 BLOG, SOLID WASTE MANAGEMENT IN INDIA

10.1 NEED FOR A RESEARCH BLOG

Information about all aspects of waste management should be laid out for the Citizens of India to make informed decisions. Public knowledge sphere holds enormous quantities of misinformation, which is easily available. It is due to such information or a lack of any information that some environmental initiatives are opposed or are not welcome. Academic research helps clear some of that fog. However, it is necessary that academic research finds easier ways to create awareness, because awareness inspires action. Most environmental movements in the world happen at the grassroots level fuelled by general observations and research findings. Environmental regulations in United States and the MSW rules 2000 in India are some examples of the results of public awareness.

The easiest way for general public to know about any topic of interest is through a simple internet search. Internet is the major source of information for public more often than ever before (Figure 39). Whenever someone needs information, “they will go to the Google search engine and type the words they want to know about and get those search results above, most likely clicking on the top link first”. (63)

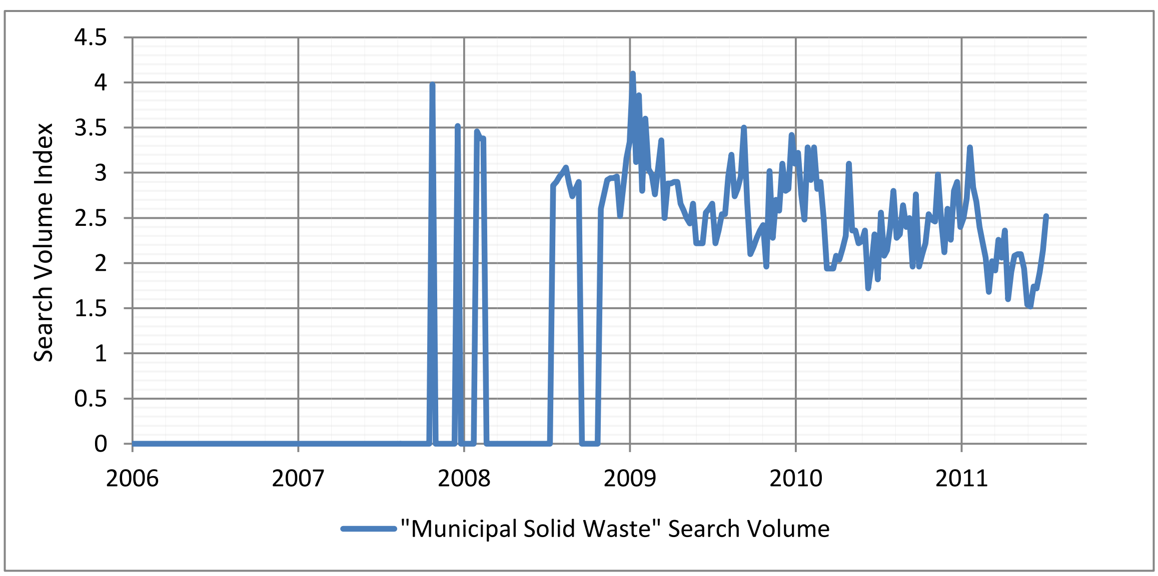


Figure 39, Internet Search for "Solid Waste Management", Source: Google Trends

Among world cities, majority of the searches (in English) on “Solid Waste Management” were from Indian cities (Figure 40). This represents a growing interest about SWM and the increasing role of internet in India. Academic research should be among the top links. This is possible through blogging because information in Blogs is easily searchable on most search engines.

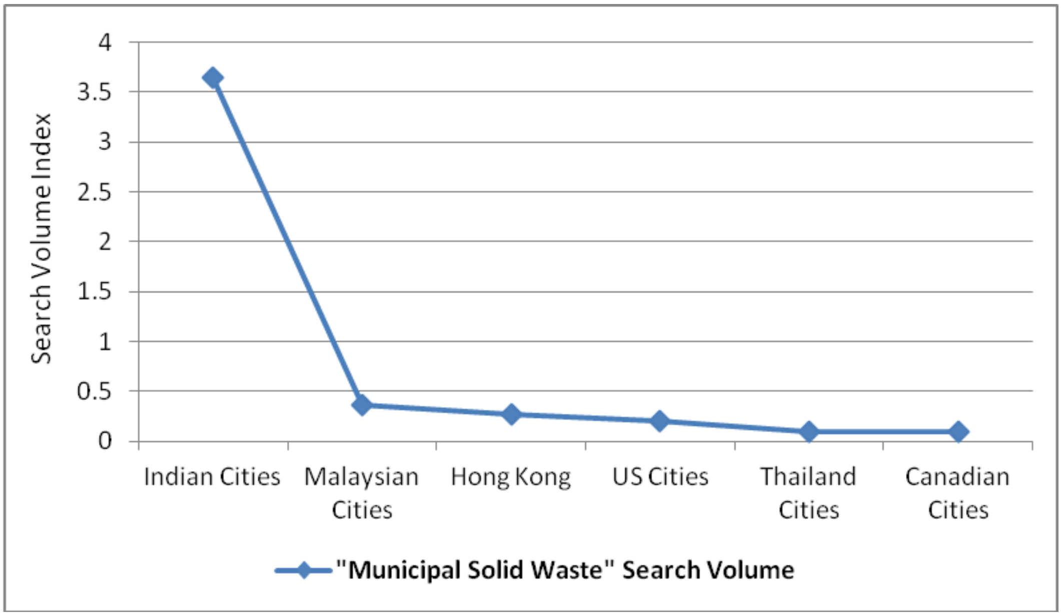


Figure 40, Internet Searches for "Solid Waste Management" from Different Cities, Source: Google Trends

10.2 BLOG DESCRIPTION AND STATISTICS

The research blog “Solid Waste Management in India” (www.SWMIndia.blogspot.com) was started in May 2009 to achieve the above discussed objectives (Section 10.1). Findings were regularly updated on the blog in the form of new posts, tables and figures. Pictures taken during research visits (whether used/not used in the posts) were made available in full size in a separate page called “Media”, so that they could be easily downloadable. This entire thesis report will also be updated on the blog, section-wise. All references used were also provided at the bottom. The blog is attributed to EEC and WTERT, the sponsors of this work on the opening page (Figure 41) and at the bottom of the blog.

Those who wanted to contact the Author were asked to do it by leaving their query in the comments section so that those queries could be tracked by others too. Those who wanted to use the excel sheets in the posts were asked to note their requirement with their email address in the comments section.

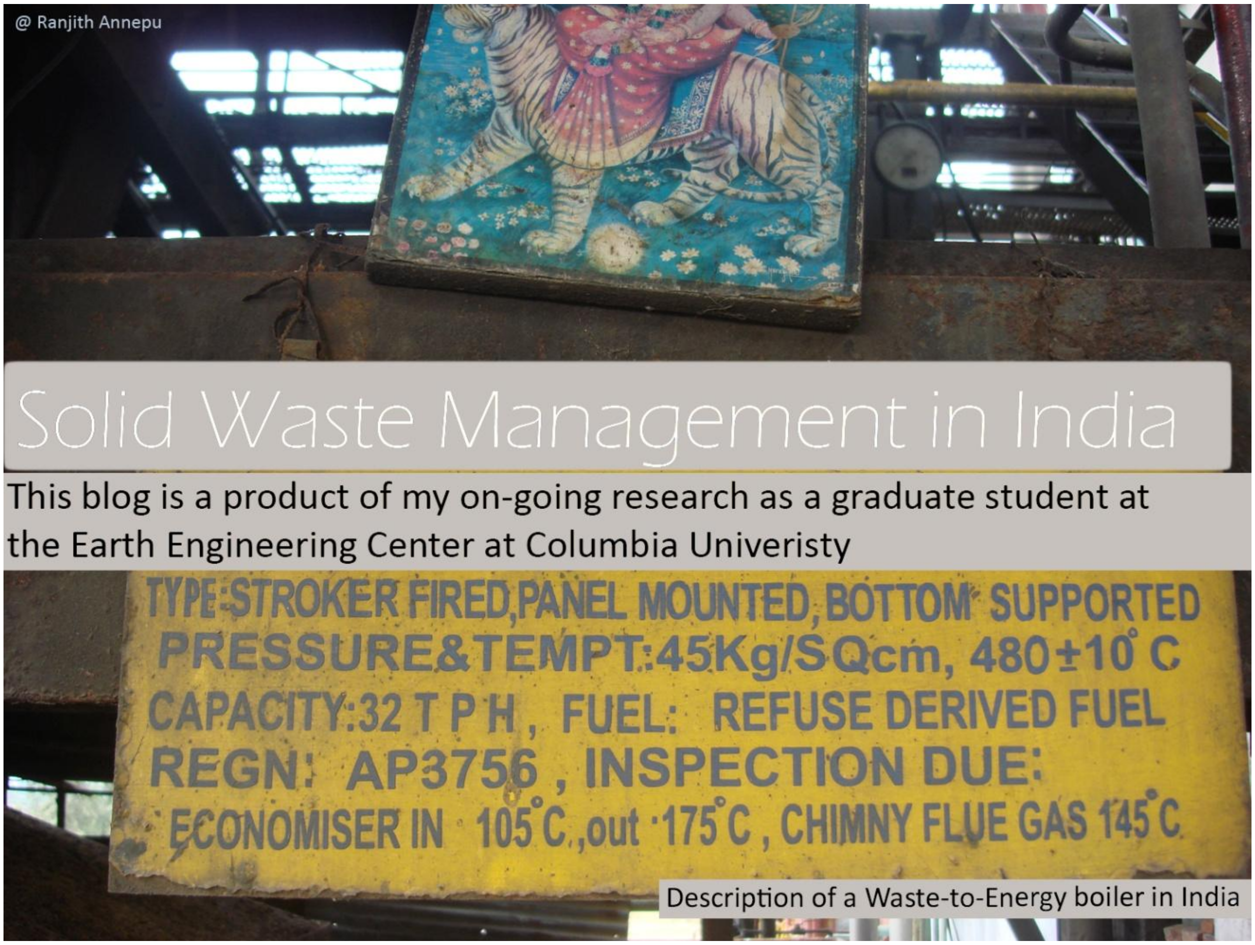


Figure 41, Opening Page of the Blog, www.SwmIndia.blogspot.com

The blog also had a "News Reel" application installed on the right hand side corner to provide blog viewers with latest news regarding waste management in India. Feedback from viewers proved it to be a useful tool. Maintaining blogs to share research findings is useful for current and future research. It provides real-time statistics and gives a better understanding on what the public thinks. It also provides the researcher with feedback and suggestions from blog readers.

Academic research generally gets confined to papers, journals and conferences. The general public, "kids doing school projects…, parents…, and anyone else who is not a research scientist will never see those. They will not go check the scientific literature in Google Scholar. They wouldn't even have access to the articles if they did". (63) Information in a blog is easily searchable on search engines like Google (Figure 42), Yahoo (Figure 43), Bing (Figure 44), Altavista (Figure 45), etc., which helps disseminating the information faster.

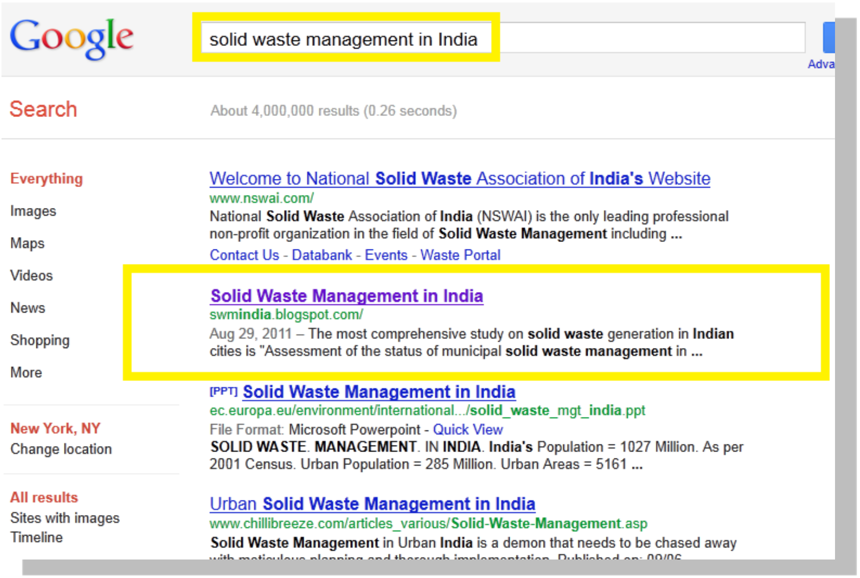


Figure 42, Top Results for "Solid Waste Management in India" on Google Search

Figure 44, Top Results for "Solid Waste Management in India" on Bing Search

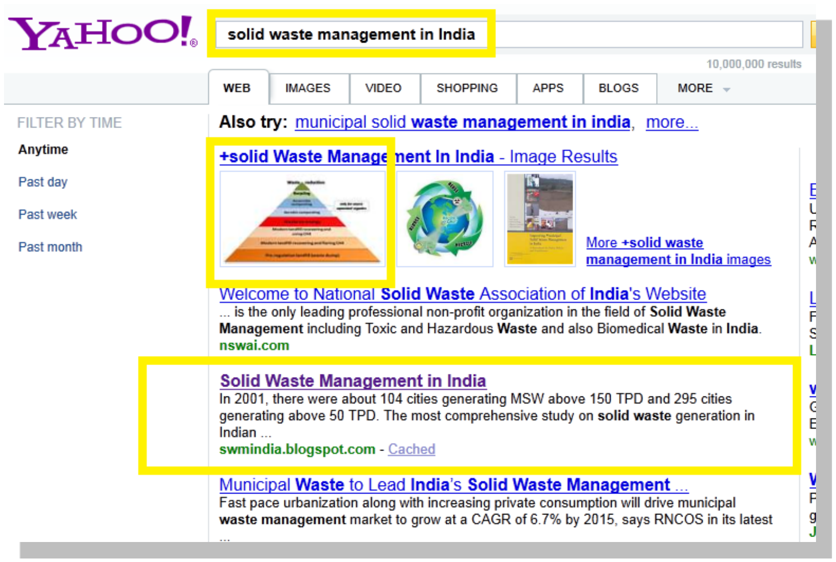


Figure 43, Top Results for "Solid Waste Management in India" on Yahoo Search

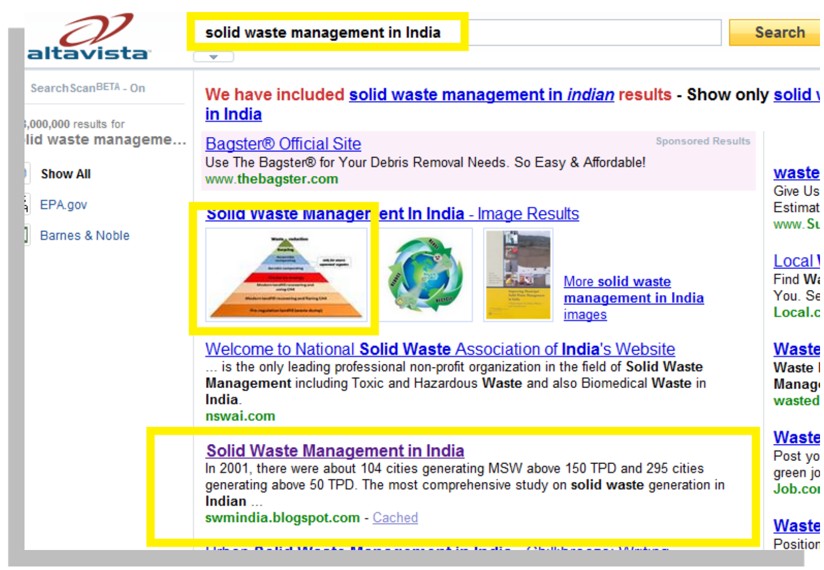


Figure 45, Top Results for "Solid Waste Management in India" on Altavista Search

10.3 PAGE VIEWS AND AUDIENCE

10.3.1 VIEWS

The first post on the blog was published in September, 2009. The number of page views went up since then. As of Dec, 2011, the blog is viewed by 3,000 visitors every month. The number of page views depended upon the amount of new content that was being posted. The dip in viewership around February, 2011 was possibly due to no new posts. The viewership also depended whether the blog included the kind of information the public was searching for. The number of page views has crossed 1,000 for the first time in June, 2011 and has been above that mark ever since. The page views for October, 2011 might be greater than 1,000 by the end of the month. Number of page views represents trending topics and public awareness on those topics and not necessarily the quality of the post.

Figure 46, Number of All-time Page Views of the Blog since its First Post in September, 09

10.3.2 AUDIENCE

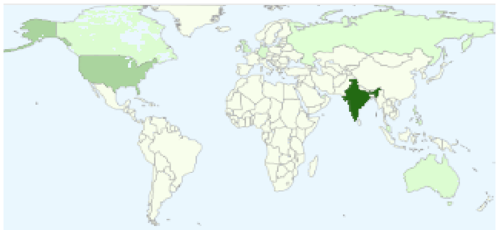
The blog was visited by viewers from more than 13 countries including India. Indians have visited the blog the most. Foreign viewership might indicate a combination of a) interest in SWM in India in particular and b) interest in SWM in general. A simple search for "Solid Waste Management" Google Trends showed that that term was most searched from Indian Cities compared to cities from any other country (Figure 40).

Solid Waste Management in India · Stats › Audience

2009 May – 2011 October

Now | Day | Week | Month | All time

Pageviews by Countries

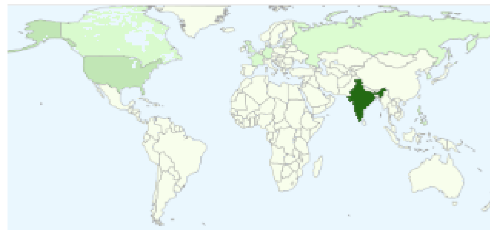


India	5,263
United States	1,488
United Kingdom	352
Philippines	169
Germany	152
Australia	82
Canada	70
Malaysia	58
Russia	39
United Arab Emirates	38

2011 Sep 18 – 2011 Oct 05

Now | Day | Week | Month | All time

Pageviews by Countries

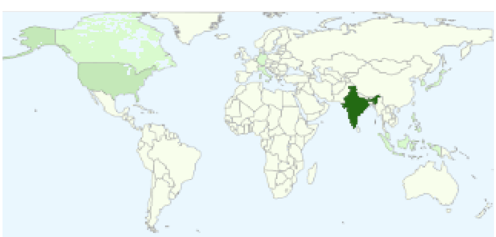


India	616
United States	104
United Kingdom	28
Philippines	26
Germany	23
Canada	20
France	16
South Korea	14
Russia	11
Singapore	9

2011 Sep 28 15:00 – 2011 Oct 05 14:00

Now | Day | Week | Month | All time

Pageviews by Countries

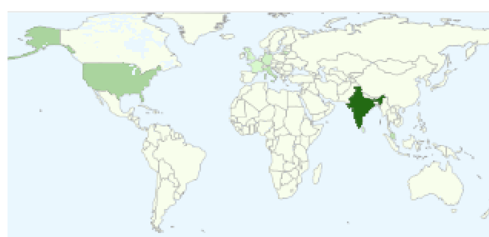


India	185
United States	27
Germany	6
Italy	6
South Korea	6
Philippines	6

2011 Oct 04 14:00 - 2011 Oct 05 14:00

Now | Day | Week | Month | All time

Pageviews by Countries



India	25
United States	7
Italy	4
Malaysia	4
Germany	2
Lithuania	2

Figure 47, Geographic Distribution of Audience to the Blog since its Creation in May, 09

10.3.3 SEARCH KEYWORDS

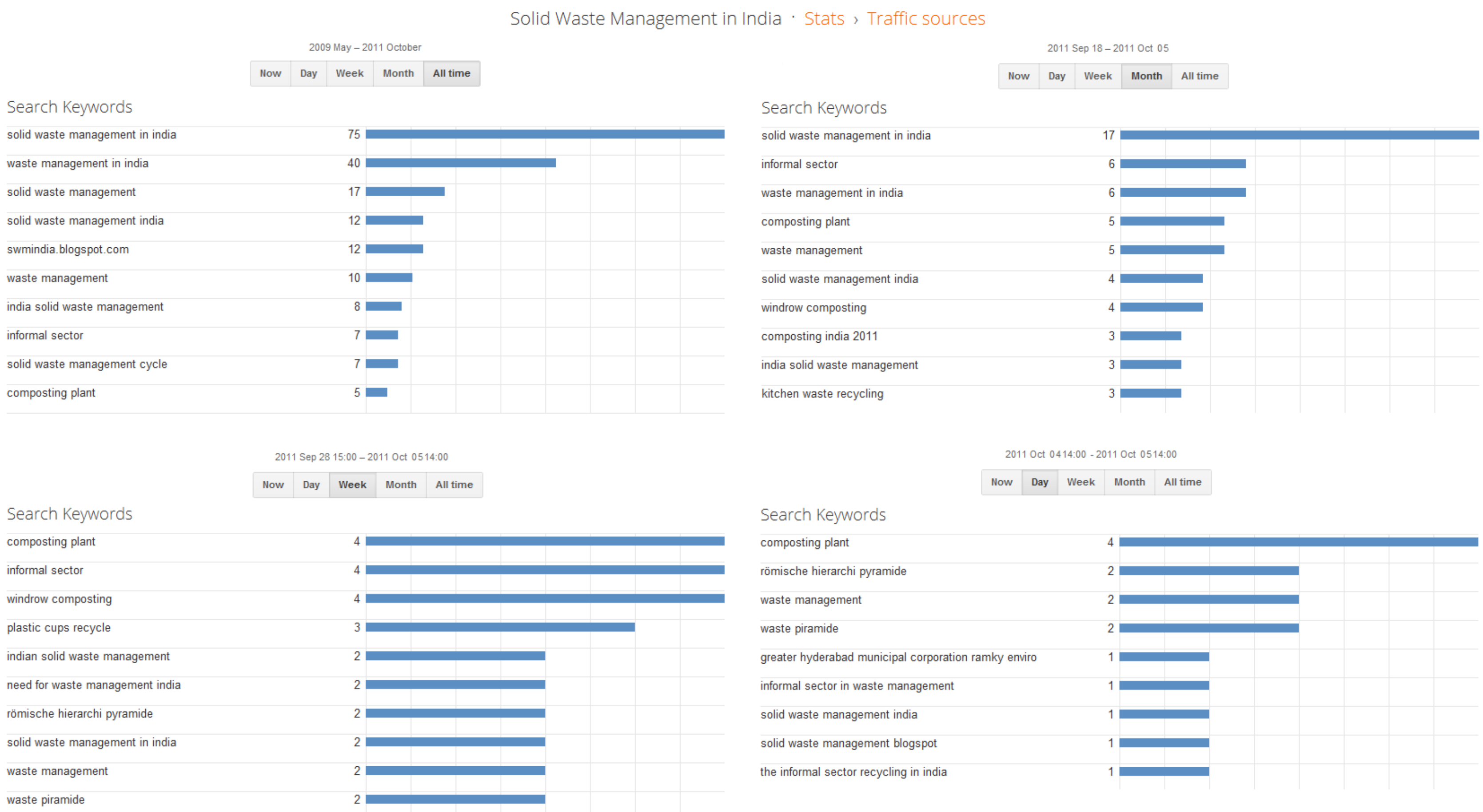


Figure 48, Distribution of the Search Keywords used by Public to find this Information (Blog)

10.3.4 POSTS

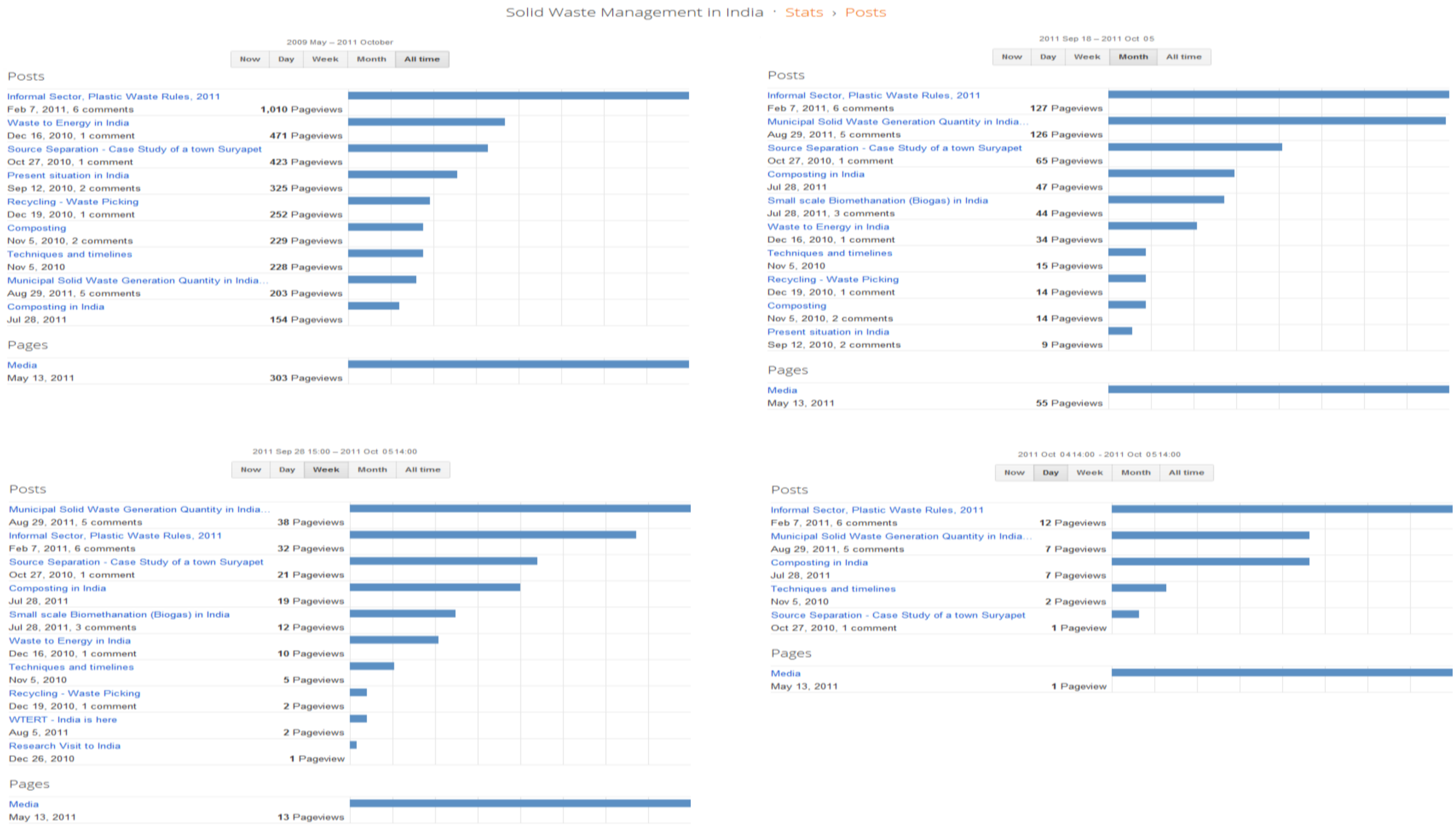


Figure 49, Distribution of the Number of Views per Article Posted on the Blog

10.3.5 COMMENTS AND INTERACTION

Blog viewers were encouraged to ask questions and provide input. Those with inputs or questions were asked to mention them in the comments section of respective posts. All questions were answered right there in the comments section to keep the discussion and conclusions open to other viewers. The answers included elaborate explanations where required. Those viewers who required detailed answers were asked to share their email ids.

Aug 29, 2011

Municipal Solid Waste Generation Quantity in Indian Cities

5 comments:

Anonymous said...

Thanks for this blog, I'll follow

August 31, 2011 4:38 AM

Anonymous said...

gr8:)

September 8, 2011 6:18 PM

Anonymous said...

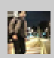
I have been looking for waste generation quantities for the cities and closely following bengaluru . I think the figure here is underestimate of current generation(2011) quantities .Easily generation is around 5000 tonnes to 8000 tonnes. Can you pl provide me clarity on this

October 17, 2011 2:59 AM

Anonymous said...

Can you also tell me the waste generation in the first excel table right at the top is it for 2011 & hw different is it from the second table generation rate

October 17, 2011 3:42 AM



Ranjith said...

Hello there,
The MSW generated in B'lore was calculated using the census 2001 population plus 30% growth rate in population. I also checked it with some on field data. I'm sure there'll be a slight underestimation cause the population in B'lore would have grown faster than the overall urban decadal growth. According to my calculation, the population of B'lore is 7.5 million, some sources indicate it to be 8.5 million, which cannot be finalized until the data for B'lore from Census 2011 is released.
However, solely based on calculations, it might not be as much as 8000 tons/day. Even if the population was 8.5 million, the waste generated value would be 3800 tons/day. What makes you think it is btw 5000 - 8000? Have you come across some kind of source that could help us get an idea?
My calculations do not include construction and demolition waste (if you were including them too)!

It'll be wonderful if you could share your email. It would make discussing this easier.

Thank you very much

October 17, 2011 4:42 PM

APPENDICES

APPENDIX 1, WASTE GENERATION QUANTITIES AND RATES IN 366 INDIAN CITIES IN 2001 AND 2011

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
1	Maharashtra	Greater Mumbai	Metro	16,434,386	0.450	7,395	21,660,521	0.514	11,124
2	West Bengal	Greater Kolkata	Metro	13,205,697	0.580	7,659	17,405,109	0.662	11,520
3	Delhi	Delhi	Metro	12,877,470	0.570	7,340	16,972,505	0.650	11,040
4	Tamil Nadu	Chennai	Metro	6,560,242	0.620	4,067	8,646,399	0.708	6,118
5	Andhra Pradesh	Greater Hyderabad	Metro	5,742,036	0.570	3,273	7,568,003	0.650	4,923
6	Karnataka	Greater Bengaluru	Metro	5,701,446	0.390	2,224	7,514,506	0.445	3,344
7	Gujarat	Ahmadabad	Class A	4,525,013	0.370	1,674	5,963,967	0.422	2,518
8	Maharashtra	Pune	Class A	3,760,636	0.460	1,730	4,956,518	0.525	2,602
9	Gujarat	Surat	Class A	2,811,614	0.410	1,153	3,705,707	0.468	1,734
10	Uttar Pradesh	Kanpur	Class A	2,715,555	0.430	1,168	3,579,101	0.491	1,756
11	Rajasthan	Jaipur	Class A	2,322,575	0.390	906	3,061,154	0.445	1,362
12	Uttar Pradesh	Lucknow	Class A	2,245,509	0.220	494	2,959,581	0.251	743
13	Maharashtra	Nagpur	Class A	2,129,500	0.250	532	2,806,681	0.285	801
14	Bihar	Patna	Class A	1,697,976	0.370	628	2,237,932	0.422	945
15	Madhya Pradesh	Indore	Class A	1,516,918	0.380	576	1,999,298	0.434	867
16	Gujarat	Vadodara	Class A	1,491,045	0.270	403	1,965,197	0.308	606
17	Maharashtra	Pimpri Chinchwad	Class A	1,470,010	0.245	360	1,937,473	0.279	541
18	Tamil Nadu	Coimbatore	Class A	1,461,139	0.570	833	1,925,781	0.650	1,253
19	Madhya Pradesh	Bhopal	Class A	1,458,416	0.400	583	1,922,192	0.456	877

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
21	Kerala	Kochi	Class A	1,355,972	0.670	909	1,787,171	0.765	1,366
22	Andhra Pradesh	Greater Visakhapatnam	Class A	1,345,938	0.590	794	1,773,946	0.673	1,194
23	Uttar Pradesh	Agra	Class A	1,331,339	0.510	679	1,754,705	0.582	1,021
24	Maharashtra	Thane	Class A	1,261,517	0.390	492	1,662,679	0.445	740
25	Uttar Pradesh	Varanasi	Class A	1,203,961	0.390	470	1,586,821	0.445	706
26	Tamil Nadu	Madurai	Class A	1,203,095	0.300	361	1,585,679	0.342	543
27	Maharashtra	Kalyan-Dombivali	Class A	1,193,266	0.358	427	1,572,725	0.408	642
28	Uttar Pradesh	Meerut	Class A	1,161,716	0.460	534	1,531,142	0.525	804
29	Maharashtra	Nashik	Class A	1,152,326	0.190	219	1,518,766	0.217	329
30	Jharkhand	Jamshedpur	Class A	1,104,713	0.310	342	1,456,012	0.354	515
31	Madhya Pradesh	Jabalpur	Class A	1,098,000	0.230	253	1,447,164	0.262	380
32	West Bengal	Asansol	Class A	1,067,369	0.440	470	1,406,792	0.502	706
33	Jharkhand	Dhanbad	Class A	1,065,327	0.390	415	1,404,101	0.445	625
34	Haryana	Faridabad	Class A	1,055,938	0.420	443	1,391,726	0.479	667
35	Uttar Pradesh	Allahabad	Class A	1,042,229	0.520	542	1,373,658	0.593	815
36	Andhra Pradesh	Vijayawada	Class A	1,039,518	0.440	457	1,370,085	0.502	688
37	Punjab	Amritsar	Class A	1,003,917	0.450	452	1,323,163	0.514	679
38	Gujarat	Rajkot	Class A	1,003,015	0.210	211	1,321,974	0.240	317
39	Jammu & Kashmir	Srinagar	Class B	988,210	0.480	474	1,302,461	0.548	713
40	Uttar Pradesh	Ghaziabad	Class B	968,256	0.471	456	1,276,161	0.537	686
41	Chhattisgarh	Durg-Bhilainagar	Class B	927,864	0.500	464	1,222,925	0.571	698
42	Maharashtra	Aurangabad	Class B	892,483	0.500	446	1,176,293	0.570	671

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44	Kerala	Kozhikode	Class B	880,247	0.324	285	1,160,166	0.369	429
45	Maharashtra	Solapur	Class B	872,478	0.401	350	1,149,926	0.458	526
46	Kerala	Thrissur	Class B	866,354	0.177	153	1,141,855	0.202	230
47	Madhya Pradesh	Gwalior	Class B	865,548	0.350	303	1,140,792	0.400	456
48	Jharkhand	Ranchi	Class B	863,495	0.250	216	1,138,086	0.285	325
49	Rajasthan	Jodhpur	Class B	860,818	0.609	524	1,134,558	0.695	788
50	Assam	Guwahati	Class B	818,809	0.200	164	1,079,190	0.228	246
51	Chandigarh	Chandigarh	Class B	808,515	0.400	323	1,065,623	0.456	486
52	Karnataka	Mysore	Class B	799,228	0.459	367	1,053,383	0.524	552
53	Karnataka	Hubli-Dharwad	Class B	786,195	0.509	400	1,036,205	0.581	602
54	Tamil Nadu	Salem	Class B	751,438	0.446	335	990,395	0.509	504
55	Uttar Pradesh	Bareilly	Class B	748,353	0.421	315	986,329	0.480	474
56	Punjab	Jalandhar	Class B	714,077	0.493	352	941,153	0.562	529
57	Rajasthan	Kota	Class B	703,150	0.617	434	926,752	0.704	653
58	Chhattisgarh	Raipur	Class B	700,113	0.300	210	922,749	0.342	316
59	Uttar Pradesh	Aligarh	Class C	669,087	0.448	300	881,857	0.512	451
60	Orissa	Bhubaneswar	Class C	658,220	0.360	237	867,534	0.411	356
61	Uttar Pradesh	Moradabad	Class C	641,583	0.452	290	845,606	0.516	436
62	Uttar Pradesh	Gorakhpur	Class C	622,701	0.454	283	820,720	0.519	426
63	Maharashtra	Bhiwandi	Class C	621,427	0.500	311	819,041	0.571	467
64	Jammu & Kashmir	Jammu	Class C	612,163	0.580	355	806,831	0.662	534
65	Orissa	Cuttack	Class C	587,182	0.296	174	773,906	0.338	262
66	Andhra Pradesh	Warangal	Class C	579,216	0.525	304	763,407	0.599	457

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68	Tamil Nadu	Tiruppur	Class C	550,826	0.533	293	725,989	0.608	441
69	Maharashtra	Amravati	Class C	549,510	0.273	150	724,254	0.312	226
70	Karnataka	Mangalore	Class C	539,387	0.500	270	710,912	0.570	405
71	Uttarakhand	Dehradun	Class C	530,263	0.310	164	698,887	0.354	247
72	Rajasthan	Bikaner	Class C	529,690	0.453	240	698,131	0.517	361
73	Gujarat	Bhavnagar	Class C	517,708	0.327	169	682,339	0.373	254
74	Andhra Pradesh	Guntur	Class C	514,461	0.386	199	678,060	0.441	299
75	Karnataka	Belgaum	Class C	506,480	0.395	200	667,541	0.451	301
76	Pondicherry	Pondicherry	Class C	505,959	0.590	299	666,854	0.673	449
77	Maharashtra	Kolhapur	Class C	505,541	0.383	194	666,303	0.438	292
78	Jharkhand	Bokaro	Class D	497,780	0.351	175	656,074	0.400	263
79	West Bengal	Durgapur	Class D	493,405	0.351	173	650,308	0.400	260
80	Rajasthan	Ajmer	Class D	490,520	0.555	272	646,505	0.633	409
81	Orissa	Raurkela	Class D	484,874	0.330	160	639,064	0.376	240
82	Maharashtra	Ulhasnagar	Class D	472,943	0.357	169	623,339	0.408	254
83	West Bengal	Siliguri	Class D	472,374	0.350	165	622,589	0.399	249
84	Uttar Pradesh	Jhansi	Class D	460,278	0.374	172	606,646	0.426	259
85	Uttar Pradesh	Saharanpur	Class D	455,754	0.448	204	600,684	0.511	307
86	Maharashtra	Sangli	Class D	447,774	0.427	191	590,166	0.488	288
87	West Bengal	Bhatpara	Class D	441,956	0.305	135	582,498	0.349	203
88	Tamil Nadu	Tirunelveli	Class D	433,352	0.480	208	571,158	0.548	313
89	Uttar Pradesh	Firozabad	Class D	432,866	0.352	152	570,517	0.401	229
90	Madhya Pradesh	Ujjain	Class D	431,162	0.369	159	568,272	0.421	239
91	Maharashtra	Nanded	Class D	430,733	0.350	151	567,706	0.399	227

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92	Karnataka	Gulbarga	Class D	430,265	0.504	217	567,089	0.576	326
93	Andhra Pradesh	Rajahmundry	Class D	413,616	0.365	151	545,146	0.417	227
94	Maharashtra	Malegaon	Class D	409,403	0.350	143	539,593	0.400	216
95	Andhra Pradesh	Nellore	Class D	404,775	0.494	200	533,493	0.564	301
96	Maharashtra	Akola	Class D	400,520	0.350	140	527,885	0.400	211
97	Bihar	Gaya	Class E	394,945	0.380	150	520,538	0.433	226
98	Tamil Nadu	Erode	Class E	389,906	0.540	210	513,896	0.616	316
99	Rajasthan	Udaipur	Class E	389,438	0.430	167	513,279	0.491	252
100	West Bengal	Maheshtala	Class E	389,214	0.306	119	512,984	0.349	179
101	Tamil Nadu	Vellore	Class E	386,746	0.502	194	509,731	0.573	292
102	Kerala	Kollam	Class E	380,091	0.505	192	500,960	0.576	289
103	Andhra Pradesh	Kakinada	Class E	376,861	0.372	140	496,703	0.424	211
104	Maharashtra	Jalgaon	Class E	368,618	0.375	138	485,839	0.428	208
105	Karnataka	Davangere	Class E	364,523	0.214	185	480,441	0.244	117
106	Haryana	Panipat	Class E	354,148	0.376	133	466,767	0.429	200
107	Bihar	Bhagalpur	Class E	350,133	0.351	123	461,475	0.400	185
108	West Bengal	Panihati	Class E	348,379	0.307	107	459,164	0.351	161
109	Maharashtra	Ahmadnagar	Class E	347,549	0.311	108	458,070	0.355	162
110	Andhra Pradesh	Kurnool	Class E	342,973	0.412	141	452,038	0.470	212
111	Maharashtra	Dhule	Class E	341,755	0.349	119	450,433	0.399	180
112	West Bengal	Rajpur Sonarpur	Class E	336,390	0.303	102	443,362	0.346	153
113	Chhattisgarh	Bilaspur	Class E	335,293	0.589	197	441,916	0.672	297
114	Uttar Pradesh	Muzaffarnagar	Class E	331,668	0.370	123	437,138	0.423	185
115	Tamil Nadu	Tiruchirapalli	Class B	866,354	0.371	357	1,141,855	0.423	483

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117	Uttar Pradesh	Mathura	Class E	323,315	0.349	113	426,129	0.398	170
118	Uttar Pradesh	Shahjahanpur	Class E	321,885	0.414	133	424,244	0.473	201
119	Karnataka	Bellary	Class E	316,766	0.505	160	417,498	0.576	241
120	Chhattisgarh	Korba	Class E	315,690	0.348	110	416,079	0.397	165
121	Tamil Nadu	Ambattur	Class E	310,967	0.229	160	409,855	0.261	107
122	Madhya Pradesh	Sagar	Class E	308,922	0.421	130	407,159	0.480	195
123	Orissa	Brahmapur	Class E	307,792	0.351	108	405,670	0.400	162
124	Haryana	Yamunanagar	Class E	306,740	0.386	118	404,283	0.440	178
125	Bihar	Muzaffarpur	Class E	305,525	0.350	107	402,682	0.399	161
126	Uttar Pradesh	Noida	Class E	305,058	0.350	107	402,066	0.400	161
127	Andhra Pradesh	Tirupati	Class E	303,521	0.343	104	400,041	0.392	157
128	Maharashtra	Latur	Class F	299,985	0.403	121	395,380	0.460	182
129	Haryana	Rohtak	Class F	294,577	0.349	103	388,252	0.398	154
130	West Bengal	Kulti	Class F	290,057	0.303	88	382,295	0.346	132
131	Maharashtra	Chandrapur	Class F	289,450	0.351	102	381,495	0.400	153
132	Andhra Pradesh	Nizamabad	Class F	288,722	0.379	109	380,536	0.432	164
133	Maharashtra	Ichalkarnji	Class F	285,860	0.351	100	376,763	0.401	151
134	West Bengal	Barddhaman	Class F	285,602	0.350	100	376,423	0.399	150
135	Kerala	Alappuzha	Class F	282,675	0.503	142	372,566	0.575	214
136	Uttar Pradesh	Rampur	Class F	281,494	0.350	98	371,009	0.399	148
137	Rajasthan	Bhilwara	Class F	280,128	0.351	98	369,209	0.400	148
138	Karnataka	Shimoga	Class F	274,352	0.499	137	361,596	0.569	206
139	West Bengal	Kharagpur	Class F	272,865	0.348	95	359,636	0.398	143
140	Meghalaya	Shillong	Class F	267,662	0.340	91	352,779	0.388	137

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142	Rajasthan	Alwar	Class F	266,203	0.362	96	350,856	0.414	145
143	Haryana	Hissar	Class F	263,186	0.349	92	346,879	0.398	138
144	Andhra Pradesh	Cuddapah	Class F	262,506	0.363	95	345,983	0.414	143
145	Maharashtra	Parbhani	Class F	259,329	0.351	91	341,796	0.400	137
146	Karnataka	Bijapur	Class F	253,891	0.499	127	334,628	0.569	190
147	Gujarat	Junagadh	Class F	252,108	0.392	99	332,278	0.447	149
148	West Bengal	Baranagar	Class F	250,615	0.303	76	330,311	0.346	114
149	Manipur	Imphal	Class F	250,234	0.190	48	329,808	0.217	72
150	Karnataka	Tumkur	Class F	248,929	0.502	125	328,088	0.573	188
151	Tamil Nadu	Thoothukkudi (Tuticorin)	Class F	243,415	0.499	122	320,821	0.570	183
152	Andhra Pradesh	Anantapur	Class F	243,143	0.383	93	320,462	0.437	140
153	Uttar Pradesh	Farrukhabad-Fatehgarh	Class F	242,997	0.424	103	320,270	0.484	155
154	West Bengal	Habra	Class F	239,209	0.353	84	315,277	0.403	127
155	Andhra Pradesh	Ramagundam	Class F	237,686	0.418	99	313,270	0.477	149
156	Maharashtra	Jalna	Class F	235,795	0.351	83	310,778	0.401	125
157	Madhya Pradesh	Ratlam	Class F	234,419	0.351	82	308,964	0.401	124
158	Gujarat	Navsari	Class F	232,411	0.352	82	306,318	0.402	123
159	Bihar	Bihar Sharif	Class F	232,071	0.352	82	305,870	0.401	123
160	Madhya Pradesh	Dewas	Class F	231,672	0.350	81	305,344	0.400	122
161	Madhya Pradesh	Satna	Class F	229,307	0.351	81	302,227	0.401	121
162	Haryana	Gurgaon	Class F	228,820	0.456	104	301,585	0.521	157
163	Mizoram	Aizwal	Class F	228,280	0.250	57	300,873	0.285	86

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165	Haryana	Sonipat	Class F	225,074	0.350	79	296,648	0.399	118
166	West Bengal	English Bazar	Class F	224,415	0.348	78	295,779	0.397	117
167	Rajasthan	Ganganagar	Class F	222,858	0.391	87	293,727	0.446	131
168	Haryana	Karnal	Class F	221,236	0.372	82	291,589	0.425	124
169	Uttarakhand	Hardwar	Class F	220,767	0.366	81	290,971	0.417	121
170	Gujarat	Anand	Class F	218,486	0.349	76	287,965	0.399	115
171	Andhra Pradesh	Karimnagar	Class F	218,302	0.501	109	287,722	0.572	164
172	Punjab	Bathinda	Class F	217,256	0.369	80	286,343	0.421	121
173	Andhra Pradesh	Eluru	Class F	215,804	0.417	90	284,430	0.476	135
174	West Bengal	Naihati	Class F	215,432	0.306	66	283,939	0.350	99
175	Tamil Nadu	Thanjavur	Class F	215,314	0.438	94	283,784	0.500	142
176	Uttar Pradesh	Maunath Bhanjan	Class F	212,657	0.350	74	280,282	0.399	112
177	Uttar Pradesh	Hapur	Class F	211,983	0.352	75	279,394	0.402	112
178	Uttar Pradesh	Etawah	Class F	210,453	0.351	74	277,377	0.401	111
179	Tamil Nadu	Nagercoil	Class F	208,179	0.499	104	274,380	0.570	156
180	Uttar Pradesh	Faizabad	Class F	208,162	0.353	73	274,358	0.403	110
181	Karnataka	Raichur	Class F	207,421	0.436	90	273,381	0.497	136
182	Rajasthan	Bharathpur	Class F	205,235	0.350	72	270,500	0.400	108
183	Uttar Pradesh	Mirzapur - Vindhyachal	Class F	205,053	0.352	72	270,260	0.402	109
184	Maharashtra	Ambarnath	Class F	203,795	0.358	73	268,602	0.409	110
185	Bihar	Arrah	Class F	203,380	0.350	71	268,055	0.400	107
186	Andhra Pradesh	Khammam	Class G	198,620	0.615	122	261,781	0.702	184
187	Gujarat	Porbandar	Class G	197,382	0.254	50	260,149	0.290	75

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189	Bihar	Purnia	Class G	197,211	0.349	69	259,924	0.398	103
190	Tamil Nadu	Dindigul	Class G	196,955	0.502	99	259,587	0.573	149
191	Gujarat	Nadiad	Class G	196,793	0.348	69	259,373	0.398	103
192	Gujarat	Gandhinagar	Class G	195,985	0.220	43	258,308	0.251	65
193	Andhra Pradesh	Vizianagaram	Class G	195,801	0.368	72	258,066	0.420	108
194	Madhya Pradesh	Burhanpur	Class G	193,725	0.352	68	255,330	0.402	103
195	Bihar	Katihar	Class G	190,873	0.353	67	251,571	0.403	101
196	Tripura	Agartala	Class G	189,998	0.400	76	250,417	0.456	114
197	Tamil Nadu	Kancheepuram	Class G	188,733	0.501	95	248,750	0.571	142
198	Bihar	Munger	Class G	188,050	0.350	66	247,850	0.399	99
199	Rajasthan	Pali	Class G	187,641	0.396	74	247,311	0.452	112
200	Maharashtra	Bhusawal	Class G	187,564	0.348	65	247,209	0.397	98
201	Madhya Pradesh	Murwara (Katni)	Class G	187,029	0.349	65	246,504	0.399	98
202	Rajasthan	Sikar	Class G	185,925	0.351	65	245,049	0.400	98
203	Madhya Pradesh	Singrauli	Class G	185,190	0.356	66	244,080	0.407	99
204	Assam	Silchar	Class G	184,105	0.350	64	242,650	0.400	97
205	Madhya Pradesh	Rewa	Class G	183,274	0.348	64	241,555	0.397	96
206	Uttar Pradesh	Sambhal	Class G	182,478	0.386	70	240,506	0.440	106
207	Andhra Pradesh	Machilipatnam	Class G	179,353	0.498	89	236,387	0.569	134
208	Bihar	Chapra	Class G	179,190	0.351	63	236,172	0.400	95
209	Uttar Pradesh	Bulandshahar	Class G	176,425	0.403	71	232,528	0.460	107
210	Gujarat	Bharuch	Class G	176,364	0.362	64	232,448	0.414	96
211	West Bengal	Raiganj	Class G	175,047	0.349	61	230,712	0.398	92
212	Karnataka	Bidar	Class G	174,257	0.546	95	229,671	0.623	143

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214	West Bengal	Haldia	Class G	170,673	0.353	60	224,947	0.403	91
215	West Bengal	Baharampur	Class G	170,322	0.347	59	224,484	0.396	89
216	Haryana	Bhiwani	Class G	169,531	0.353	60	223,442	0.402	90
217	Uttar Pradesh	Rae Bareli	Class G	169,333	0.350	59	223,181	0.400	89
218	Punjab	Pathankot	Class G	168,485	0.353	59	222,063	0.403	89
219	Uttar Pradesh	Bahraich	Class G	168,323	0.383	64	221,850	0.437	97
220	Uttar Pradesh	Amroha	Class G	165,129	0.398	66	217,640	0.455	99
221	Karnataka	Hosepet	Class G	164,240	0.500	82	216,468	0.570	123
222	Andhra Pradesh	Adoni	Class G	162,458	0.502	82	214,120	0.573	123
223	Tamil Nadu	Kumbakonam	Class G	160,767	0.502	81	211,891	0.573	121
224	Haryana	Sirsa	Class G	160,735	0.352	57	211,849	0.402	85
225	Karnataka	Bhadravati	Class G	160,662	0.723	116	211,753	0.825	175
226	Uttar Pradesh	Jaunpur	Class G	160,055	0.383	61	210,952	0.437	92
227	Uttarakhand	Haldwani-cum-Kathgodam	Class G	158,896	0.390	62	209,425	0.445	93
228	Tamil Nadu	Cuddalore	Class G	158,634	0.497	79	209,080	0.567	119
229	Gujarat	Veraval	Class G	158,032	0.351	55	208,286	0.400	83
230	Orissa	Puri	Class G	157,837	0.573	91	208,029	0.654	136
231	Andhra Pradesh	Nandyal	Class G	157,120	0.428	67	207,084	0.488	101
232	Karnataka	Robertson Pet	Class G	157,084	0.490	77	207,037	0.559	116
233	Orissa	Baleshwar	Class G	156,430	0.347	54	206,175	0.396	82
234	Gujarat	Dudhrej	Class G	156,417	0.482	75	206,158	0.550	113
235	Karnataka	Gadag-Betigeri	Class G	154,982	0.502	78	204,266	0.573	117
236	Andhra Pradesh	Ongole	Class G	153,829	0.499	77	202,747	0.570	116

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
238	Madhya Pradesh	Bhind	Class G	153,752	0.349	54	202,645	0.398	81
239	Madhya Pradesh	Chhindwara	Class G	153,552	0.287	44	202,382	0.327	66
240	Andhra Pradesh	Chittoor	Class G	152,654	0.356	54	201,198	0.406	82
241	Uttar Pradesh	Fatehpur	Class G	152,078	0.357	54	200,439	0.407	82
242	Uttar Pradesh	Sitapur	Class G	151,908	0.403	61	200,215	0.460	92
243	Madhya Pradesh	Morena	Class G	150,959	0.349	53	198,964	0.398	79
244	Andhra Pradesh	Proddatur	Class G	150,309	0.421	63	198,107	0.480	95
245	West Bengal	Medinipur	Class H	149,769	0.342	51	197,396	0.391	77
246	Punjab	Hoshiarpur	Class H	149,668	0.334	50	197,262	0.381	75
247	West Bengal	Krishna Nagar	Class H	148,709	0.350	52	195,998	0.400	78
248	Uttar Pradesh	Budaun	Class H	148,029	0.480	71	195,102	0.547	107
249	Punjab	Batala	Class H	147,872	0.331	49	194,895	0.378	74
250	Madhya Pradesh	Shivpuri	Class H	146,892	0.347	51	193,604	0.396	77
251	Himachal Pradesh	Shimla	Class H	144,975	0.270	39	191,077	0.308	59
252	Uttar Pradesh	Unnao	Class H	144,662	0.377	55	190,665	0.430	82
253	West Bengal	Barrackpur	Class H	144,331	0.305	44	190,228	0.348	66
254	Chhattisgarh	Rajnandgaon	Class H	143,770	0.351	50	189,489	0.400	76
255	West Bengal	Balurghat	Class H	143,321	0.353	51	188,897	0.403	76
256	Andhra Pradesh	Bhimavaram	Class H	142,064	0.395	56	187,240	0.450	84
257	Uttar Pradesh	Modinagar	Class H	139,929	0.362	51	184,426	0.414	76
258	Maharashtra	Yavatmal	Class H	139,835	0.353	49	184,303	0.402	74
259	Andhra Pradesh	Mahbubnagar	Class H	139,662	0.337	47	184,075	0.384	71
260	Uttar Pradesh	Banda	Class H	139,436	0.466	65	183,777	0.532	98

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
262	Haryana	Ambala Sadar	Class H	139,279	0.216	54	183,570	0.246	45
263	Haryana	Ambala	Class H	139,279	0.366	51	183,570	0.418	77
264	West Bengal	Santipur	Class H	138,235	0.352	49	182,194	0.402	73
265	Maharashtra	Beed	Class H	138091	0.347	48	182,004	0.396	72
266	Tamil Nadu	Neyveli	Class H	138,035	0.392	54	181,930	0.447	81
267	Assam	Dibrugarh	Class H	137,661	0.349	48	181,437	0.398	72
268	Madhya Pradesh	Guna	Class H	137,175	0.352	48	180,797	0.402	73
269	Haryana	Jind	Class H	135,855	0.493	67	179,057	0.563	101
270	Rajasthan	Tonk	Class H	135,689	0.431	58	178,838	0.492	88
271	Jharkhand	Hazaribagh	Class H	135,473	0.288	39	178,553	0.329	59
272	Punjab	Moga	Class H	135,279	0.364	49	178,298	0.415	74
273	Karnataka	Hassan	Class H	133,262	0.457	61	175,639	0.521	92
274	Haryana	Bahadurgarh	Class H	131,925	0.448	58	173,877	0.511	89
275	Karnataka	Mandya	Class H	131,179	0.399	52	172,894	0.456	79
276	Gujarat	Godhra	Class H	131,172	0.352	46	172,885	0.402	70
277	Bihar	Sasaram	Class H	131,172	0.327	40	172,885	0.373	65
278	Tamil Nadu	Tiruvannamalai	Class H	130,567	0.422	55	172,087	0.482	83
279	Bihar	Dinapur Nizamat	Class H	130,339	0.305	40	171,787	0.348	60
280	Rajasthan	Hanumangarh	Class H	129,556	0.494	64	170,755	0.564	96
281	West Bengal	Jamuria	Class H	129,456	0.301	39	170,623	0.344	59
282	Andhra Pradesh	Adilabad	Class H	129,403	0.440	58	170,553	0.502	86
283	West Bengal	Bankura	Class H	128,781	0.348	45	169,733	0.397	67
284	Madhya Pradesh	Damoh	Class H	127,967	0.354	45	168,661	0.404	68
285	Karnataka	Udupi	Class H	127,124	0.500	64	167,549	0.570	96

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
287	Rajasthan	Beawar	Class H	125,981	0.493	62	166,043	0.562	93
288	Madhya Pradesh	Vidisha	Class H	125,453	0.359	45	165,347	0.409	68
289	West Bengal	Nabadwip	Class H	125,341	0.352	44	165,199	0.402	66
290	Karnataka	Chitradurga	Class H	125,170	0.498	62	164,974	0.568	94
291	Bihar	Saharsa	Class H	125,167	0.354	38	164,970	0.404	67
292	Andhra Pradesh	Hindupur	Class H	125,074	0.435	54	164,848	0.496	82
293	Punjab	Abohar	Class H	124,339	0.364	45	163,879	0.415	68
294	Uttar Pradesh	Pilibhit	Class H	124,245	0.402	50	163,755	0.459	75
295	West Bengal	North Barrackpur	Class H	123523	0.352	38	162,803	0.401	65
296	Assam	Nagaon	Class H	123,265	0.260	32	162,463	0.296	48
297	West Bengal	Raniganj	Class H	122,891	0.350	43	161,970	0.399	65
298	Haryana	Thanesar	Class H	122,319	0.490	59	161,216	0.560	90
299	Tamil Nadu	Rajapalayam	Class H	122,307	0.464	57	161,201	0.529	85
300	Gujarat	Palanpur	Class H	122,300	0.307	40	161,191	0.350	56
301	Uttar Pradesh	Lakhimpur	Class H	121,486	0.486	59	160,119	0.554	89
302	Uttar Pradesh	Loni	Class H	120,945	0.480	58	159,406	0.547	87
303	Maharashtra	Gondiya	Class H	120,902	0.376	45	159,349	0.429	68
304	Uttar Pradesh	Gonda	Class H	120,301	0.482	59	158,557	0.550	87
305	Bihar	Hajipur	Class H	119,412	0.353	37	157,385	0.403	63
306	Jharkhand	Adityapur	Class H	119221	0.310	37	157,133	0.354	56
307	Bihar	Dehri	Class H	119,057	0.359	36	156,917	0.410	64
308	Madhya Pradesh	Mandsaur	Class H	117,555	0.349	41	154,937	0.398	62
309	Andhra Pradesh	Srikakulam	Class H	117,320	0.503	59	154,628	0.574	89
310	Haryana	Kaithal	Class H	117,285	0.486	57	154,582	0.555	86

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
312	Maharashtra	Navghar-Manikpur	Class H	116700	0.360	42	153,811	0.411	63
313	Bihar	Bettiah	Class H	116,670	0.300	35	153,771	0.342	53
314	Rajasthan	Kishangarh	Class H	116,222	0.542	56	153,181	0.618	95
315	Chhattisgarh	Raigarh	Class H	115,908	0.343	39	152,767	0.391	60
316	Karnataka	Kolar	Class H	113,907	0.498	57	150,129	0.568	85
317	West Bengal	Puruliya	Class H	113,806	0.312	35	149,996	0.357	53
318	Gujarat	Patan	Class H	113,749	0.336	39	149,921	0.384	58
319	Gujarat	Vejalpur	Class H	113304	0.353	40	149,335	0.403	60
320	West Bengal	Basirhat	Class H	113,159	0.349	40	149,144	0.399	59
321	Andhra Pradesh	Gudivada	Class H	113,054	0.398	45	149,005	0.454	68
322	Madhya Pradesh	Neemuch	Class H	112,852	0.337	38	148,739	0.384	57
323	Uttar Pradesh	Hardoi	Class H	112,486	0.388	54	148,257	0.442	66
324	Gujarat	Kalol	Class H	112,013	0.308	35	147,633	0.351	52
325	Uttar Pradesh	Lalitpur	Class H	111,892	0.483	54	147,474	0.551	81
326	West Bengal	Ashoknagar Kalyangarh	Class H	111475	0.305	34	146,924	0.348	51
327	Andhra Pradesh	Nalgonda	Class H	111,380	0.539	60	146,799	0.615	90
328	Maharashtra	Wardha	Class H	111,118	0.354	39	146,454	0.403	59
329	Bihar	Siwan	Class H	109,919	0.336	33	144,873	0.384	56
330	Tamil Nadu	Pudukkottai	Class H	109,217	0.531	58	143,948	0.606	87
331	West Bengal	Darjiling	Class H	108,830	0.300	33	143,438	0.343	49
332	Bihar	Motihari	Class H	108,428	0.309	31	142,908	0.353	50
333	Maharashtra	Satara	Class H	108,048	0.358	38	142,407	0.408	58
334	Uttar Pradesh	Basti	Class H	107,601	0.477	51	141,818	0.544	77

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
336	Uttar Pradesh	Etah	Class H	107,110	0.485	52	141,171	0.554	78
337	Punjab	Malerkotla	Class H	107,009	0.545	51	141,038	0.622	88
338	Gujarat	Ghatlodiya	Class H	106259	0.308	38	140,049	0.351	49
339	Maharashtra	Barshi	Class H	104,785	0.310	37	138,107	0.354	49
340	Gujarat	Jetpur Navagadh	Class H	104,312	0.355	37	137,483	0.405	56
341	Uttar Pradesh	Deoria	Class H	104,227	0.482	50	137,371	0.550	76
342	Uttar Pradesh	Chandausi	Class H	103,749	0.480	50	136,741	0.547	75
343	Andhra Pradesh	Dharmavaram	Class H	103,357	0.358	56	136,225	0.409	56
344	Punjab	Khanna	Class H	103,099	0.485	50	135,884	0.553	75
345	Andhra Pradesh	Tadepalligudem	Class H	102,622	0.543	55	135,256	0.620	84
346	West Bengal	Bangaon	Class H	102,163	0.286	31	134,651	0.326	44
347	Uttar Pradesh	Ballia	Class H	101,465	0.483	49	133,731	0.551	74
348	Haryana	Jagadhri	Class H	101300	0.484	49	133,513	0.552	74
349	Karnataka	Chikmagalur	Class H	101,251	0.536	55	133,449	0.612	82
350	Haryana	Palwal	Class H	100,722	0.486	49	132,752	0.555	74
351	Haryana	Rewari	Class H	100,684	0.487	49	132,702	0.555	74
352	Rajasthan	Jhunjhunun	Class H	100,485	0.179	48	132,439	0.205	27
353	West Bengal	Jalpaiguri	Class H	100,348	0.303	31	132,259	0.346	46
354	Gujarat	Botad	Class H	100,194	0.302	36	132,056	0.345	46
355	Uttar Pradesh	Sultanpur	Class H	100,065	0.480	48	131,886	0.547	72
356	Andaman & Nicobar	Port Blair	Class 2	99,984	0.760	76	131,779	0.867	114
357	Goa	Panaji	Class 2	99,677	0.540	54	131,374	0.616	81
358	Nagaland	Dimapur	Class 2	98,096	0.303	33	129,291	0.346	45

S.No.	State	City	Class (2011 Population)	2001			2011		
				Population	Per capita Waste generation (kg/day)	MSW Generated (TPD)	Population	Per Capita Waste Generation (kg/day)	MSW Generated (TPD)
360	Maharashtra	Navi Mumbai	Class 2	81,855	0.474	289	107,885	0.541	58
361	Nagaland	Kohima	Class 2	77,030	0.170	13	101,526	0.194	20
362	Daman & Diu	Daman	Class 3	35,770	0.420	15	47,145	0.479	23
363	Arunachal Pradesh	Itanagar	Class 3	35,022	0.340	12	46,159	0.388	18
364	Sikkim	Gangtok	Class 3	29,354	0.440	13	38,689	0.502	19
365	Dadra & Nagar Haveli	Silvassa	Class 3	21,893	0.320	7	28,855	0.365	11
366	Lakshadweep	Kavarati	Class 4	10,119	0.300	3	13,337	0.342	5
	TOTAL			**197,313,948**	**0.439**	**86,657**	**260,059,784**	**0.498**	**129,593**
				Per year (TPY)		**31,629,961**	**Per year (TPY)**		**47,301,346**
		Percentage increase in MSW generation since 2001				**49.54601535 = 50%**			

APPENDIX 2, MSW GENERATED CUMULATIVELY UNTIL 2021 BY THE 366 CITIES STUDIED AND MSW GENERATED BY ENTIRE URBAN INDIA

Year	Population of the 366 cities	Per Capita Waste Generation (kg/day)	Waste Generated by 366 Cities		Waste Generated by entire Urban India	
			Tons/day	Tons/year	Tons/day	Tons/year
2011	260,059,784	0.498	129,593	47,301,346	185,132	67,573,351
2012	267,341,458	0.505	134,993	49,272,506	192,847	70,389,295
2013	274,827,018	0.512	140,619	51,325,810	200,884	73,322,585
2014	282,522,175	0.518	146,479	53,464,680	209,255	76,378,114
2015	290,432,796	0.525	152,583	55,692,681	217,975	79,560,973
2016	298,564,914	0.532	158,941	58,013,529	227,059	82,876,470
2017	306,924,732	0.539	165,565	60,431,092	236,521	86,330,131
2018	315,518,624	0.547	172,464	62,949,400	246,377	89,927,715
2019	324,353,146	0.554	179,651	65,572,653	256,644	93,675,218
2020	333,435,034	0.561	187,138	68,305,223	267,339	97,578,890
2021	342,771,215	0.569	194,936	71,151,665	278,480	101,645,236
Cumulative Waste Generated			**1,762,961**	**643,480,584**	**2,518,515**	**919,257,977**

APPENDIX 3, COMPARISON BETWEEN WASTE HANDLING TECHNIQUES IN 2008 AND 2010

S.No.	City	MSW Generation (TPD)		*Composting (TPD) or (YES/NO)*		*Biomethanation (TPD) or (YES/NO)*		*RDF/ WTE (TPD) or (YES/NO)*		*LFG recovery*		*Sanitary Landfill*		*Earth Cover*		*Alignment/ Compaction*	
		2001	**2011**	**2008**	**2010**	**2008**	**2010**	**2008**	**2012**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**
1	Greater Kolkata	7,659	12,060	700	700	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
2	Greater Mumbai	7,395	11,645	YES	370	NO	YES	NO	80*	NO	YES	NO	NO	YES	YES	YES	YES
3	Delhi	7,340	11,558	NO	825	NO	YES	NO	1350	NO	NO	NO	NO	NO	NO	YES	YES
4	Chennai	4,067	6,404	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
5	Greater Hyderabad	3,273	5,154	700	40*	NO	NO	NO	700*	NO	NO	NO	NO	NO	NO	YES	YES
6	Greater Bengaluru	2,224	3,501	300	450	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7	Pune	1,175 (1,730)	2,724	YES	600	YES	YES	NO	NO	NO	YES	NO	YES	NO	YES	YES	YES
8	Ahmadabad	1,302 (1,674)	2,636	500	500	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES
9	Kanpur	1,100 (1,168)	1,839	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
10	Surat	1,153	1,815	YES	YES	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	YES
11	Kochi	400 (909)	1,431	NO	YES	NO	20**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
12	Jaipur	904 (905)	1,426	YES	NO	NO	NO	NO	500	NO	NO	NO	NO	YES	YES	YES	YES
13	Coimbatore	530 (833)	1,311	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
14	Greater Visakhapatnam	794	1,250	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES
15	Ludhiana	735 (741)	1,167	NO	NO	NO	**NO**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
16	Agra	654 (679)	1,069	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES	YES
17	Patna	511 (628)	989	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
18	Bhopal	574 (583)	919	100	100	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES
19	Indore	557 (576)	908	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES
20	Allahabad	509 (542)	853	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
21	Meerut	490 (534)	841	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
22	Nagpur	504 (532)	838	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
23	Jodhpur	524	825	-	216	-	NO	-	NO	-	NO	-	YES	-	YES	-	YES
25	Srinagar	428 (474)	747	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
26	Varanasi	425 (470)	739	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
27	Vijayawada	374 (457)	720	NO	YES	YES	YES	225*	225*	NO	NO	NO	NO	NO	NO	YES	YES
28	Amritsar	438 (452)	711	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
29	Asansol	207 (470)	706	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	YES	-

S.No.	City	MSW Generation (TPD)		Composting (TPD) or (YES/NO)		Biomethanation (TPD) or (YES/NO)		RDF/ WTE (TPD) or (YES/NO)		LFG recovery		Sanitary Landfill		Earth Cover		Alignment/ Compaction	
		2001	2011	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010
30	Aurangabad	446	702	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
33	Dhanbad	77 (415)	625	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
34	Mysore	367	578	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
35	Madurai	275 (361)	568	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
36	Pimpri Chinchwad	360	567	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
37	Jammu	215 (355)	559	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
38	Jalandhar	352	554	-	350	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
39	Jamshedpur	338 (342)	539	40	40	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
40	Chandigarh	326 (323)	509	NO	YES	NO	YES	NO	500	NO	NO	YES	YES	NO	YES	NO	YES
41	Bhiwandi	311	489	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
42	Gwalior	303	477	-	120	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
43	Tiruppur	293	462	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
44	Navi Mumbai	289	455	-	NO	-	NO	-	NO	-	NO	-	YES	-	YES	-	YES
45	Pondicherry	130 (299)	449	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
46	Mangalore	270	424	-	NO	-	NO	-	NO	-	NO	-	YES	-	YES	-	YES
47	Jabalpur	216 (253)	398	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
48	Bhubaneshwar	234 (237)	373	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
49	Nashik	200 (219)	345	300	300	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES
50	Ranchi	208 (216)	340	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
51	Rajkot	207 (211)	332	NO	YES	NO	NO	NO	300*	NO	NO	NO	NO	YES	YES	NO	NO
52	Raipur	184 (210)	331	100	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
53	Thiruvananthapuram	171 (205)	322	150	150	NO	20 **	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
54	Guntur	199	313	-	NO	-	NO	275*	275*	-	NO	-	NO	-	NO	-	NO
55	Kolhapur	194	305	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
56	Bhavnagar	169	266	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
57	Udaipur	167	264	-	YES	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
58	Dehradun	131 (164)	259	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
59	Guwahati	166 (164)	258	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES
60	Jalgaon	138	208	-	100	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO
61	Shillong	45 (91)	137	100	YES	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
62	Port Blair	76	114	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
63	Agartala	77 (76)	114	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
64	Aizwal	57	86	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-

65	Panaji	32 (54)	81	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	YES	-
66	Imphal	43 (48)	72	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	YES	-
67	Gandhinagar	44 (43)	65	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
S.No.	**City**	**MSW Generation (TPD)**		*Composting (TPD) or (YES/NO)*		*Biomethanation (TPD) or (YES/NO)*		*RDF/ WTE (TPD) or (YES/NO)*		*LFG recovery*		*Sanitary Landfill*		*Earth Cover*		*Alignment/ Compaction*	
		2001	**2011**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**
69	Daman	15	23	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	YES	-
70	Kohima	13	20	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
71	Gangtok	13	19	50	-	NO	-	NO	-	NO	-	NO	-	NO	-	YES	-
72	Itanagar	12	18	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
73	Silvassa	16 (7)	11	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
74	Kavaratti	3	5	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-	NO	-
	Count: 74 cities			**22**	**40**	**3**	**9**	**1**	**7**	**0**	**3**	**1**	**8**	**15**	**21**	**25**	**24**
	TOTAL (TPD)			**3,080**	**4,861**			**500**	**3,930**								

* Not in operation

APPENDIX 4, AIR EMISSIONS FROM ALL SOURCES IN MUMBAI

Emission Load for Mumbai City from All Sources					
	PM	CO	SO2	NOx	HC
a) Area Source					
Bakeries	1,554.6	11,348.1	25.2	120.1	10,287.4
Crematoria	300.7	2,213.0	7.9	44.4	1,991.9
Open eat outs	281.6	167.8	16.2	9.4	0.1
Hotel restaurants	593.1	755.2	274.0	499.0	25.4
Domestic sector	564.9	19,723.7	1,262.0	9,946.9	368.1
Open burning	734.0	2,292.0	27.0	164.0	1,173.0
Landfill Open Burning	2,906.0	9,082.0	108.0	649.0	4,649.0
Total Open Burning	3,640.0	11,374.0	135.0	813.0	5,822.0
Construction Activity	2,288.9				
Locomotive					
(Cen.+ Wes. Rly)	514.0	3,147.0	1,449.0	19,708.0	
Aircraft	75.6	788.4	77.0	985.5	32.3
Marine vessels	1.8	3.3	19.7	17.9	1.5
Total (A)	**9,815.3**	**49,520.5**	**3,266.0**	**32,144.2**	**18,528.6**
B) Industrial Source					
Power plant	5,628.3	3,215.7	24,473.3	28,944.5	1,266.6
39 Industries	503.7	879.7	28,510.2	8,435.2	116.8
Stone crushers	1,394.3				
Total (B)	**7,526.3**	**4,095.4**	**52,983.5**	**37,379.7**	**1,383.4**
C) Line Source					
2 wheelers	70.1	3,303.2	2.7	540.5	1,221.2
3 wheelers	225.9	1,320.9	363.7	3,943.5	
Car diesel	313.8	1,150.5	87.2	1,063.3	435.8
Car petrol	15.7	7,867.5	13.1	313.7	496.6
HMV	916.7	4,435.5	126.7	6,875.0	273.5
Taxies	2.6	778.6	13.0	467.1	
Paved Road dust	3,163.0				
Unpaved Road dust	4,761.4				
Total (C)	**9,469.2**	**18,856.2**	**229.7**	**9,169.2**	**6,837.7**
Total (A+B+C)	**26,810.8**	**72,472.1**	**56,479.2**	**78,693.1**	**26,749.7**
** All values expressed in TPY., -- Vehicle Fuel used CNG/LPG*					

This table was modified to get Table 11 and find the emissions from open burning of MSW. Emissions from Open Burning and Landfill Open Burning were combined to find emissions due to overall Open Burning of MSW. Emissions from Bakeries, Open eat outs, and Hotels and

Restaurants were combined to calculate the emissions from Commercial Food Sector. Emissions from 2 wheelers, 3 wheelers, Taxies, Diesel Cards, Petrol Cars, and Heavy Motor Vehicles (HMV) were combined to calculate the overall emissions from Road Transportation.

APPENDIX 5, CALCULATION FOR SMALL SCALE BIOMETHANATION (IN KERALA STATE)

All Biogas units accounted in this calculation were those installed by Biotech Center for Development of Biogas Technology and Other Non-Conventional Energy Sources (Biotech). Biogas units were installed by some more companies, but those are not accounted due to lack of data and confusion about the number of units installed by them in urban and rural areas. Therefore, the original values of waste diverted from landfills, savings on collection and transportation to municipal authorities and GHG emissions avoided will be higher than those calculated in this appendix.

Per capita waste generation in Thiruvananthapuram = 0.262 kg/day

Per capita organic waste generation (72.96% of total MSW) = 0.191 kg/day

Assuming 4 persons/household, per capita organic waste generated by a single household
= 0.765 kg/day

Biogas units installed in Thiruvananthapuram = 10,000 Units

Total organic waste diverted in Thiruvananthapuram = 0.765*10000 = 7650 kg/day
= 7.65 TPD

= 2792.25 TPY

MSW generated in Thiruvananthapuram = 308 TPD

Total Organic Waste generated in Thiruvananthapuram = 225 TPD

Percentage of organic waste diverted by Biogas Units in Thiruvananthapuram = 3.4%

Percentage of total MSW diverted by Biogas Units in Thiruvananthapuram = 2.45%

Per capita waste generation in Kochi = 0.765 kg/day

Per capita organic waste generation (57.34% of total MSW) = 0.439 kg/day

Assuming 4 persons/household, per capita organic waste generated by a single household
= 1.755 kg/day

Biogas Units installed in Kochi = 10,000 Units

Total organic waste diverted by these units in Kochi = 17.55 TPD

= 6406.5 TPY

MSW generated in Kochi = 1,366 TPD

Total Organic Waste generated in Kochi = 783 TPD

Percentage of organic waste diverted by Biogas Units in Kochi = 2.24%

Percentage of total MSW diverted by Biogas Units in Kochi = 1.3%

Overall tonnage of Waste diverted by small scale Biogas units from landfill, and transportation and collection = 25.2 TPD

= 9198 TPY

Overall percentage of waste diverted from landfill, and transportation and collection
= 2.5% of Organic waste generated

= 1.5% of total MSW generated

Overall savings on collection and transportation of MSW to the municipal authorities (Appendix 11) = 24,445 Rs/year * 9198 TPY

= 224,845,110 Rs/year

= USD 4.5 million/year

Total green house gas emissions avoided by using small scale biogas units (Appendix 11)

= 721.4 kg/year * 9198 TPY

= 6,635 TPY of CO_2 emissions

APPENDIX 6, PERCENTAGE OF RECYCLABLES RECOVERED AND EFFICIENCY OF SEPARATING RECYCLABLES BY WASTE PICKERS (WPS) FROM FORMALLY COLLECTED MSW IN PUNE; SOURCE: CHINTAN

MSW collected by formal system = 365,000 TPY

MSW burnt on streets or not collected = 17,885 TPY

⇨ Total MSW generated = 382,885 TPY

Therefore, percentage of MSW burnt or not collected = 17885/382885

= 4.671%

NEERI found out that 2% of wastes generated are burnt on streets, so 4.7% above falls close to expected range as it includes MSW not collected too.

Moisture loss during MSW handling = 20,440 TPY

Percentage of weight change due to moisture loss = 5.6%

MSW after moisture loss = 344,560 TPY

Assuming 20% recyclables in the formally collected MSW stream,

Amount of Recyclables = 0.2 * 344560

= **68,912 TPY**

Recyclables recovered by WPs at MRFs = 2,190 TPY

Percentage of MSW recovered by WPs at MRFs = 2190/344560

= 0.636 % of total MSW

Percentage of recyclables recovered by WPs at MRFs = 2190/68912

= **3.2% of Recyclables**

MSW transported to disposal site = 344560 - 2190

= 342,370 TPY

Additional retrieval of Recyclables by WPs at landfills = 12,045 TPY

Percentage of MSW recovered by WPs at landfills = 12045/344560

= 3.5% of total MSW

Percentage of recyclables recovered by WPs at landfills = 12045/68912

= **17.48 % of recyclables**

MSW left at disposal site = 342,370 - 12,045

= 330,325 TPY

Percentage of MSW left at landfill after all possible informal recycling = 330325/344560

= 95.87 % of MSW collected formally (excluding loss in moisture)

(It has to be noted that by integrating the informal recycling sector into the waste management system has the potential of increasing recyclables recovery, thus decreasing amount of MSW landfilled)

Percentage of recyclables recovered from formally collected recyclables

= (2190+12045)/68912

= **20.65 % of recyclables in MSW stream collected formally**

A recycling percentage of 21% is as good as recycling rates in many OECD nations. It is greater than the recycling rates in many US states. Recycling rates in OECD countries are at their present high after considerable public awareness programs and centralized infrastructure intensive waste management systems.

Percentage of WPs who recover recyclables from formally collected MSW is only 20%. Rest of the WP population recovers recyclables from streets and garbage bins. Recyclables recovered in this manner are not accounted for, by formal waste management systems. This results in an underestimation of MSW generated in a city when measured at the dump.

Calculating the recyclables recovery efficiency from formally collected MSW at MRFs and landfills

Total WPs in Pune = 7,000

Population of WPs working at MRFs and landfills = 0.2*7000

= 1,400

MSW collected by 1,400 WPs = 12045 + 2190

= 14,235 TPY

Assuming 300 effective working days for the overall WP population, considering seasonal changes in populations,

Recyclables recovered by one WP = (14235*1000)/(1400*300)

= **34 kg/person/day at MRFs and landfills combined**

APPENDIX 7, LANDFILL MINING PROJECTS AROUND THE WORLD, SOURCE: (64)

Year	Country	Location	Motive					
			Compost Recovery	***Recycling***	***WTE***	***Avoidance of Ground Water Contamination***	***Land reclamation***	***Demonstration Project***
1990	USA	Edinburg, Texas						YES
1991	USA	Lancaster County	YES		YES			
1992	USA	Bethlehem				YES	YES	
1992	USA	Thomson, Connecticut					YES	
1993	USA	Nashville, Tennessee	YES			YES		
1993	USA	Newbury, Massachusetts				YES	YES	
1994	USA	Hague, New York					YES	
1994	Canada	McDougal, Ontario				YES		
1994	Germany	Berghot		YES			YES	
1994	Sardinia						YES	
1994	Sweden	Filborna						YES
1998	Sweden	Gladsax		YES	YES			
2001	Netherlands	Arnhem					YES	
2001	Netherlands	Heiloo					YES	
Total Count			**2**	**2**	**2**	**4**	**8**	**2**

APPENDIX 8, COMPOSTING PLANTS IN OPERATION IN INDIA, SOURCE: CPCB

S. No.	Composting Plants in Operation		New Composting Plants Proposed	
	City/District	**State**	**City/District**	**State**
1	Hyderabad (Dundigal)	Andhra Pradesh	Port Blair	Andaman & Nicobar Islands
2	Vijayawada	Andhra Pradesh	Itanagar	Arunachal Pradesh
3	Kamrup	Assam	Naharlagun	Arunachal Pradesh
4	Tejpur	Assam	Dharamsala	Himachal Pradesh
5	Patna	Bihar	Hamirpur	Himachal Pradesh
6	Bhilla	Chhattisgarh	Nirmalnagar	Karnataka
7	Chirmiri	Chhattisgarh	Ujjain	Madhya Pradesh
8	Dhamtari	Chhattisgarh	Ambad	Maharashtra
9	Dury	Chhattisgarh	Jalna	Maharashtra
10	Jagdalpur	Chhattisgarh	Murud-Jaljira	Maharashtra
11	Korba	Chhattisgarh	Navapur	Maharashtra
12	Raigarh	Chhattisgarh	Panvel	Maharashtra
13	Raipur	Chhattisgarh	Sonepat	Maharashtra
14	Rajnandgaon	Chhattisgarh	Wardha	Maharashtra
15	Delhi	Delhi	Yavatmal	Maharashtra
16	Ahmadabad	Gujarat	Aizwal	Mizoram
17	Junagarh	Gujarat	Kohima	Nagaland
18	Surat	Gujarat	Karaikal	Pondicherry
19	Vadodara	Gujarat	Pondicherry	Pondicherry
20	Ambala	Haryana	Kartarpur	Punjab
21	Sirsa	Haryana	Mandi Gobindgarh	Punjab
22	Bhuntar	Himachal Pradesh	Agartala	Tripura
23	Bilaspur	Himachal Pradesh	Ghaziabad	Uttar Pradesh
24	Kangra	Himachal Pradesh	Noida	Uttar Pradesh
25	Kullu	Himachal Pradesh	Barrackpore	West Bengal
26	Mandi	Himachal Pradesh	Bhadreshwar	West Bengal
27	Nagrota	Himachal Pradesh	Dum Dum	West Bengal
28	Nahan	Himachal Pradesh	Garulia	West Bengal
29	Shimla	Himachal Pradesh	Kachrapara	West Bengal
30	Sirmour	Himachal Pradesh	Kalna	West Bengal
31	Solan	Himachal Pradesh	Kalyani	West Bengal

S. No.	Composting Plants in Operation		New Composting Plants Proposed	
	City/District	State	City/District	State
32	Una	Himachal Pradesh	Panihati	West Bengal
33	Bengaluru	Karnataka	Rishtra	West Bengal
34	Mangalore	Karnataka	Serampore	West Bengal
35	Kochi	Kerala	Siliguri	West Bengal
36	Bhopal	Madhya Pradesh		
37	Gwalior	Madhya Pradesh		
38	Indore	Madhya Pradesh		
39	Achalpur	Maharashtra		
40	Akola	Maharashtra		
41	Aurangabad	Maharashtra		
42	Barshi	Maharashtra		
43	Beed	Maharashtra		
44	Bhiwandi- Nizampur	Maharashtra		
45	Chandrapur	Maharashtra		
46	Dhule	Maharashtra		
47	Kolhapur	Maharashtra		
48	Latur	Maharashtra		
49	Malegaon	Maharashtra		
50	Miraj-kuped	Maharashtra		
51	Mumbai	Maharashtra		
52	Nagpur	Maharashtra		
53	Parbhani	Maharashtra		
54	Pimpri- Chinchwad	Maharashtra		
55	Pune	Maharashtra		
56	Sangli	Maharashtra		
57	Satara	Maharashtra		
58	Shillong	Meghalaya		
59	Barbil	Orissa		
60	Berhampur	Orissa		
61	Jatni	Orissa		
62	Kotpad	Orissa		
63	Paradeep	Orissa		
64	Puri	Orissa		
65	Rayagada	Orissa		
66	Karaikal	Pondicherry		

S. No.	Composting Plants in Operation	
	City/District	State
67	Pondicherry	Pondicherry
68	Adampur	Punjab
69	Jalandhar	Punjab
70	Jodhpur	Rajasthan
71	Chennai	Tamil Nadu
72	Coimbatore	Tamil Nadu
73	Namakkal	Tamil Nadu
74	Tiruppur	Tamil Nadu
75	Bareilly	Uttar Pradesh
76	Hindon	Uttar Pradesh
77	Kanpur	Uttar Pradesh
78	Lucknow	Uttar Pradesh
79	Kolkata	West Bengal

APPENDIX 9, AREA OCCUPIED BY KNOWN LANDFILLS IN INDIA AND PROPOSALS FOR NEW LANDFILLS; SOURCE: CPCB

S.No.	Name of city	No. of landfill sites	Area of landfill (ha)	Life of landfill (Years)	New site proposed (YES/NO)
1	Chennai	2	465.5	24/17	No
2	Coimbatore	2	292	-	No
3	Surat	1	200	-	No
4	Greater Mumbai	3	140	-	No
5	Greater Hyderabad	1	121.5	-	No
6	Ahmadabad	1	84	30	Yes
7	Delhi	3	66.4	-	No
8	Jabalpur	1	60.7	-	Yes
9	Indore	1	59.5	-	No
10	Madurai	1	48.6	35	No
11	Greater Bengaluru	2	40.7	-	No
12	Greater Visakhapatnam	1	40.5	25	No
13	Ludhiana	1	40.4	-	No
14	Nashik	1	34.4	15	No
15	Jaipur	3	31.4	-	No
16	Srinagar	1	30.4	-	No
17	Kanpur	1	27	-	No
18	Kolkata	1	24.7	35	Yes
19	Chandigarh	1	18	-	No
20	Ranchi	1	15	-	No
21	Raipur	1	14.6	-	Yes
22	Meerut	2	14.2	-	No
23	Guwahati	1	13.2	-	No
24	Thiruvananthpuram	1	12.15	-	No
25	Vadodara	1	8.1	-	Yes
26	Agartala	1	6.8	14	Yes
27	Dehradun	1	4.5	-	Yes
28	Jamshedpur	2	4.1	-	No
29	Gangtok	1	2.8	-	No

S.No.	Name of city	No. of landfill sites	Area of landfill (ha)	Life of landfill (Years)	New site proposed (YES/NO)
30	Faridabad	3	2.4	-	No
31	Asansol	1	2	7	No
32	Varanasi	1	2	-	Yes
33	Agra	1	1.5	30	No
34	Lucknow	1	1.4	3	Yes
35	Panjim	1	1.2	30	No
36	Rajkot	2	1.2	-	Yes
37	Simla	1	0.6	-	No
38	Kavaratti	1	0.2	-	No
39	Port Blair	1	0.2	6	Yes
40	Dhanbad	3		-	No
41	Allahabad	2		-	No
42	Daman	2		-	No
43	Aizwal	1		-	No
44	Bhopal	1		-	No
45	Imphal	1		-	No
46	Itanagar	1		-	No
47	Kochi	1		-	No
48	Kohima	1		-	No
49	Nagpur	1		-	No
50	Pune	1		-	No
51	Shillong	1		-	No
52	Silvassa	1		-	No
53	Vijayawada			-	No
54	Bhubaneshwar	4		-	Yes
55	Amritsar	1		-	Yes
56	Jammu	1		10	Yes
57	Gandhinagar			-	Yes
58	Patna			-	Yes
59	Pondicherry			-	Yes
	TOTAL	76	1,934		

APPENDIX 10, INCIDENCE OF HEALTH RISK AND DISEASES IN WASTE PICKERS AND MUNICIPAL WORKERS; SOURCE: CPCB

Health assessment studies on 732 individuals were conducted in Kolkata. The studies included clinical examination of 376 conservancy workers (MSW Staff), 151 waste pickers (WPs) and 205 controls (Control Population). These results were used to calculate the incidence of health problems in WPs (Figure 26). The results of testing these individuals for 16 different health problems are as follows:

Health problems Tested	Control Population Tested Positive	Waste Pickers Tested Positive	MSW Staff Tested Positive	Incidence of Health Problems in Control Population (%)	Incidence of Health Problems in WPs (%)	Incidence of Health Problems in MSW Staff (%)	Increase in Incidence in WPs Compared to Control Population	Increase in Incidence in MSW Staff Compared to Control Population
Chromosome break	8	68	82	4	45	22	11.5	5.6
Elevated mucus production	2	16	25	1	11	7	10.9	6.8
Covert lung hemorrhage	6	34	44	3	23	12	7.7	4.0
Cardiovascular risk	21	117	162	10	77	43	7.6	4.2
High PM_{10} exposure	12	65	85	6	43	23	7.4	3.9
Altered immunity	23	96	167	11	64	44	5.7	4.0
Infection, Inflammation	13	53	64	6	35	17	5.5	2.7
Other infections	7	26	34	3	17	9	5.0	2.6
High pollution load	8	23	32	4	15	9	3.9	2.2
Allergy, asthma	11	28	36	5	19	10	3.5	1.8
Lung infection	32	80	89	16	53	24	3.4	1.5
Bacterial infection	2	5	10	1	3	3	3.4	2.7
Obstruction in airways	2	4	5	1	3	1	2.7	1.4
Breathing problem	43	84	71	21	56	19	2.7	0.9
Nose & throat infections	43	82	93	21	54	25	2.6	1.2
Anemia	17	32	45	8	21	12	2.6	1.4

APPENDIX 11, COST AND CARBON DIOXIDE EMISSIONS OF TRANSPORTING ON TON OF MSW IN INDIA; SOURCES: (9), USEPA, WWW.MYPETROLPRICE.COM

Capacity of each truck used for MSW transportation	= 12 tons
Mileage of each truck	= 4.5 km/litre
Diesel Price	= 45 Rs/litre
Therefore, cost per km	= 10 Rs/km

Conservative assumption, Distance travelled to landfill/other disposal facilities

	= 20 km
Number of trips by each truck	= 3
Total Distance travelled by each truck	= 120 km
Cost of fuel	= 1200 Rs
Total MSW handled by each truck	= 36 TPD
Maintenance costs per truck	= 150,000 Rs/year
	= 411 Rs/day/truck
No. of Drivers required for 3 trips	= 3
Salary of each Driver	= 8000 Rs/month
	= 266.67 Rs/day/driver
Total Salary of Drivers	= 800 Rs/day/truck
Therefore, cost of transporting 36 TPD of MSW	= 2411 Rs/day
⇨ Cost of transporting 1 ton	= **67.0 Rs/day**
	= **24,444.8611 Rs/year**

Savings on avoiding the transportation of one Ton of MSW to landfill

= 24,445 Rs/year (USD 500) per ton of MSW transportation

Calculating Carbon Dioxide Emissions from Transporting MSW

Carbon Dioxide Emissions from Diesel fuel	= 10.1 kg/gallon
	= 2.7 kg/liter
Distance travelled by each truck	= 120 km/day
Mileage	= 4.5 km/liter
Therefore, Diesel consumption	= 26.67 liters/day
⇨ CO_2 Emissions from transporting 36 TPD of MSW	= 71.2 kg/day
CO2 Emissions for transporting 1 ton of MSW	**= 2.0 kg/day**
	= 721.3854 kg/year

CO2 Emissions avoided by avoiding the transport of 1 ton of MSW

= **721.4 kg/year** per ton of MSW transportation

APPENDIX 12, HEAVY METALS CONCENTRATION IN MIXED WASTE COMPOST; SOURCE: IISS

Concentrations of all heavy metals except Cadmium are expressed in mg/kg dry mass of compost. Cadmium concentration is expressed in mg/100 kg dry mass of compost.

Heavy Metals in Mixed Waste Composts	**Concentration**		**Median (mg/kg)**	Quality Control standard (mg/kg)
	Lowest (mg/kg)	**Highest (mg/kg)**		
Zinc	82	946	252	1000
Copper	25	865	198	300
Cadmium*	0	8	0.94	5
Lead	11	647	133	100
Nickel	9	190	25	50
Chromium	14	401	69	50
**Cadmium concentration units are mg/100 kg*				

APPENDIX 13, POTENTIAL HAZARD OF INTRODUCING HEAVY METALS INTO AGRICULTURAL SOILS

If all MSW generated in India from 2011-2021 is treated in MBT facilities and the compost was used for agriculture, it would introduce 73,000 tons of heavy metals into agricultural soils.

Year	**Heavy Metals**						
	Zinc	**Copper**	**Cadmium**	**Lead**	**Nickel**	**Chromium**	**Total**
2011	1,818.4	1,625.1	10.1	1,106.9	180.1	623.7	**5,364**
2012	1,894.2	1,692.9	10.5	1,153.0	187.6	649.7	**5,588**
2013	1,973.1	1,763.4	11.0	1,201.0	195.4	676.8	**5,821**
2014	2,055.3	1,836.9	11.4	1,251.1	203.5	705.0	**6,063**
2015	2,141.0	1,913.4	11.9	1,303.2	212.0	734.3	**6,316**
2016	2,230.2	1,993.2	12.4	1,357.5	220.9	764.9	**6,579**
2017	2,323.1	2,076.2	12.9	1,414.1	230.1	796.8	**6,853**
2018	2,420.0	2,162.8	13.4	1,473.0	239.7	830.0	**7,139**
2019	2,520.8	2,252.9	14.0	1,534.4	249.6	864.6	**7,436**
2020	2,625.8	2,346.8	14.6	1,598.3	260.0	900.7	**7,746**
2021	2,735.3	2,444.6	15.2	1,664.9	270.9	938.2	**8,069**
Total	**24,737**	**22,108**	**137**	**15,057**	**2,450**	**8,485**	**72,975**

APPENDIX 14, DIOXINS/FURANS EMISSIONS FROM OPEN BURNING OF MSW IN MUMBAI, SOURCES: (5), (65)

Data for the amount of MSW burnt in Mumbai is obtained from CPCB and NEERI study (5). Wards and landfills are listed accordingly. The Dioxins/Furans emissions factor assumed is 35,196 ng/kg of MSW openly-burnt from the World Bank document on SWM Holistic Decision Modeling (65).

Ward/Landfill	MSW Openly Burnt (TPD)	Dioxins/Furans (g/day)	MSW Openly Burnt (TPY)	Dioxins/Furans (g/year)
A	8.01	0.282	2923.65	102.9007854
B	2.646	0.093	965.79	33.99194484
C	5.176	0.182	1889.24	66.49369104
D	10.44	0.367	3810.6	134.1178776
E	10.08	0.355	3679.2	129.4931232
F/S	5.85	0.206	2135.25	75.152259
F/N	6.3	0.222	2299.5	80.933202
G/S	7.47	0.263	2726.55	95.9636538
G/N	10.62	0.374	3876.3	136.4302548
H/E	5.076	0.179	1852.74	65.20903704
H/W	6.48	0.228	2365.2	83.2455792
K/E	6.75	0.238	2463.75	86.714145
K/W	8.236	0.290	3006.14	105.8041034
P/S	4.05	0.143	1478.25	52.028487
P/N	6.66	0.234	2430.9	85.5579564
R/S	3.214	0.113	1173.11	41.28877956
R/C	6.03	0.212	2200.95	77.4646362
R/N	3.016	0.106	1100.84	38.74516464
L	8.352	0.294	3048.48	107.2943021
M/E	5.626	0.198	2053.49	72.27463404
M/W	5.986	0.211	2184.89	76.89938844
N	4.59	0.162	1675.35	58.9656186
S	5.22	0.184	1905.3	67.0589388
T	3.61	0.127	1317.65	46.3760094
GORAI (R/S)	119	4.188	43435	1528.73826
DEONAR (M/E)	410	14.430	149650	5267.0814
MULUND (T)	63	2.217	22995	809.33202
TOTAL	**741**	**26.10**	**270,643**	**9,525.6**

APPENDIX 15, MATERIAL AND ENERGY RESOURCE WASTAGE IN THE NEXT DECADE DUE TO CURRENT LANDFILLING PRACTICES IN INDIA

State/UT	MSW Generated (Tons)	No. of Oil Barrel eq. landfilled	Compost landfilled (Tons)	Recyclables landfilled (Tons)
Maharashtra	8,107,366	9,153,817	1,752,002	1,093,368
West Bengal	5,687,953	7,188,941	1,115,408	721,961
Uttar Pradesh	4,741,415	6,152,425	929,791	677,046
Tamil Nadu	4,297,001	4,851,633	859,830	647,674
Delhi	4,218,548	5,473,957	827,257	602,383
Andhra Pradesh	4,156,349	4,692,826	831,685	626,474
Karnataka	2,850,532	3,218,462	570,391	429,652
Gujarat	2,584,597	2,918,202	558,531	348,561
Rajasthan	1,812,892	2,352,396	355,508	258,870
Madhya Pradesh	1,641,615	1,853,505	354,753	221,390
Punjab	1,168,347	1,516,039	229,113	166,833
Kerala	1,075,727	1,214,576	215,253	162,141
Bihar	1,010,183	1,276,759	198,097	128,220
Haryana	956,718	1,241,430	187,612	136,614
Jharkhand	672,159	849,534	131,810	85,316
Chhattisgarh	588,262	763,324	115,358	84,000
Orissa	493,128	623,259	96,702	62,592
Jammu & Kashmir	455,336	590,840	89,291	65,019
Chandigarh	177,549	230,386	34,817	25,353
Assam	169,241	213,902	33,188	21,481
Uttarakhand	168,583	218,752	33,059	24,072
Pondicherry	163,884	185,038	32,793	24,702
Meghalaya	49,962	63,146	9,797	6,342
Tripura	41,723	52,734	8,182	5,296
Andaman & Nicobar	41,717	65,380	9,349	8,935
Mizoram	31,331	39,599	6,144	3,977
Goa	30,935	34,928	6,685	4,172
Manipur	26,102	32,990	5,119	3,313
Nagaland	23,519	29,726	4,612	2,985
Himachal Pradesh	22,496	29,191	4,412	3,212
Daman & Diu	8,634	9,749	1,866	1,164
Sikkim	7,091	8,962	1,390	900
Arunachal Pradesh	6,537	8,262	1,282	830
Dadra & Nagar Haveli	4,026	4,546	870	543
Lakshadweep	1,667	2,612	373	357
TOTAL		**57,161,825**	**9,612,334**	**6,655,749**

DATED THIS 24th DAY OF MAY 2011

Between

EARTH ENGINEERING CENTER (EEC)
COLUMBIA UNIVERSITY, NEW YORK, U.S.A.

AND

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE (NEERI)
NEHRU MARG, INDIA

MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding ("MOU") is made this ___ day of _____________ 2011 between

(1) **EARTH ENGINEERING CENTER**, located in Columbia University in the City of New York (hereinafter referred to as "**EEC**") is the parent organization of the Waste-to-Energy Research and Technology Council (WTERT) along with its sister organizations in Germany, Greece, Japan, China, France, UK and the Council for Sustainable Use of Resources (SUR);

and

(2) **NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE**, headquartered at Nehru Marg, Nagpur-440 020, India (hereinafter referred to as "**NEERI**"), a constituent of Council of Scientific and Industrial Research, New Delhi; which shall hereinafter be collectively referred to as the "Parties" and individually as a "Party".

WHEREAS

(A) The Parties are desirous of pursuing and promoting joint research and development activities of mutual interest in various aspects of municipal solid waste management in India in accordance with their respective needs and objectives and shall, by joint agreement, determine the areas and subject of such collaboration, on the basis of this MOU which sets out the general understanding of the Parties' collaboration in research and development.

1. AREAS OF COOPERATION

1.1 The Parties agree to cooperate on research activities in the following areas in accordance with their respective needs and objectives:

(a) Joint research projects in the area of municipal solid waste management;

(b) Visits by staff and students for discussions and research on research projects;

(c) Joint conferences, workshops and training programs for staff and students aimed at skills development.

(collectively referred to as the "Activities")

1.2 A specific obligation of NEERI under this MOU is to form and host a WTERT-India web page that links various academic, industry and government groups in India who are concerned with advancing the goals of sustainable waste management in India and provides information to the public on this subject, as detailed in Appendix 1 to this document ("Charter of Global WTERT Council").

2. ARRANGEMENTS AND FUNDING

2.1 To implement the collaborative activities envisaged under this MOU, representatives of the Parties may meet periodically to negotiate and conclude specific and definitive programs of cooperation ("Projects"), including their financing for each Project and possible collaboration with other parties, provided that neither of the Parties shall have the power to bind the other Party without such other's consent in writing thereto.

2.2 The financial and other arrangements relating to each Project, including any sharing or access to resources, facilities and equipment, will be in accordance with the specific definitive agreements to be entered into between the Parties ("Project Agreements").

2.3 A specific obligation of EEC under this MOU is to provide to NEERI a seed grant of US$1,000 (one thousand U.S. dollars) to be used by NEERI in implementing the WTERT-India web page, as described in Clause 1.2 of this Agreement.

3. CO-ORDINATION COMMITTEE

3.1 A Co-ordination Committee shall be formed to drive, initiate and co-ordinate the Activities. The Co-ordination Committee shall consist of:
(a) Director, EEC, and/or his nominee(s)
(b) Director, NEERI and/or his nominee(s)
(c) Other members to be invited as required

3.2 The Co-ordination Committee shall:
(a) Review the progress of the identified Activities (at least once a year);
(b) Consider new research proposals for joint collaboration;
(c) Define new areas and programs of cooperation.

4. PUBLICATIONS AND INTELLECTUAL PROPERTY

4.1 The Parties agree that in general all publications under the MOU shall be co-authored by the relevant faculty, staff or research fellow(s) of the Parties.

4.2 Specific terms on the ownership, protection and management of any intellectual property rights, inventions and innovations arising from joint research activities between the Parties ("Research IP") shall be included in the relevant Project Agreement for each Project.

4.3 The Parties agree that the principles outlined below shall generally apply to Research IP, subject to the specific terms and conditions in the relevant Project Agreement, which terms and conditions shall prevail:

(a) Any background intellectual property belonging to or in the control of a Party which the Party may introduce or disclose to the other Party for the purposes of a Project ("Background IP") shall remain the property of the Party introducing and/or disclosing the same. Each Party shall only use the other Party's Background IP for the purposes of the Project for which the Background IP was introduced or disclosed.

(b) All Research IP created or developed solely by the employees, students or agents of a Party shall be solely owned by such Party.

(c) All Research IP created or developed jointly by employees, students or agents of both Parties shall be jointly owned ("Joint IP"). The Parties shall jointly agree on the management and protection of such Joint IP, including the sharing of any expenses related thereto of such Joint IP.

5. CONFIDENTIALITY

5.1 Each Party agrees to use any Confidential Information (as defined below) of the other Party disclosed under this MOU solely for the purposes of this MOU. "Confidential Information" means any device, graphics, written information, or information in any other tangible form that is disclosed by the disclosing Party to the receiving Party for the purposes of this MOU, that is marked at the time of disclosure as being "Confidential" or "Proprietary" or words of similar import. Information disclosed orally or visually and identified at the time as "Confidential" shall be considered "Confidential Information" if it is designated "Confidential," concurrent with the oral or visual disclosure.

5.2 Neither of the Parties shall, without the prior written consent of the other Party, disclose any "Confidential Information" relating to this MOU to any third party.

5.3 Each Party agrees to make Confidential Information available only to those employees and students who require access to it in the performance of this MOU, and to inform them of the confidential nature of such information and their obligation to protect such confidentiality. Each Party shall exert reasonable efforts, no less than the protection given its own confidential information, to maintain such information in confidence.

5.4 Each Party agrees that the obligations of confidentiality contained herein shall not attach to information that:-

(a) is or was already known to the receiving Party at the time of disclosure to it as evidenced by written records; or

(b) is at the time of disclosure to the receiving Party or thereafter becomes public knowledge through no fault or omission of the receiving Party; or

(c) is lawfully obtained by the receiving Party from a third party who is not under any confidentiality obligation to the disclosing Party; or

(d) is required to be disclosed by court rule or governmental law or regulation, provided that the receiving Party gives the disclosing Party prompt notice of any such requirement and cooperates with the disclosing Party in attempting to limit such disclosure.

5.5 The obligation of confidentiality hereunder shall carry on in force for a period of five (5) years from the termination or expiry of this MOU.

5.6 Nothing in this MOU constitutes or implies any representation, warranty or undertaking by the disclosing party of the accuracy or completeness of the information or materials provided as part of its involvement hereunder.

6. AMENDMENTS

6.1 This MOU may be amended and supplemented in writing at any time as decided and agreed by mutual written consent of the Parties.

7. TERM OF MOU

7.1 This MOU shall commence on the date first written above and shall remain in force for a period of three (3) years. Either of the Parties may terminate this MOU by giving twelve (12) months written notification of its desire to terminate to the other Party. The termination of this MOU shall not affect the implementation of the Projects established under it prior to such termination. This MOU can be extended by mutual written agreement of both Parties.

8. DISPUTE RESOLUTION

8.1 The Parties undertake to resolve any disputes arising under or in connection with this MOU amicably by mutual agreement.

9. NON-BINDING NATURE OF THIS MOU

9.1 Except for Clause 5 on "Confidentiality" and Clauses 1.2 and 2.3 on the formation of WTERT-India which shall be legally binding, this MOU is a non-binding expression of the current intentions of the Parties, and neither Party will incur nor be bound by any legal obligation or expense hereunder to the other Party until and unless definitive agreements have been negotiated, approved by the necessary management levels of each Party and executed and delivered by authorized representatives of both Parties.

CHARTER OF THE GLOBAL WTERT COUNCIL

Introduction

For nearly two decades, the Earth Engineering Center (EEC) of Columbia University has conducted research on the generation and disposition of used materials and products in the U.S. and globally. Economic development has resulted in the annual generation of billions of tons of used materials which represent a considerable resource but, when not managed properly, constitute a major environmental problem both in developed and developing nations. The goal of EEC is to identify and help develop the most suitable means for managing various solid wastes research, and disseminate this information by means of publications, the web, and technical meetings. EEC is also collaborating with BIOCYCLE journal in carrying out a bi-annual survey of generation and disposition of MSW in the U.S. that is now being used by U.S. EPA in computing greenhouse emissions from waste management.

This research has engaged many M.S. and Ph.D. students on all aspects of waste management. Since 2000, EEC has produced thirty M.S. and Ph.D. theses and published nearly one hundred technical papers. In 2002, EEC co-founded, with the U.S. Energy Recovery Council (ERC; www.wte.org), the Waste-to-Energy Research and Technology Council (WTERT), which is by now the foremost research organization on the recovery of energy and metals from solid wastes in the U.S.

In the course of its studies, EEC established that one billion tons of MSW are landfilled each year, landfilling will continue to be used in the foreseeable future, and nearly 80% of the world's landfills are not equipped to capture landfill gas (LFG) and protect surface and ground waters from contamination. Therefore, in 2008 EEC proposed the expanded Hierarchy of Waste Management that differentiates between traditional and sanitary landfills.

In recent years, sister organizations to the WTERT in the U.S. have been created in several other nations such as Brazil, Canada, China, France, Greece, Japan and India. In the interest of the common goal of these organizations, of advancing sustainable waste management, it is necessary to establish a WTERT "Charter" that is agreed upon by the existing members of the global WTERT Council and can be then used to explain the operations of the Council to other nations that wish to become members and also to prospective industrial and government sponsors.

The Name of the WTERT Council

The principal tool for disseminating information by the U.S. and other existing members of WTERT has been the internet. The web addresses used (www.wtert.org, www.wtert.eu, www.wtert.gr, etc.) all include the acronym WTERT and this has the advantage that when one types WTERT in Google or other search engine, automatically one links to WTERT organizations in different countries. Thus WTERT has become a valuable brand name and can be very helpful to people seeking information on waste management in a particular country (e.g. Greece) by using the acronym WTERT and then the name of the country or letters representing it (e.g. "gr"). It is therefore necessary for member nations to register and use the "wtert" web address (e.g. www.wtert.gr) as well as whatever other name and address they wish. For example, the sister organization in Greece chose the name "SYNERGIA" so one can find their web either by going to www.wtert.gr or by using the SYNERGIA address.

Therefore, each national member should choose whatever word or words are most suitable to express the mission of their organization in their national language; and also use the second name "WTERT-Greece, WTERT-France, etc. to express the fact that they are also a member of the global WTERT Council.

Mission of WTERT Council

The mission of the global WTERT Council is to identify the best available technologies for the treatment of various waste materials, conduct additional academic research as required, and disseminate this information by means of publications, the WTERT web pages, and periodic meetings. In particular, WTERT strives to increase the global recovery of materials and energy from used solids, by means of recycling, composting, waste-to-energy, and sanitary landfilling with LFG utilization. The guiding principle is that responsible management of wastes must be based on science and best available technology at a particular location and not what seems to be inexpensive now but can be very costly in the future.

Figure 1 shows the general rule of the accepted "hierarchy of waste management". However, WTERT understands that for practical or economic reasons it may be not be possible to follow this hierarchy at all times and at all locations. For example, waste-to-energy requires a much larger initial investment than a landfill and therefore may not be attainable at a certain stage of economic development of a community; in such a case, a sanitary landfill with LFG recovery would be the next preferable option. As another example, an EEC study has shown that use of yard wastes as Alternative Daily Cover in sanitary landfills, in place of soil, is environmentally advantageous to windrow composting of the yard wastes.

Figure 1: The hierarchy of waste management

Scope of Operations of WTERT Council

The WTERT Council consists of designated representatives of each national WTERT organization. These representatives will form the governing board of the Council. The Chair of the governing board of the Council will be elected by majority vote of all members for a tenure period of two years. The Council will review and vote on the WTERT Charter and subsequent actions affecting the operations and Charter of the Council. Most communications will be by e-mail or telephone conference. However, occasional meetings of the Council will be called, preferably to be held in conjunction with an international meeting on waste management.

The WTERT Council realizes that waste management solutions vary from region to region. It is hoped that through the new and powerful tool of the internet, we can collectively create a global platform for sharing of experience, expertise and information that will advance the goals of sustainable waste management world-wide. The Council may also provide start up funding for new WTERT organizations.

Scope of Operations of Each National WTERT Organization

The objectives of each WTERT national organization are:

1. To develop and maintain a WTERT web page that describes the mission and scope of the organization and links as many as possible academic and industrial research groups

working on various aspects of waste management, within the nation. Preferably, this web page will be hosted at a major university that is conducting research on resource recovery from wastes. Most of the material in this web page will be in the national language so as to inform the general public and policymakers as well as academia and industry. However, the front web page should also provide for English language translation of part of the content, as discussed in (2) below.

2. To identify the most suitable technologies for the treatment of various waste materials in the nation, encourage additional academic research as required, disseminate this information within the nation, and provide an English language window for the outside world to learn about problems and opportunities for advancing waste management in their respective nation.

3. Once the organization platform described in (a) and (b) has been created, the national WTERT can seek sponsorship and funding by industry and government organizations concerned with advancing waste management in the nation. This model of operation has been successful with some of the existing WTERT national members who are willing to advise and assist new members.

Current WTERT national members and contact information (in chronological order of joining WTERT Council)

1. **WTERT-US (www.WTERT.org)**

   Earth Engineering Center, Columbia University
   500 West 120th St., New York, NY 10027, U.S.A.

   Prof. N.J. Themelis <njt1@columbia.edu>

   Prof. M.J. Castaldi <mc2352@columbia.edu>

2. **WTERT-Canada (www.WTERT.ca)**

   Canadian EfW Coalition (CEFWC)

   10 Rambert Crescent
   Toronto, Ontario M6S 1E6, Canada

   Mr. John Foden <jpfoden@presterjohn.ca>

3. **WTERT-Greece (www.WTERT.gr)**

Name: SYNERGIA

19 km Peania-Markopoulo Ave.
Peania 19002, Attica, Greece

Dr. Efstratios Kalogirou <stkal@intranet.gr>

4. WTERT-China (www.WTERT.cn)

Name: C-WTERT

Waste-to-Energy Department
Chongqing University of Science and Technology (CQUST)

Songtao Kong <kst@tom.com>

5. WTERT-Germany (www.WTERT.eu}

Name: W_tERT

Technical University of Munich, Munich

Prof. Martin Faulstich <m.faulstich@wzw.tum.de>

Prof. Peter Quicker (RWTH, Aachen, Germany) <quicker@teer.rwth-aachen.de>

6. WTERT-Japan (www.WTERT.jp)

Tokyo Institute of Technology

Suzukakedai Campus
4259 G5-8 Nagatsuta-cho, Midori-ku
Yokohama, Kanagawa, 226-8503, Japan

Prof. Kunio Yoshikawa <yoshikawa.k.aa@m.titech.ac.jp>

7. WTERT-Brazil (www.WTERT.br)

Name: CONGENERES

University of Brazil, Rio de Janeiro (UFRJ)

Dr. Sergio Guerreiro Ribeiro <sergiog@rjnet.com.br>

8. **WTERT-France (www.WTERT.fr)**

Name: Pending

Ecole des Mines d'Albi-Carmaux
Campus Jarlard - Route de Teillet,
ALBI CT Cedex, France

Prof. Ange Nzihou <ange.nzihou@mines-albi.fr>

9. **WTERT-U.K. (www.WTERT.uk)**

Name: Pending

Department of Civil and Environmental Engineering
Imperial College, London, U.K.

Dr. Chris Cheeseman <c.cheeseman@imperial.ac.uk>

10. **WTERT-Italy (www.WTERT.it)**

Name: Materials & Energy from Waste (MEFW)

Department of Energy - School of Industrial Engineering - Politecnico di Milano
Campus Piacenza, Piacenza, Italy

Prof. Stefano Consonni < stefano.consonni@polimi.it >

Prof. Mario Grosso < mario.grosso@polimi.it>

11. **WTERT-India** (Website address pending)

National Environmental Engineering Research Institute (NEERI)

Dr. Sunil Kumar <s_kumar@neeri.res.in>

Ranjith Annepu <rka2109@columbia.edu>

ANNEXURE III, PRESS RELEASE REGARDING THE FORMATION OF WTERT-INDIA

Source: NEERI News, NEERI and Columbia University signed an MOU to form WTERT-India

Date: August 04, 2011

Waste-to-Energy Research and Technology Council, India (WTERT, India)

The Earth Engineering Center (EEC) at Columbia University in the City of New York decided to team up with the National Environmental Engineering Research Institute (NEERI) to set-up Waste-to-Energy Research and Technology (WTERT) Council in India. This association between the above two prime research organizations in the world is established to address the rising interest, increasing investments, to create awareness and, to funnel important decisions related to municipal solid waste management (MSWM) in India in the right direction. WTERT-India would also be added to the WTERT's global charter where it would function as India's window to the world on the entire spectrum of solid waste management issues.

For nearly two decades, the Earth Engineering Center (EEC) of Columbia University has conducted research on the generation and disposition of used materials and products in the U.S. and globally. This research has engaged many researchers on all aspects of waste management. Since 2000, EEC has produced thirty M.S. and Ph.D. theses and published nearly one hundred technical papers. In 2002, EEC co-founded, with the U.S. Energy Recovery Council (ERC; www.wte.org), the Waste-to-Energy Research and Technology Council (WTERT), which is by now the foremost research organization on the recovery of energy and metals from solid wastes in the U.S.

The National Environmental Engineering Research Institute (NEERI) headquartered at Nagpur and with five other branches in Chennai, Delhi, Hyderabad, Kolkata and Mumbai is one of the prime research institutes in India. It is a forerunner in research on solid waste management with dedicated researchers. Research conducted by NEERI in 2005 on MSWM in fifty nine cities is one of the comprehensive studies on this issue. The other important studies on SWM include India's Initial National Communication to the United Nations Framework Convention on Climate Change. The work related to Landfill Gas use as LNG in transport sector as well as new LFG model development is under progress with Texas Transportation Institute, US. The researchers engaged in solid waste management at NEERI are recognized internationally.

WTERT, India will be the latest addition to the global WTERT Council which is already operating in the U.S., Canada, Greece, China, Germany, Japan, Brazil, France, U.K. and Italy. The mission of this council is to identify the best available technologies for the treatment of various waste materials, conduct additional academic research as required, and disseminate this information by means of publications, the WTERT web pages, and periodic meetings. In particular, WTERT strives to increase the global recovery of materials and energy from used solids, by means of recycling, composting, waste-to-energy, and, sanitary landfilling with LFG utilization. The guiding principle is that responsible management of wastes must be based on science and best available technology at a particular location and not on ideology and economics that exclude environmental costs and seem to be inexpensive now but can be very costly in the future. WTERT, India is set-up with the understanding that solutions vary from region to region and is committed to researching locally available technologies.

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Advancing Sustainable Waste Management

Improper solid waste management is an everyday nuisance to urban Indians