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Solid waste management in India: options and opportunities

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Abstract

In India, the collection, transportation and disposal of MSW are unscientific and chaotic. Uncontrolled dumping of wastes on outskirts of towns and cities has created overflowing landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have serious environmental implications in terms of ground water pollution and contribution to global warming. Burning of waste leads to air pollution in terms of increased TSP and PM_{10} emissions, which is equivalent to vehicular emissions at times.

In the absence of waste segregation practices, recycling has remained to be an informal sector working on outdated technology, but nevertheless thriving owing to waste material availability and market demand of cheaper recycled products. Paper and plastic recycling have been especially growing due to continuously increasing consumption levels of both the commodities.

Composting-aerobic and anaerobic, both the options are available to the country for scientific disposal of waste in future. However, country also needs something in terms of policy and guidelines to enable the municipal corporations to run the waste services efficiently. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Municipal solid waste; Recycling; Disposal; Projections; Paper; Plastic; India

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1. Introduction

Until recently, environment was not an issue in a third world country like India and solid waste management was definitely not the prime concern of environmentalists and the government, when the awakening to the issue finally did happen. It is only in very recent times, when certain NGO'S started working and highlighting the pathetic state of municipal waste services provision in country, that the Indian decision makers realized the importance of this particular aspect of environmental management.

India lacks well formulated guidelines and policy structure regarding waste management services, in the absence of which the municipal agencies have not been performing their duties in this aspect satisfactorily. Though, few rules are there within the various municipal acts, which govern the day-to-day running of these agencies, the same however due to lack of enforcement, have not served much purpose. This paper looks in brief at the current waste management scenario in India in terms of collection, transportation and disposal and henceforth the various options available to the country for efficient management have been investigated in the light of environmental impacts associated with the current and envisaged practices.

1.1. Background information of this publication

Tata Energy Research Institute, New Delhi took up an exhaustive study in 1995 to document the environmental degradation which had occurred in India, over the last 50 years of its independence due to prolonged and uninhibited use of its natural resources, and if the present trends continued where would the country reach by 2047 AD [1]. The study was carried over a period of two years and covered all natural resources, i.e. forestry, soil, water, biodiversity, and pollution, air water and solid waste. This paper describes the solid waste component of this study, whereby various aspects of solid waste management issue have been looked into in the urban context. Both, the past and expected future trends were studied largely on the basis of secondary information collected from various sources.

1.2. Background informution about India

Covering an area of 3287263 krn, India is the seventh largest country in the world. Lying entirely in the northern hemisphere, the Indian mainland extends between latitudes 8° 4′ and 37° 6′ north, longitudes 68° 7′ and 97° 25′ east and measures about 3214 km from north to south between the extreme latitudes and about 2933 km from east to west between the extreme longitudes.

It has achieved multifaceted socio-economic progress during the last 50 years of its independence and is now the tenth industrialized nation in the world, with a complete self-sufficiency in field of agriculture. India's population, as in March 1991 stood at 856 million [1], making it the second largest populous country of the world. Assuming an annual growth rate of 1.3%, the estimated figures for 2021 AD are 1296.8 million [2]. The current per capita GDP figure is Rs. 3197.21 and is projected to increase to Rs. 11599.7 by 2021 (unpublished data, TERI). The quantum of waste generated in the country is increasing day-by-day on account of its increasing population and increased GDP, though the civic services have not been expanding proportionately and hence are under tremendous pressure.

2. Waste transportation services

Municipal solid waste management is the responsibility of local governments in India. Transportation of waste is carried out by the municipalities employing vehicles like open trucks, tractor-trailers, tipper trucks, dumper trucks and animal-drawn carts (mostly in small towns and rural areas). The recent trend in big cities and towns is however, towards using container-carriers and dumper-placers, wherein the containers of the vehicles are themselves the community bins.

The volume of the waste to be transported is generally expressed in the terms of cubic meter per million of population. Calculations done on the basis of waste density, waste generated etc. indicate that on an average 320 m^3 of transportation capacity is required for daily transportation of waste generated by population of one million. However, a paper published in 1996 by Bhoyar et al. [3], wherein data of 44 Indian cities has been compiled and analyzed, indicates that 70% of these 44 cities do not have the 320 m^3/million transport capacity. This percentage might be still higher as the vehicular fleet of most of the cities is several years old and is off the road for a large proportion of the year for want of repairs.

3. Waste collection services

In the absence of modernization and automization of waste management services, its various components, i.e. collection, transportation and disposal, continue to be labour-intensive activities in India. About 80% of the total budget of all municipal corporations is accounted for by the salaries of sanitation workers engaged in road sweeping and related activities. A survey of 159 cities conducted by the National Institute of Urban Affairs (NIUA) in 1989 [4] revealed that the waste collection efficiency in these cities varied from 66% to 77% and the national average was a poor 72.5%, as compared to the developed countries where the waste collection is almost complete except for the most rural areas.

Waste collection efficiency is a function of two major factors; manpower availability and transport capacity. Less than 10% of the 157 cities surveyed in 1989 had more than 2800 workers/million population which is an accepted benchmark of optimum workforce requirement, by most of the municipal corporations in India. Data of Bhoyar paper [3] and the NIUA study [4] has been compiled in Table 1 to give a percentagewise breakdown of the cities for manpower shortfall and transport carrying capacity shortfall. Though, the cities perused in both the studies are not exactly similar and the data for both refers to different time periods, in the absence

Table 1
Statistics determining waste collection efficiency

Man power shortfall (% cities)	Man power shortfall[a] (% shortfall)	Transport volume shortfall (% cities)	Transport volume shortfall[b] (% shortfall)
56.1	>64.2	4.5	>68.7
25.2	46.4	34.1	53.1
11.0	10.7	29.6	21.8
7.7	+85.7	31.8	+34.3

Man power shortfall calculations are based on benchmark of 2800 workers/million population and [a] NIUA [4] survey of 155 cities.
Transport volume shortfall calculations are based on the figure of 320 m3 transport capacity requirement for one million population and [b] Bhoyar et al. [3].
The '+sign' indicates excess.

of any other data, when examined simultaneously the collection efficiency appears to be much lower than the national average figure of 72%.

4. Waste characteristics

The composition of waste depends on a wide range of factors such as food habits, cultural traditions, lifestyles, climate and income etc. The variations due to such factors are found across different countries as well as across different regions within one country. The inter-regional variations are, however, not as marked as those across the countries. Variation also occurs within a region over the years as a consequence of economic and social changes. India is no exception to this, and the data given in Table 2 clearly shows the changes in the composition of Indian MSW over a time period of about 25 years. The most remarkable change is in the

Table 2
Physico-chemical characteristics of Indian MSW

Component	Percentage on wet weight basis	
	1971–1973[a]	1995[b]
Paper	4.1	5.8
Plastics	0.7	3.9
Metals	0.5	1.9
Glass	0.4	2.1
Rags	3.8	3.5
Ash and fine earth	49.2	40.3
Total compostable matter	41.3	42.5

[a] Bhide and Sundaresan, 1983 [5].
[b] EPTRI, 1995 [6].

percentage of recyclables (plastic, metals etc.) which increased from 9.6% in 1971/73 [5] to 17.2% in 1995 [6] owing to changing lifestyles and the increasingly consummeristic attitude of the common man in the country. This increase has given rise to the phenomenon of ragpicking activity especially in the metro cities of the country wherein the recycling units have mushroomed on the peripheral areas providing employment to thousands of unskilled labor.

The organic matter has more or less remained the same, whereas ash and fine earth has decreased corresponding to the increase in recyclables. A shift in energy resources consumption from coal and wood to petrochemical-based products could be a plausible explanation for the ash and fine earth percentage decrease.

5. Recycling and reuse

Though the consumption levels in India are very low as compared to those in the developed world, the idea of reuse has always been there largely due to prevailing socioeconomic conditions and partly due to traditional practices. Segregating and selling old newspapers, magazines, books, empty bottles of glass and plastic, metal cans etc. has been prevalent in all the income groups for a very long time now. Till a few years ago the stress was on recover-reuse which, however, has lately shifted to recover-recycle. This change from reuse to recycle has been due to the changing life styles and attitude of people towards the kind of products they use. Use and discard culture is fast catching up with the Indian masses and this in turn has led to a spurt in especially plastic and paper waste and hence the growth of the recycling industry.

In the following few sections we have discussed paper and plastic consumption at length and have attempted at projecting their future consumption levels in India. This data, in the absence of any other kind of estimations regarding waste composition in coming years, will provide some indication about their expected levels in waste streams then. In case of paper, we have considered only the packaging paper as it is this category of paper which invariably finds its way to the waste bins in the end, but, if segregated at the source itself, could be the input material for paper recycling units.

5.1. Plastic

According to a primary survey done by the Tata Energy Research Institute in 1996 [7], plastic waste is in the range of 4–9% in households across different income levels in Indian society as compared to the figure of 0.7% reported for 1971 [5]. Some types of plastic wastes, e.g. bottles and jars, are segregated by the households and sold to itinerant waste buyers. Packaging waste, colored polythene bags, etc. are generally discarded along with household waste; the waste pickers salvage these and through a chain of several other middlemen, the salvaged waste reaches the plastic recycling units.

The plastic industry is raw-material-intensive and raw material accounts for about 70% of the total production cost, thereby implying a wide scope for plastic recycling to develop and expand, saving scarce and valuable petro-based virgin raw material reserves of the country in the process.

The production and consumption of plastics have witnessed a quantum leap during the last ten years. Though consumption of plastics increased by more than 10 times between 1986 and 1995, still the current consumption figure of 1.8 kg/capita per annum is very low compared to the world average of 18.0 kg/capita per annum and developed world average of 80 kg/capita per annum [8]. India recycles about 40% to 80% of its plastic waste compared to 10–15% in the developed nations of the world [9]. A survey conducted by National Council for Applied Economic Research in 1988–89 for Indian Petrochemicals Limited showed that about 2000 plastic recycling units in the country have a production output of about 323210 tonnes which was 37.2% of the total thermoplastics available in the country including imports [10]. These units, though beset with the grave environmental problems because of outdated technology, poor raw material quality and absence of governmental support, are extensive and manufacture products spanning slipper straps to automobile tyres.

A logistic function of the form expressed below has been used to estimate the per capita plastic consumption figures for India in the coming years:

$$Y_t = Y_{max.}/(1 + e^{a - bt})$$

where: Y_t is consumption level at time t; $Y_{max.}$ is saturation point for consumption for the time series considered; a and b are parameters, determined econometrically.

The logistic function assumes that the growth rate is not linear rather, it increases slowly in the initial stages, accelerates exponentially in the middle phase and then decreases before stabilizing. In this case $Y_{max.}$ is 18 kg, which represents the world average, and 80 kg, the average for the developed countries being too high has not been considered. The year of saturation for India has been set at 2047 mainly because this paper is a part of a larger study Green India-2047 [1] in which all the future estimates have been done till 2047 to mark 100 years of India's independence.

The projected estimates as calculated are illustrated in Fig. 1. The country will reach 10.9 kg/ capita consumption figure in 2021 which seems a realistic figure considering the rapidity with which plastics are replacing other kinds of material in virtually every field today. High durability, material strength, economic viability and easy processibility have enabled plastics to replace the traditional packaging materials in the world of consumer goods as well in construction, agriculture and telecommunications.

The above estimates for plastics are probably on the conservative side. Statistics available from the plastic industry indicate that the consumption of plastics will increase from the present figure of 1.8 million tonnes to 3.5 million tonnes by AD 2000. This would mean a per capita consumption of 3.5 kg in AD 2000, which is 20% higher than the projected figure of 2.9 in 2001.

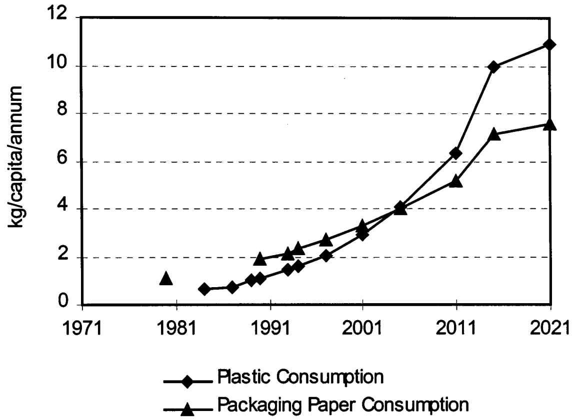

Fig. 1. Per capita consumption of Paper and Plastic—Past and Future Trends.

Packaging constitutes 52% of the plastic consumption today according to a report [11] released by National Plastic Waste Management Task Force in August this year. After reaching the consumer, this packaging which comes to 0.93 million tonnes quanta is discarded along with the household waste for disposal. Ragpickers salvage a sizeable portion of this packaging waste, but a lot more of this, being soiled with the organic matter, is not fit for recycling and is left in the waste bins.

5.2. Paper

In recent years, shortage of raw material, high capital investments, large energy requirements and environmental problems have all contributed towards shifting the focus from wood-pulp-based paper production to agricultural-residue and waste paper-based production of paper. Such papers accounted for 62% of the paper production capacity in 1995 as compared to 35% in 1985 (Fig. 2).

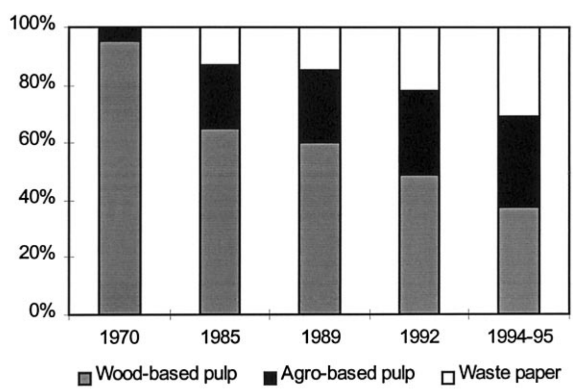

Fig. 2. Raw Material Input in Paper Manufacture. Source. IPMA, 1996 [12]; Rao, 1989 [13]; Khanolkar, 1995 [14]; JCPI, 1996 [15].

The mills based on wastepaper prefer to use imported wastepaper because of its better quality in terms of fibre strength and also due to inadequate domestic supply owing to the unorganized collection of waste paper within the country. The yield from each tonne of imported wastepaper can be as high as 0.9 tonne, which is considerably higher than the figure for 0.4 for agro-pulp and 0.5 tonne for wood pulp-based paper. Also, using wastepaper consumes only 40% of the energy required for a process based on other raw materials. This difference in consumption of energy is due to the less energy-intensive pulping stage of the production process based on wastepaper.

India's average waste paper utilization rate for 1990/91 was about 29% [16] as compared to the global average of 36%. The recovery rate was 14% of the total paper consumption in the same year. The global recovery rate was, however, much higher at 37%.

Given the current stress on liberalization and industrial growth, paper consumption is going to rise in the near future. At present, the per capita consumption figures in India is 3.6 kg [12] which is very low as compared to the world average of 45.6 kg. The consumption levels are estimated to reach 5.0 kg in 2000/01 and 6.0 kg in 2005/06 [12]. Further, the demand will be more for the packaging paper, which has been continually increasing over the past years as revealed by statistics available. This trend towards higher consumption of packaging paper is also evident from the increasing share of paper in MSW. A study done by TERI [7] showed that about 6–10% of the household waste consists of paper which, due to the absence of waste segregating practices goes to landfill sites, to be dumped along with all other kinds of waste. However, a small percentage of this which can be recycled and has not been soiled by kitchen waste, is recovered by the vast network of ragpickers operating mainly in large towns and cities. It is important to note here that in addition to the above 6–10% of waste paper, old newspapers, magazines and books segregated and sold by households to itinerant waste buyers is also recycled.

The percentage of wastepaper is going to be much higher in future as paper consumption itself increases. However, to keep pace with demand, one would need to recover and reuse/recycle paper considering the likely shortage of paper. Since it is largely the packaging paper, which is not segregated by the households and finds its way to the waste bin to be disposed by municipal authorities, only packaging paper has been considered for projections. A logistic function similar to one used for plastic consumption projections has been used. $Y_{max.}$ is 17.1 kg which is the consumption of packaging and industrial paper in the United States [17]. The US is taken to represent the saturation level because it is at a higher developmental level and represents a highly consumption oriented society.

Projections indicate that the per capita consumption in 2021 will be 7.6 kg (Fig. 1), and as a consequence of this, the total packaging paper generated will be approximately 10.2 million tonnes. This implies that there will be a nearly fourfold increase in the quantity of packaging paper found in waste streams over the current levels, which is not even 1% of the total waste generated today.

Talking about paper as a whole, the major driving forces for consumption in future are going to be the growing literacy (it is a well-established fact that paper consumption increases with an increase in literacy levels), communication and information dissemination, and packaging. However, it is not necessary that the paper supply would commensurate with the demand, shortage of raw material and restrictions on foreign exchange for import being the constraining factors. In addition to these two limiting factors, considering the ongoing replacement of paper packaging by plastic and the rapid advances being made in information technology which would promote communication and information dissemination by electronic media instead of printed material, paper consumption and in turn its percentage in waste might not be as high as per the projections.

In addition, paper and plastic, glass and metals are also found in Indian MSW, and are recovered and recycled, but we have not considered those in this paper because of their lower percentage share in the waste and lack of data availability.

6. Present and future rates of waste generation

6.1. Methodology

In the absence of adequate past data on waste generation rates, it was extremely difficult to decide upon the methodology to make any kind of projections for the future. Hardly any primary survey studies have been conducted in the country which indicate the actual waste quantum generated. As a result, except for two data points for the years 1971 [18] and 1995 [6], there is no data available on the basis of which any future projections could be made. The methodologies used in arriving at the figures might be different as the sources for both are different and no details are available regarding the methodology. Nevertheless, considering the acute paucity of data, the same have been utilized to initially calculate the per capita GDP elasticity of waste generation which comes out to be 0.35. Assuming that the elasticity is going to remain the same in the next 26 years, the percentage increase per capita waste generation has been calculated. The per capita GDP projections were taken from unpublished data from TERI. These were then used to calculate the total waste generation quantum for the urban India.

Simultaneously, calculations have been done using the per capita increase rate of 1.33% as suggested by NEERI [3] on the basis of studies carried out by it in Calcutta in 1970. This rate was also calculated by correlating to GDP and although this rate might not be valid 27 years hence, nevertheless in the absence of any other kind of rates the same has been used.

6.2. Results

Fig. 3 illustrates the estimates of waste quantum for period from 1971–2021. The figure shows that if GDP elasticity to waste calculations are considered, then in 2021 the total waste quantity generated should be expected to be about 140 million

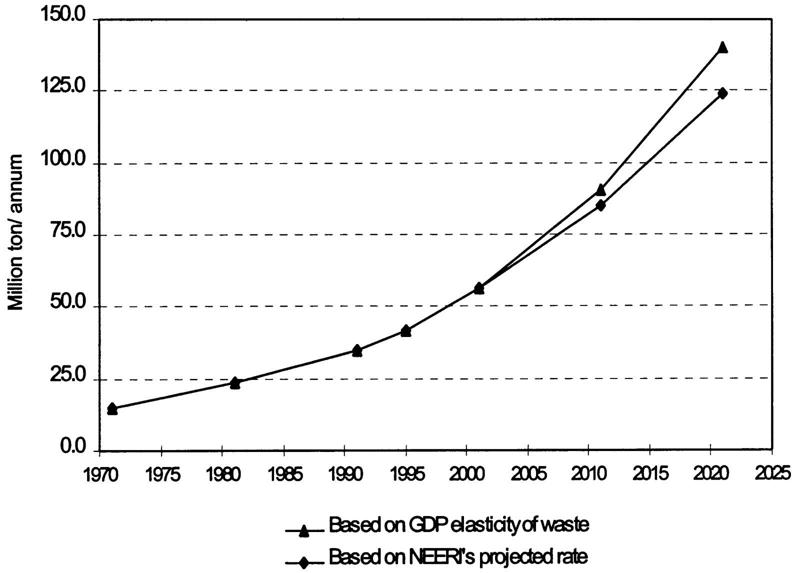

Fig. 3. Urban Municipal Waste Quantums.

tonnes, whereas it is 124 million tonnes if NEERI rate is considered. The 124 million tonne figure seems more appropriate as the elasticity cannot actually remain constant throughout. Considering that the elasticity normally decreases with the increase in GDP for necessity items, if the same is assumed for waste generation rate then the actual waste quanta figure will be lesser than 140 Mt. As there is no other figure available except the NEERI based one, this looks more approachable for the coming years. In the forthcoming sections, wherever calculations have been made using the waste quanta figures, the lower bound conservative estimates of NEERI have been used.

A study done in 1978 by Maung [19] for the United Nations Industrial Development Organization on municipal waste composting projects states that in the developing countries, an annual increase in waste production can be estimated as the sum of an increase in population growth rate and increase in per capita waste production, which commensurate with the per capita increase in Gross National Product (GNP). GNP projections (unpublished data, TERI) for India tell us that the GNP will increase at the rate of about 5.4% in the coming years, thereby implying that per capita waste generation rate will also increase by the same percentage. Further, the population projections estimate the urban population to grow at the rate of 1.3% [1]. Thus, the total waste in the coming years should increase at the rate of almost 6.7% which means that the waste quanta generated in 2021 will be approximately 225 million tonnes which seems highly improbable for a developing country like India.

It is important to mention here that the above projections are national aggregates; local figures on MSW also depend upon food habits of people, their standard of living and the degree of commercial and industrial activity in the area.

7. Waste disposal practices

In majority of urban centers in India, MSW is disposed by depositing the same in low-lying areas outside the city. Compaction and levelling of waste and a final covering by earth are rarely observed practices at most of these disposal sites. These low-lying disposal sites, being devoid of a leachate collection system, landfill gas monitoring and collection equipment, can hardly be called sanitary landfills and are more in the nature of dumping sites. Nearly all the Indian cities dispose of their waste by simple dumping and only about 9% practice the environment friendly way of disposal, namely composting (Table 3).

The Indian municipal waste can be broadly categorized into organic waste, recyclables and ash and fine earth. Of these three, the organic waste component has remained constant over the past many years at approximately 40% and is not expected to change much in absolute terms in the near future. However, the ratio between the other two components has changed in past years (Table 1) and is expected to change further, with the shift occurring in favor of recyclables. At the moment, the country has no policy on segregation of recyclables and hence these too, are dumped along with the organic waste.

7.1. Future land requirement for waste disposal

7.1.1. Methodology

In the absence of any kind of changes in collection services provision, the collection efficiency of waste can be safely presumed to be the same as calculated in NIUA report [4], for land requirement projections, though in actual, as mentioned in previous sections we believe the figure to be a grossly exaggerated one. Further, assuming the average depth of an Indian landfill site as 4 m and waste density as 0.9 tonne/m^3 at the landfill site, Table 4 gives the figures for land required for disposal of municipal waste for the next 20 years assuming a business-as-usual scenario (BAU).

Scenario 1 has been constructed assuming that the waste collection efficiency will increase to more than 90% in the coming years, which would also increase the pressure on land. However, if modifications are done to increase the landfill depth from the present average of 4 m to 9–10 m, the land requirement will actually decrease (Scenario 2).

Table 3
Waste disposal trends in India

Waste disposal method	1971 (40 cities)[a]	1991 (23 cities)[b]
Land dumping	Almost all	89.8
Composting	—	8.6
Others (pelletization, vermicomposting)	—	1.6

[a] Nath, 1984 [20]
[b] EPTRI, 1995 [6].

Table 4
Future land (cumulative) requirement for MSW disposal; various scenarios

Land (sq. km)	1997	2001	2011	2021
BAU	195.4	237.4	379.6	590.1
Scenario 1	204.3	256.7	434.5	697.6
Scenario 2	197.8	221.1	300.2	417.1
Scenario 3	197.3	218.3	289.4	394.7
Scenario 4	194.7	204.1	235.7	282.5

The coming years should presumably bring some change in the management system of garbage by our corporations and if 50% of the recyclable component is separated and sent to recycling units, the land requirement would drop further (Scenario 3). Scenario 4 gives the minimum unavoidable land required for disposal of only the ash and fine earth component typical of Indian MSW. The figures reflect the land requirement when all the recyclables are sent to recycling units and the entire organic matter is composted.

7.1.2. Results

The BAU indicates that if the total waste generated in the country in 1997 is stacked to the height of 1.7 m (an average man's height), it would occupy more than 3300 football grounds. Till the end of year 1997, if the land which has been occupied in the last 50 years is considered the number of football grounds comes to a mind-boggling 71000.

For increased collection efficiency of more than 90% (Scenario 1) the municipal corporations will have to invest in such infra structural facilities as community bins at proper distances, vehicles to transport the waste and manpower. The number of football grounds in this case will be 93000 by 2001.

It would be more worthwhile to adopt a scientific waste disposal system in addition to adequate collection system for complete management of waste. Landfills being the prime way of waste disposal in India, these need to be designed with leachate collection and gas monitoring and collection system. The first step towards ensuring reduced land for waste disposal could be to increase the landfill depth to 9–10 m. This in addition would ensure that proper anaerobiosis takes place and the methane generated is large enough to be subsequently collected and used. This will generate additional revenue, with the added advantage of greenhouse gas (methane) abatement. (Scenario 2) gives the land requirement for the next few years using this assumption. The cumulative land (beginning from 1947) figures indicate that in 2021 these would be something like almost the entire Greater Bombay, dug up to a depth of 9 m.

Approximately, 40% of Indian MSW consists of biodegradable organic matter which can be composted either aerobically or anaerobically. Another 18% comprises of recyclables such as paper, plastic and glass. Assuming that this fraction recyclables is segregated from the municipal waste before being transported to the disposal site, the remaining 40% is grit and rubble, which is safe enough either to be land filled or utilized by the corporations for other purposes. Scenario 4 gives the land requirement figures for disposal of this 40% fraction. An area as large as about three and a half times the size of the city of Greater Bombay could be filled to an average man's height with waste in 2021 as compared to five times area in case the recyclables and organic matter are also dumped (alternatively Scenario 2 conditions).

Keeping in mind the current acute shortage of land and the rising land prices, it will not be an easy task for the municipal authorities to acquire land for waste disposal in the coming future. In addition, the common man today is far more aware of the hazards associated with a landfill site and the corporations will not find it easy to persuade the public to permit locating the sites near their dwellings.

7.2. Global warming

7.2.1. Methodology

In India landfill emissions are the third largest contributors to global warming. The landfill gas is 50–60% methane, which is a greenhouse gas contributing significantly to global warming. Emissions have been calculated using the Bingemer and Crutzen approach [21], which assumes that 50% of the carbon emissions in the landfills is transformed into methane.

However, use of sophisticated gas control measures such as actively-pumped gas extraction wells can result in exploitation of this landfill gas as a fuel, thereby complementing the objectives of environmental protection and, at the same time, providing an additional revenue stream and reducing the use of fossil fuels. Calculations have been done to estimate the amount of coal that can be saved if the landfill gas is used as a replacement fuel in kilns and boilers.

7.2.2. Results

Table 5 gives the estimates of methane emissions from landfill sites. By the end of 1997, the landfills would have contributed 6.8 Gg of methane into the atmosphere and had this been collected and utilized for its thermal value energy equivalent to 11.6 million tonnes of coal worth 4.6 billion rupees could have been saved. This saving has been calculated at the pit head before any kind of tax is

Table 5
Methane emission potential from landfill sites

Year	Methane emissions (Gg/a)	Coal energy equivalent (million tonnes)	Monetary savings due to methan emission utilisation[a] (Billion rupees)
1997	6.8	11.6	4.63
2001	8.3	14.1	5.63
2011	12.5	21.3	8.51
2021	18.3	31.0	12.42

[a] At pithead cost price.

levied by the government. The savings for 2021 amount to 12.4 billion rupees worth of coal if the investments are made in the years before.

The landfill gas can also be utilized for power generation. Power plants working on landfills are in use in many developed countries but a beginning has yet to be made in India.

Since, sanitary landfills are expensive to maintain, health and environmental safety should be the overriding factors and not the energy gain. Misplaced emphasis on energy aspects of landfill gas utilization could possibly complicate the landfill construction program.

Talking about the associated health and environmental safety, indiscriminate land filling leads to serious damages in terms of deteriorated quality of water in neighborhood areas of landfill sites due to leachate percolation, adverse health impacts on people living nearby, bad odors and the constant fear of an explosion of methane gas emitted from landfill sites.

7.3. Air pollution

We have assumed the average waste collection efficiency in the country to be 72%, and need to account for the remaining 28%. A substantial proportion of waste is scavenged by the ragpickers before it is collected by the municipal authorities for recyclables like paper, plastic and glass. Also, a little portion of the organic matter is eaten away by the stray animals, cows, pigs and dogs. Since waste collection services in India are not as they ought to be, to get rid of the waste, in some cases the corporation employees burn the waste. According to a study report [22] released by the World Bank in October 1996, refuse burning is one of the major causes contributing to the deteriorating air quality in Bombay. The emissions of total suspended particulate matter have been estimated to be roughly the same from refuse burning as from the vehicle exhaust [22]. About 25% of total annual PM_{10} and 13% of total annual TSP emissions in 1992/93 in the city were due to burning of refuse at homes and at dump sites [22]. Methodology of this study has been used to calculate pollution loadings due to waste burning for the whole of India.

7.3.1. Methodology

Since little data is available on the actual amount of waste burnt in households, we assumed a value of 1 kg a week for each household. In the absence of any projections of average household size, we also assumed the current household size of 5.5 [23] to remain same in the coming years. The amount of garbage burnt comes to approximately 5% of total generation which seems to be a reasonable estimate. TSP and PM_{10} loads have been calculated using the emission factor of 37 g/kg based on WHO 1993 [24] and NILU experiments [25].

7.3.2. Results

The annual emissions of TSP and PM_{10} for current year as well as for years till 2021 are given in Table 6.

Table 6
Annual air emissions due to open domestic waste burning ('000 tta)

Year	TSP	PM_{10}
1997	94.6	94.6
2001	109.1	109.1
2005	122.4	122.4
2011	144.5	144.5
2015	159.6	159.6
2021	184.7	184.7

The PM_{10} emissions are more damaging to health than TSP because PM_{10} particulates are easily inhaled. The inhaled particles can lead to chronic bronchitis, restricted activity days, respiratory diseases and asthma. It is difficult to draw an alternative scenario for this as no data are available. However, one can say that the above particulate emissions can be controlled if the waste collection efficiency is increased from the present 72% to more than 95% and also if the general public is made aware of the issue and the harmful impacts of this practice.

8. Conclusions

The municipal corporations being the responsible authority in India for SWM in addition to a wide range of responsibilities related to health and sanitation, have not been very effective as far as SWM services are concerned. Collection, transportation and disposal—all the three components of waste lack in terms of infrastructure, maintenance and upgradation. However, the weakest link in the chain of waste management in Indian situation is the collection of waste.

Proper segregation of waste into different components and their separate collection can definitely lead to remarkable changes in the entire system. One of the immediate measures to revamp the existing collection services structure would involve provision of community waste bins at proper distances for the people to deposit domestic waste. This as the first step will ensure that people do not throw their garbage on the roads and hence do not create open dumpsites. This will enable the sanitation workers to transfer the waste to the transportation vehicle quickly and efficiently with minimum health risk involved and will also help in maintaining the aesthetics of surroundings.

The second measure should entail at the source—separation of waste into biodegradable and non-biodegradable components. This would be a long drawn exercise as it involves attitudinal changes in people and will have to be done with careful planning, in a phased manner. The general public will have to be first sensitized towards the whole concept and educated about the need and advantages of doing the segregation. Segregation of waste at the source itself is extremely important as municipal solid waste, which is otherwise environmentally benign on getting mixed with hazardous waste like paints, dyes, batteries, human excrete turns hazardous. The recyclables like paper and plastic etc. becomes unsuitable for recycling as these get soiled by the organic matter. Although, it would be more fruitful to sort and place the different kind of recyclables in different receptacles however to begin with the waste could be segregated into just two categories.

Proper segregation would lead to better options and opportunities for scientific disposal of waste. The recyclables could be straightway transported to recycling units which in turn would pay certain amount to the corporations, thereby adding to their income. This would help in formalizing the existing informal set up of recycling units and this formalization in turn could lead to multi-advantages. To mention a few—enabling technology upgradation, better quality products and saving of valuable raw material resources of country. In addition, a dialogue with the consumer's industry should be undertaken to impress upon them the need for life-cycle assessment of goods manufactured and to reduce the packaging material content associated with every final product.

The biodegradable matter could be disposed off either by aerobic composting, anaerobic digestion or sanitary land filling. Depending upon land availability and financial resources either of these disposal methods could be adopted. However, it appears that in this context land filling would continue to be the most widely adopted practice in India in the coming few years, in which case certain improvements will have to be done to ensure that it is sanitary land filling and not merely dumping of waste. The contribution to global warming due to landfill gas release in the atmosphere can be abated if the disposal sites are designed and constructed with the gas collection equipment installations. This will have the dual advantage of minimum greenhouse emissions and also income generation if the gas generated is utilized either directly as a thermal fuel or by conversion into electricity. However, this is a long term measure and needs to be incorporated at the stage when a disposal site is being designed. The hazard of groundwater pollution due to leachate percolation, noise pollution etc. can all be minimized by good land filling practices.

Aerobic composting is a fast catching option for waste disposal and a beginning in it has already been made. The first aerobic composting plant of the country was set up in Bombay in 1992 to handle 500 tonnes of waste per day by a private company. However, only 300 tonnes/day capacity is being utilized currently due to certain problems but the plant is working very successfully and the compost produced is being sold off at the rate of 2 rupees/kg. Another plant of 150 tonnes/day capacity has been operating in the city of Vijaywada for about a year now. A similar plant is expected to become operational in the garden city of Bangalore by year end. Calcutta, Thane, Chandigarh, Gwalior, Solan and Delhi too, are towing the same line and have either signed agreements or are in the process of doing so to have the composting facilities very soon. Composting has an edge over sanitary landfilling as it does away with the emission and leachate problems and the end product which is good quality compost can be sold off.

Anaerobic digestion, though expensive as compared to sanitary landfilling and aerobic composting too, holds a good promise as a future disposal option. It however needs more research and experimentation before being adopted on a large scale.

Incineration is yet another option available for waste disposal. The low calorific value range of 800-110 Kcal/kg of Indian MSW, however rules out the incineration option for it. Also, the existing trend all over the world is to move away from incineration and India too, can safely opt out of this option except for certain kinds of hazardous waste like hospital waste.

The options and opportunities are many, it is upto the corporations to select and adopt the ones most suitable to them. Constituting a nodal body at the level of Ministry of Urban Affairs with the power of framing guidelines and standards and issuing notifications could come a long way in assisting corporations in their work. This nodal body could also build up and maintain a central database which would contain detailed information about the infra structural, financial and administrative details of all the municipal corporations and councillors in the country. Another very good idea for an overall improvement in waste management services could be privatization of one of the aspects of waste management. Once the private sector takes over the certain share of corporations work, the corporations could probably spend and concentrate more on the rest in terms of financial and administrative resources.

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