Municipal Solid Waste Management in India-Current State and Future Challenges: A Review

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Abstract

Estimation on the quantity and characteristics of municipal solid waste and its forecasting over the planning period is the key to a successful management plan. This study analyses the changing trend in the MSW quantities and characteristics in major urban agglomerations in India over last four decades. The study critically reviews the present practices of estimating and forecasting of MSW and highlights their limitations. The changing need for the appropriate waste management technologies with respect to the changing pattern of the waste generation is also highlighted, which can help the urban local bodies responsible for MSW management in preparing more efficient plans.

Key Words: Municipal solid waste; Projections; Paper; Plastic.

1. Introduction

Due to population growth, industrialization, urbanization and economic growth, a trend of significant increase in municipal solid waste (MSW) generation has been recorded worldwide. MSW generation, in terms of kg/capita/day, has shown a positive correlation with economic development at world scale. Due to rapid industrial growth and migration of people from villages to cities, the urban population is increasing rapidly. Waste generation has been observed to increase annually in proportion to the rise in population and urbanization. The per capita generation of MSW has also increased tremendously with improved life style and social status of the populations in urban centres [1]. As more land is needed for the ultimate disposal of these solid wastes, issues related to disposal have become highly challenging [2].

India, with a population of over 1.21 billion account for 17.5% of the world population (Census of India 2011). According to the provisional figures of Census of India 2011, 377 million people live in the urban areas of the country. This is 31.16 % of the Country's total population. Figure 1 illustrates that the growth of urban population is at a much faster rate than the growth of rural population. India has 475 Urban Agglomerations (UA), three of which has population over 10 million. Table 1 gives the top five UAs in terms of population. The very high rate of urbanisation coupled with improper planning and poor financial condition has made MSW management in Indian cities a herculean task.

Table-1

Cities	Population
Greater Mumbai UA	18.4 Millions
Delhi UA	16.3 Millions
Kolkata UA	14.1 Millions
Chennai UA	8.7 Millions
Bangalore UA	8.5 Millions

Source: censusindia.gov.in/2011-Documents/UAs-Cities-Rv.ppt

Generally in India, MSW is disposed of in low-lying areas without taking proper precautions or operational controls. Therefore, municipal solid waste management (MSWM) is one of the major environmental problems of Indian megacities. SWM involves activities associated with generation, storage and collection, transfer and transport, treatment and disposal of solid wastes. But, in most Indian cities, the MSWM system comprises only four activities, i.e., waste generation, collection, transportation, and disposal. Poor collection and inadequate transportation causes the accumulation of MSW at every nook and corner. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amounts of MSW generated daily in metropolitan cities. Adverse impact on all components of the environment and human health occurs due to unscientific disposal of MSW [3-7]. The MSW amount is expected to increase significantly in the near future as India strives to attain an industrialized nation status by the year 2020 [8-10].
MSW management encompasses planning, engineering, organization, administration, financial and legal aspects of activities associated with generation, storage, collection, transport, processing and disposal in an environmentally compatible manner adopting principles of economy, aesthetics, energy-conservation and opportunities. The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. This becomes increasingly expensive and complex due to the continuous and unplanned growth of urban centres. The difficulties in providing the desired level of public service in the urban centres are often attributed to the poor financial status of the managing municipal corporations [11-13]. In the present study, an attempt has been made to provide a comprehensive review of the trend of the MSW components during last four decades and also the forecasted MSW components trend, in India, to evaluate the current and projected future status for identifying the problems of MSWM in major Indian cities.

2. MSW Quantity

The quantity of MSW generated depends on a number of factors such as food habits, standard of living, degree of commercial activities and seasons. Data on quantity variation and generation are useful in planning for collection and disposal systems. Indian cities now generate eight times more MSW than they did in 1947 because of increasing urbanization and changing life styles [14]. The rate of increase of MSW generated per capita is estimated at 1 to 1.33% annually [15-16]. MSW generation rates in small towns are lower than those of metro cities, and the per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/ day. It was also estimated that the total MSW generated by 217 million people living in urban areas was 23.86 million t/yr in 1991, and more than 39 million ton in 2001 [18-22]. The Central Pollution Control Board (CPCB) had conducted a survey of solid waste management in 299 cities and has given the data (Table-2) of waste generation for different cities.

Table-2

S. No.	Name of the State	No. of cities	Municipal population	Municipal solid waste (t/day)	Per capita generated (kg/day
1	Andhra Pradesh	32	10,845,907	3943	0.364
2	Assam	4	878,310	196	0.223
3	Bihar	17	5,278,361	1479	0.280
4	Gujarat	21	8,443,962	3805	0.451
5	Haryana	12	2,254,353	623	0.276
6	Himachal	1	82,054	35	0.427
7	Karnataka	21	8,283,498	3118	0.376
8	Kerala	146	3107358	1220	0.393
9	Madhya Pradesh	23	7225833	2286	0.316
10	Maharashtra	27	22727186	8589	0.378
11	Manipur	1	198535	40	0.201
12	Meghalaya	1	223366	35	0.157
13	Mizoram	1	155240	46	0.296
14	Orissa	7	1766021	646	0.366
15	Punjab	10	3209903	1001	0.312
16	Rajasthan	14	4979301	1768	0.355
17	Tamil Nadu	25	10745773	5021	0.467
18	Tripura	1	157358	33	0.210
19	Uttar Pradesh	41	14480479	5515	0.381
20	West Bengal	23	13943445	4475	0.321
21	Chandigarh	1	504094	200	0.397
22	Delhi	1	8419084	4000	0.475
23	Pondicherry	1	203065	60	0.295
		299	128113865	48134	0.376

Source: Status of MSW generation, collection, treatment and disposal in class-I cities [23]

Table-3: Per Capita Quantity of Municipal Solid Waste in Indian Cities

SN	Population	Waste Generation Rate Kg/capita/day
1	Cities with a population < 0.1 million (8 cities)	0.17-0.54
2	Cities with a population of 0.1–0.5 million (11 cities)	0.22-0.59
3	Cities with a population of 1–2 million (16 cities)	0.19-0.53
4	Cities with a population > 2 million (13 cities)	0.22-0.62

Source:[24]

Table-3 suggest the per capita quantity of municipal solid waste in Indian cities. It also suggests that average municipal solid waste production from 0.21 to 0.50 Kg per capita per day in India. The urban population of India is approx. 341 million in 2010. Fig.-1 suggest the projected MSW quantities are expected to increase from 34 million tonnes in 2000 to 83.8 million tonnes in 2015 and 221 million tonnes in 2030.It is also reported that per capita per day production will increase to 1.032 kg, and urban population as 586 million in 2030.

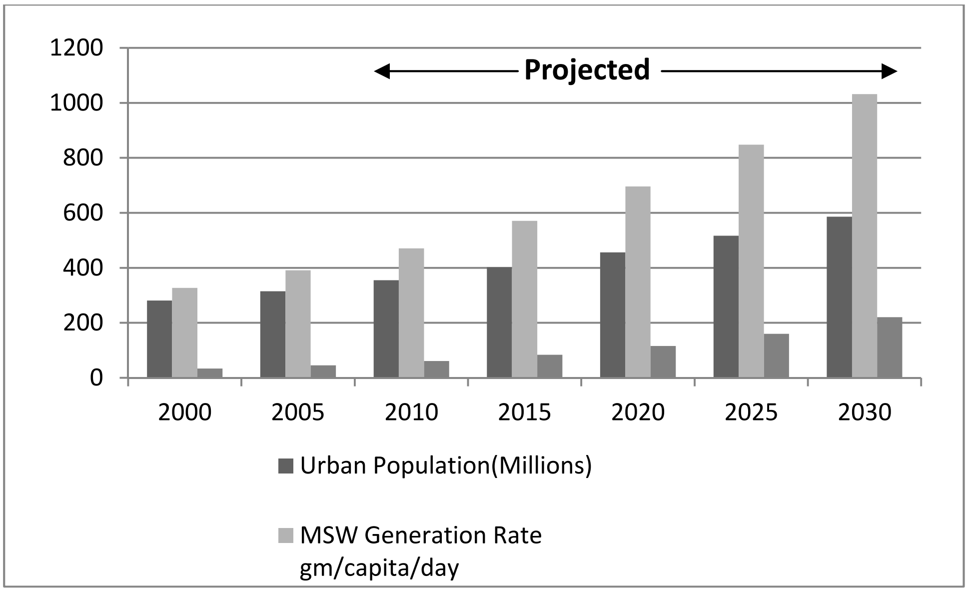


Figure 1: Projected Municipal Waste Generations for Urban Population in India

Source: Information from web site of CPCB

2.1 MSWM and Economy

There is generally a correlation between the amount of municipal waste and the Gross Domestic Product (GDP) of the country. Higher the GDP of a country, higher is the quantity of waste produced. Such relationship is illustrated in Fig.2. A number of studies have revealed the strong correlation between solid waste composition and socioeconomic factors [25-26]. Over the decades, the socioeconomic conditions in India have been fast changing. For example per capita income of India has changed from US$ 17.22 to US$ 253.78 and GDP from US$ 9382.67 million to US$ 238504.7 million during 1971–1995 [27].

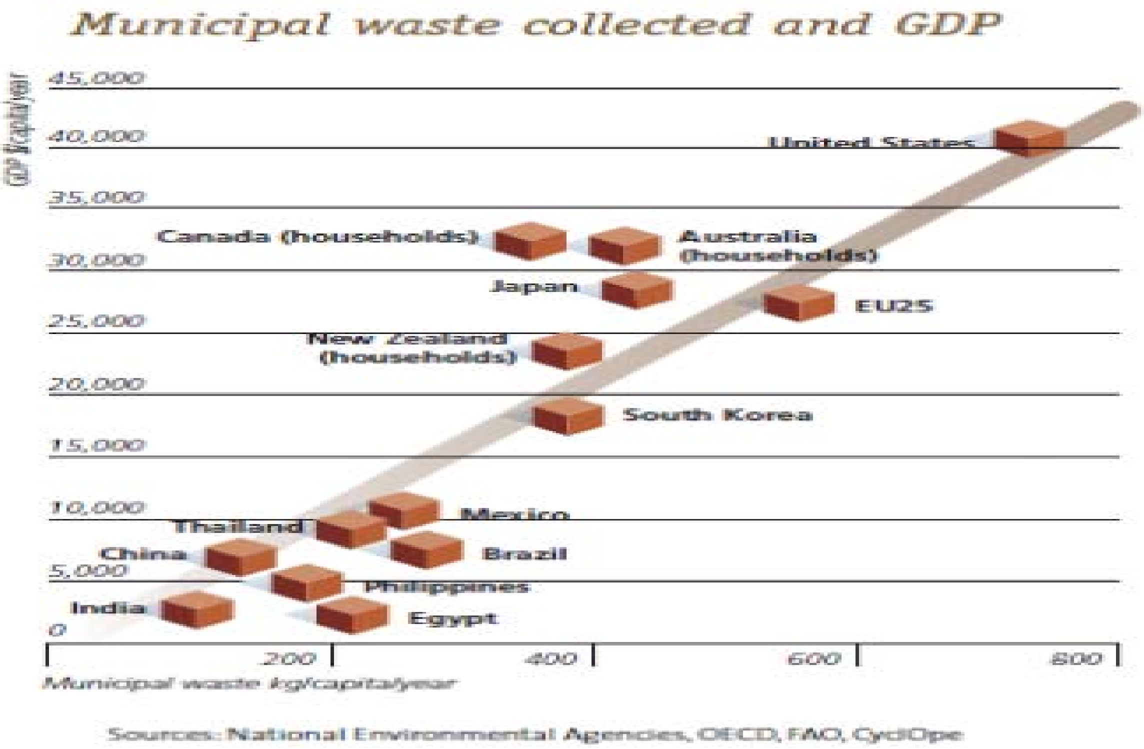


Figure 2 [28]

Studies have indicated that for every Indian Rs. 1000 increase in income the solid waste generation increases by one kilogram per month [29]. The growth of GDP for every decade since 1960 is given in Fig-3 which suggests that Indian GDP growing rapidly during last few decades

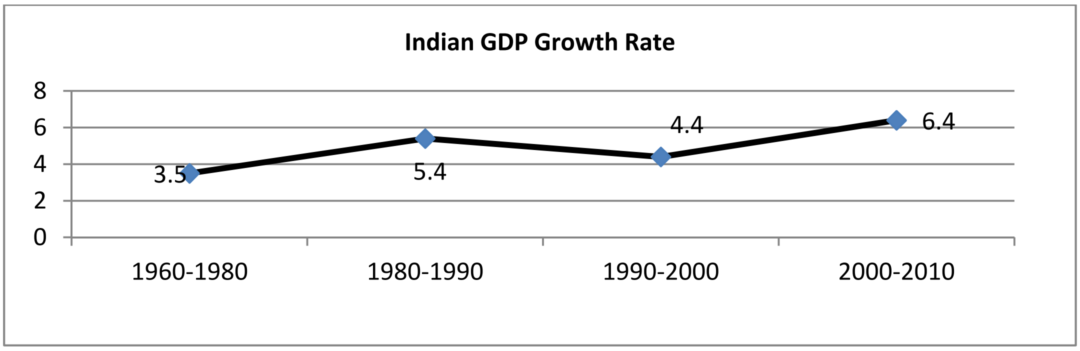


Figure 3

On the basis of per capita income in year 2000-2001 in India, the states can be divided as shown in Table 4.

Table 4

Per Capita Income (Rs)	City or States
Less than Rs 15,000	Low Income
Rs 15,000-30,000	Medium Income
Above Rs 30,000	High Income

Source: [30]

In low-income group of cities municipal bodies dispose MSW in low lying areas in the outskirt of the city and fill these areas one after the other haphazardly due to limited knowledge and awareness regarding contamination, waste reduction techniques and other aspects of MSW management [14]. Although MSW generation rate is high in states of the high income, they are well equipped and have well-surveyed mass and material flow data from cradle to crest, which are sometimes unavailable for low-income states.

The quantity of average MSW generated [22] and the average generation rate of MSW for low, medium and high (per capita) income states from Table 2 are combined together in Fig. 4, which suggest that solid waste generation depends on the economy of the people and per capita generation increases with the level of income of the family or individual. The quantity of MSW (T/d) and per capita generation rate is high in high (per capita) income states (Delhi) in comparison to medium (Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh) and low (per capita) income states(Uttar Pradesh, Madhya Pradesh, Bihar, Manipur) in India. This may be due to the high living standards, the rapid economic growth and the high level of urbanization in comparatively high (per capita) income states.

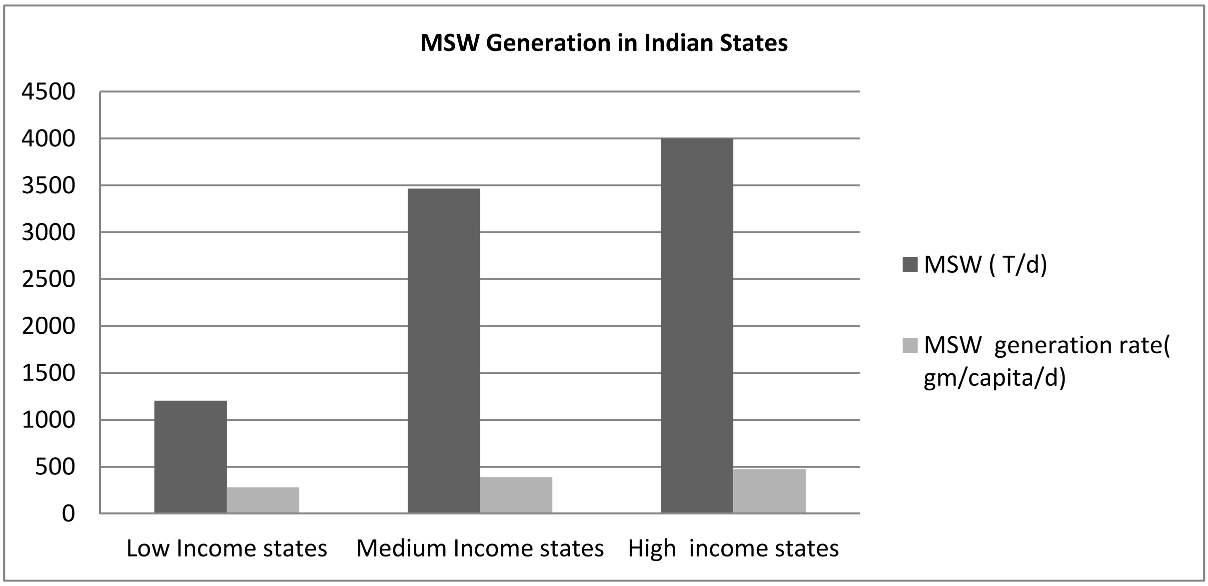


Figure 4

3. Characteristics and composition of MSW

As compare to the western countries, MSW differs greatly with regard to the composition and hazardous nature, in India [31-33].Many categories of MSW are found such as food waste, rubbish, commercial waste, institutional waste, street sweeping waste, industrial waste, construction and demolition waste, and sanitation waste. MSW contains compostable organic matter (fruit and vegetable peels, food waste), recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), and soiled waste (blood stained cotton, sanitary napkins, disposable syringes) [34-35]. MSW composition at generation sources and collection points ,determined on a wet weight basis, consists mainly of a large organic fraction (40–60%), ash and fine earth (30–40%), paper (3–6%) and plastic, glass and metals (each less than 1%). The C/N ratio ranges between 20 and 30, and the lower calorific value ranges between 800 and 1000 kcal/kg [14].

3.1 Compositional Changes Reported for India since 1971

Changes in the average composition of municipal solid waste for 1971-2005 have been shown in Fig.-5 [31, 36-37]. It suggest that MSW components like Paper, Plastic, Glass are having the increasing trend from 4.1%, 0.7% and 0.4% respectively in 1971 to 8.18%, 9.22% and 1.01 respectively in 2005, metals are also having the increasing trend during the same period while inert materials and compostable matter are having the decreasing trend from 49.2% and 41.3% respectively in 1971 to 25.16% and 40% in 2005. Increasing trend suggest that the establishment of the formal recovery and recycle facilities will be economically a viable option.

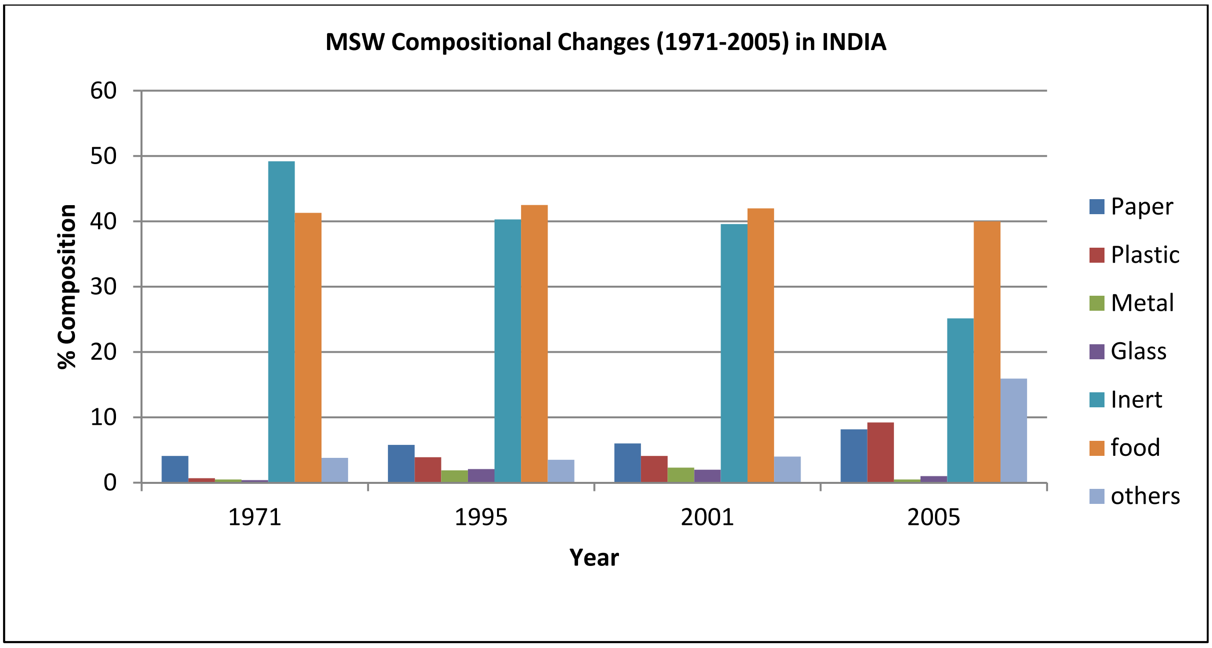


Figure 5

As countries develop economically and become more urbanized, the waste composition undergoes a change as the increase in the paper, paper packaging, plastics, multi material packing items and 'consumer products and decrease in the organic share.

3.2 MSW Compositional changes of Four Mega Cities in India:

Population of Mumbai increased from 8.2 million in 1981, to 12.3 million in 1991, a growth of 49%. However MSW generated, increased from 3.2 to 5.35 Gg per day during the same period, recording a growth of 67% [34]. In Chennai, the population increase was about 21% between 1991 and 2001, while waste generation increased by 61% from 1996 to 2002 [34]. This indicates the rapid increase in municipal waste generation in the Indian mega-cities outpacing the population growth. In Mumbai (Figure 6), Delhi (Figure 7) and Chennai (Figure 8) the compostable matter has a decreasing trend while in Kolkata (Figure 9), it has a slightly increasing trend [34]. Inert material has a decreasing trend in all four mega cities. Plastic and paper are showing the increasing trends in all four mega cities during 1971-2001.

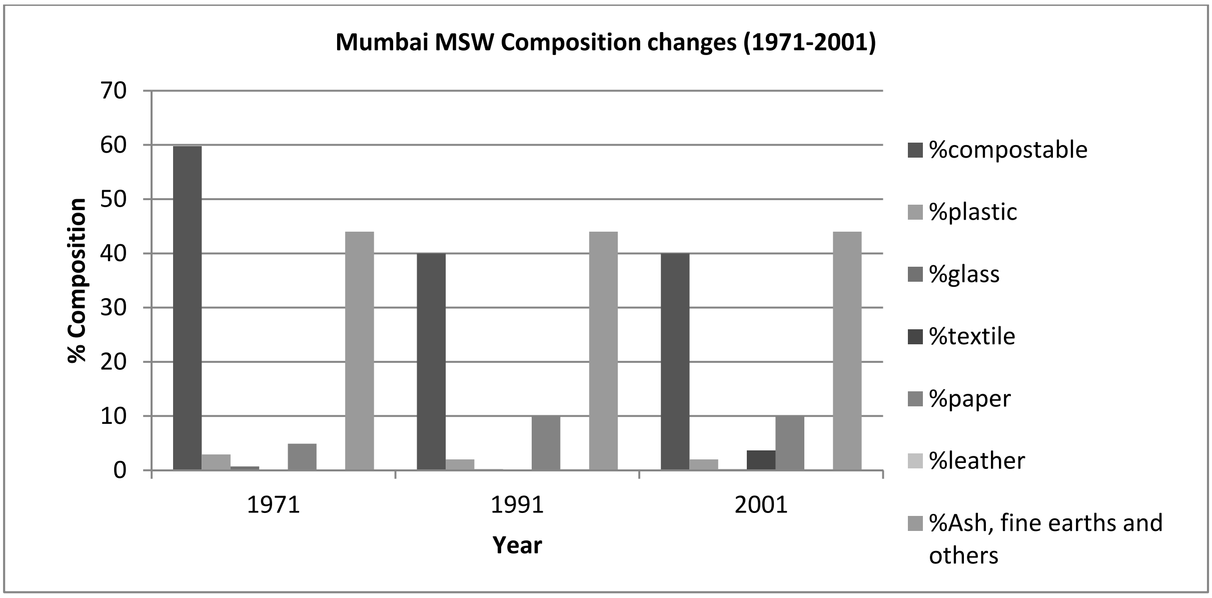
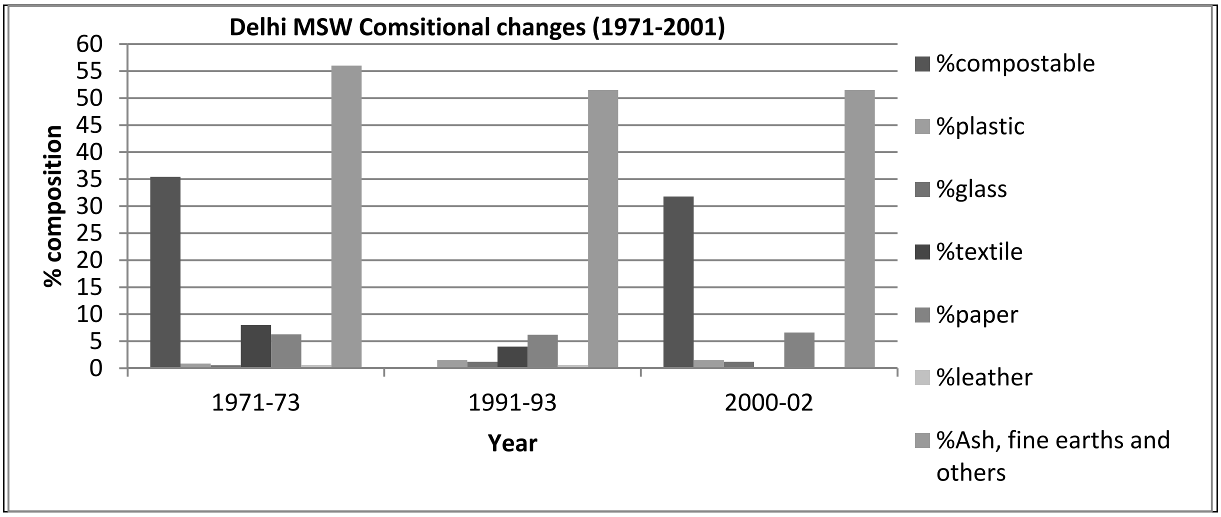


Figure 6



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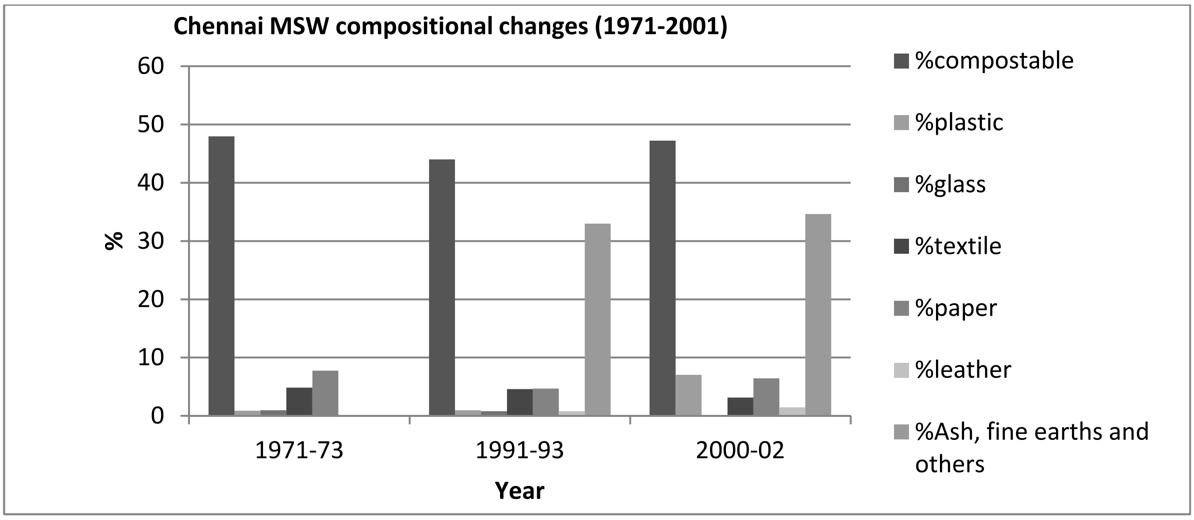

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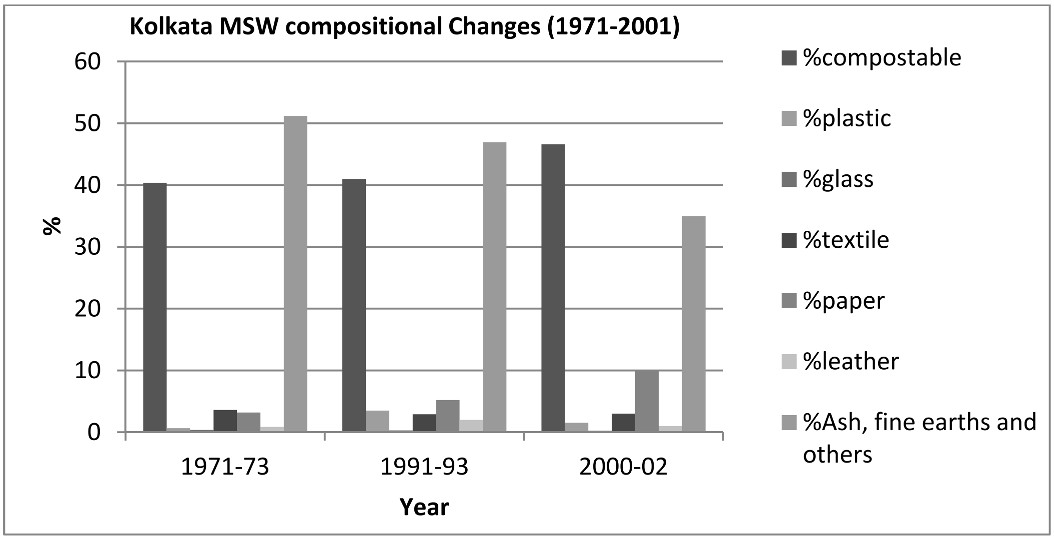

Figure 9

A compositional change on the basis of income of people in low, medium and high income cities has been shown in Figure 10. It suggest that as country gets richer, the organic share decreases whereas the paper and plastic increases.

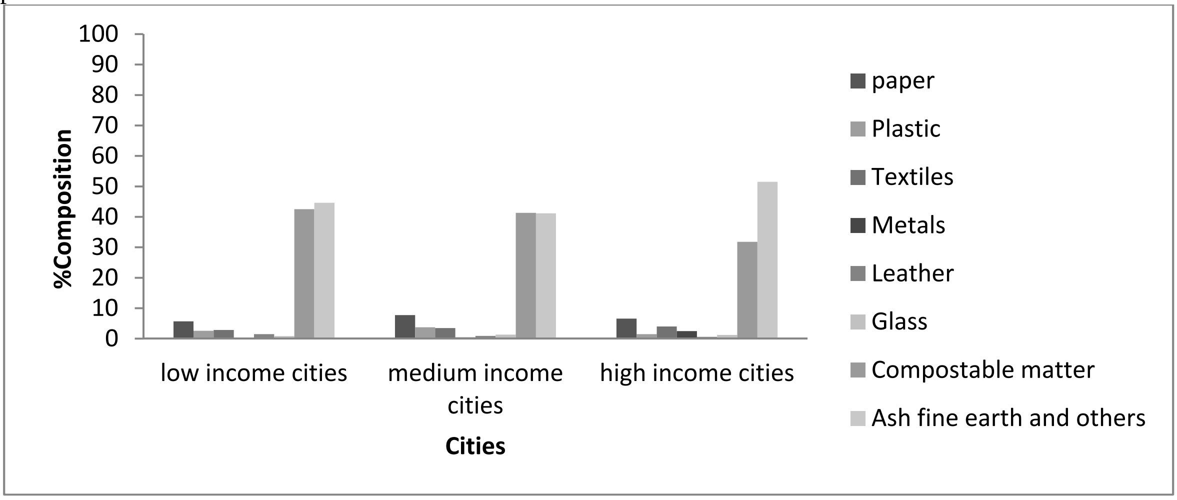

Figure 10

4. Collections and Storage of MSW

In India most of the urban areas are lacking in MSW storage at the source, significantly. For both decomposable and non-decomposable waste common bins are used to collect the waste without any segregation, and disposed off at a community disposal centre. Two types of storage bins are used- movable bins and fixed bins. The fixed bins are more durable but their positions cannot be changed once they have been constructed, while the movable bins are flexible in transportation but lacking in durability [38-39].Collection of MSW is the responsibility of corporations/municipalities. In most of the cities the predominant system of collection (through the communal bins) at various points along the roads, and sometimes this leads to the creation of unauthorized open collection points. House-to-house collection is just starting in many megacities such as Delhi, Mumbai, Bangalore, Madras and Hyderabad with the help of NGOs. Some urban areas are using the welfare associations, on specified monthly payment, to arrange collection. Private contractors for secondary transportation from the communal bins or collection points to the disposal sites, have been employed by many municipalities while other have employed NGOs and citizen's committees to supervise segregation and collection from the generation source to collection points located at intermediate points between sources and dumpsites. The average collection efficiency for MSW in Indian cities and states is about 72%, which shows that the collection efficiency is high in the states, where private contractors and NGOs are employed for the collection and transportation of MSW. Most of the states are unable to provide waste collection services to all cities. [5, 31, 38, 40-41].

In low-income states MSW collection and disposal services are very poor. In these states many practices are often illegal and the people are unwilling or unable to pay for the services. Citizens throw away the waste near or around their houses at different times. It makes the collection and transportation of waste very difficult. The Central Pollution Control Board (CPCB) has found that manual collection comprises 50%, while collection using trucks comprises only 49% [23], in a survey of 299 class-I cities in India.

5. Treatments and Disposal of MSW

India is facing the lacking of resources or the technical expertise necessary to deal with the disposal of MSW. The disposal method trend adopted in India has been shown in Fig. 11[42]. For the years 2001 and 2005, waste dumps or open burning continue to be the principal method of waste disposal. These methods causes several accidents are continuous source of emission of harmful gases and highly toxic liquid leachate.

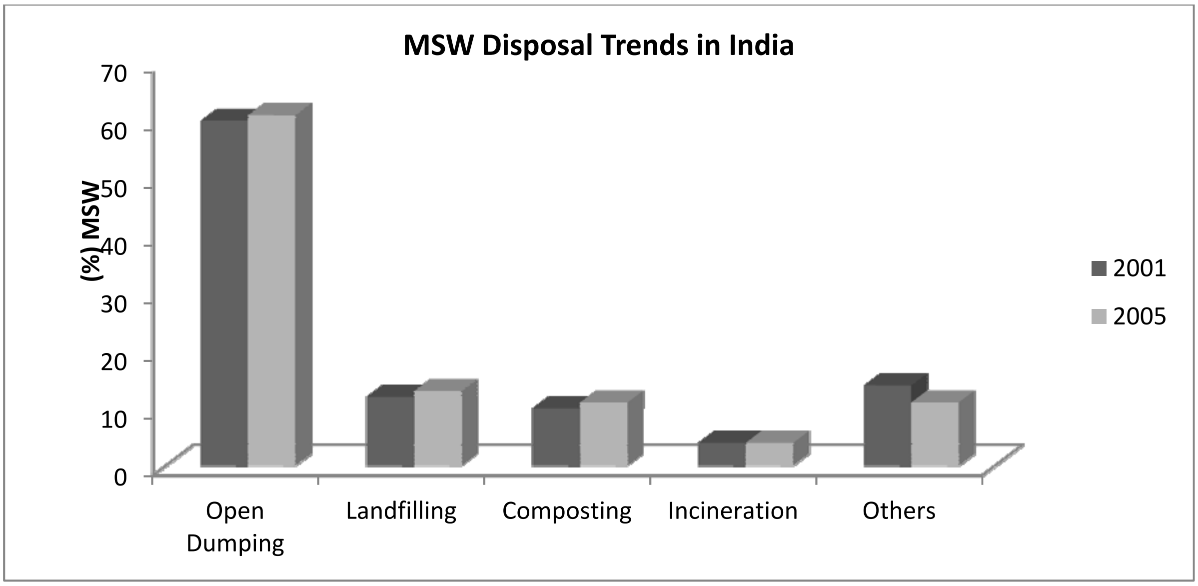

Figure 11

5.1 Composting

Composting has a long tradition particularly in rural India [43].Composting is difficult process because the waste arrives in a mixed form and contains a lot of non-organic material. When mixed waste is composted, the end product is of poor quality. The presence of plastic objects in the waste stream is especially problematic, since these materials do not get recycled or have a secondary market. In the absence of segregation, even the best waste management system or plant will be rendered useless. The first large-scale aerobic composting plant in the country was set up in Mumbai in 1992 to handle 500 t/ day of MSW by Excel Industries Ltd. However, only 300 t/ day capacity is being utilized currently due to certain problems, but the plant is working very successfully and the compost produced is being sold at the rate of 2 Rs. /kg. Another plant with 150 t/day capacity has been operated in the city of Vijaywada, and over the years a number of other plants have been implemented in the principal cities of the country such as Delhi, Bangalore, Ahmadabad, Hyderabad, Bhopal, Lucknow and Gwalior. Many other cities have either signed agreements or are in the process of doing so, to have composting facilities very soon. In India, composting is used around 10-12% because composting needs segregation of waste and sorting is not widely practiced [35, 44].

5.2 Incineration

In India the incineration is a poor option as the waste consists mainly high organic material (40–60%) and high inert content (30–50%) also low calorific value content (800–1100 kcal/kg), high moisture content (40–60%) in MSW and the high costs of setting up and running the plants [18]. The first large-scale MSW incineration plant was constructed at Timarpur, New Delhi in 1987 with a capacity of 300 t/day and a cost of Rs. 250 million (US$5.7 million) by Miljotecknik volunteer, Denmark. The plant was out of operation after 6 month and the Municipal Corporation of Delhi was forced to shut down the plant due to its poor performance. Small incinerators, in many cities in India, are being used for burning hospital waste however [7, 21, 45].

5.3 Gasification Technology

Gasification is the solid waste incineration under oxygen deficient conditions, to produce fuel gas. In India, there are very few gasifiers in operation, but they are mostly for burning of biomass such as agro-residues, sawmill dust, and forest wastes. Gasification can also be used for MSW treatment after drying, removing the inert and shredding for size reduction. In India one gasification unit installed at Gaul Pahari campus, New Delhi by Tata Energy Research Institute (TERI) and other is installed at Nohar, Hanungarh, Rajasthan by Narvreet Energy Research and Information (NERI) for the burning of agro-wastes, sawmill dust, and forest wastes. The waste-feeding rate is about 50–150 kg/h and its efficiency about 70–80%. About 25% of the fuel gas produced may be recycled back into the system to support the gasification process, and the remaining is recovered and used for power generation [9].

5.4 Refuse Derived Fuel (RFD) Plants

It produces an improved solid fuel or pellets from MSW. The RDF plant reduces the pressure on landfills. Combustion of the RDF from MSW is technically sound and is capable of generating power. RDF may be fired along with the conventional fuels like coal without any ill effects for generating heat. Operation of the thermal treatment systems involves not only higher cost, but also a relatively higher degree of expertise. Many RDF plants are in operation in India, in Bangalore RFD plant was established and has had regular production of fuel pellets since October, 1989, compacting 50 t/day of garbage, converting into 5 t of fuel pellets, which can be designed both for industrial and domestic uses. The RDF plant at Deonar, Mumbai was set up in the early 1990s for processing garbage into fuel pellets. It is based on indigenous technology. However, the plant has not been in operation for the last few years and it is owned by Excel India at present. The Hyderabad RDF plant was commissioned in 1999 near the Golconda dumping ground with a 1000 t/day capacity (but receiving only 700 t/day at present).The RDF production is about 210 t/day as fluff and pellets, and it is going to be used for producing power (about 6.6 MW)[46].

5.5 Landfilling

A landfill is an area of land onto or into which waste is deposited. The aim is to avoid any contact between the waste and the surrounding environment, particularly the groundwater. In India open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation.60%- 90% of MSW in cities and towns are directly disposed of on land in an unsatisfactory manner. These methods are not in accordance with the practices of sanitary landfilling. The dumping is often done in low lying areas, which are prone to flooding, increasing the possibility of surface water contamination during the rainy season. The pollution of groundwater, though largely unassessed, is definitely a threat posed by the dumping of wastes. Such dumping activity in many coastal towns has led to heavy metals rapidly leaching into the coastal waters. The daily cover techniques are poor, which makes leakage easier. This is mainly because of a lack of knowledge and skill on the part of the local authorities. This forces local authorities to curtail the implementation of even known precautions and practices. However, it appears that landfilling would continue to be the most widely adopted practice in India in the coming few years, during which certain improvements will have to be made to ensure the sanitary landfilling, even though the major cities like Delhi, Mumbai, Kolkata and Chennai are facing the problem of the limited availability of land for waste disposal [44, 47].

5.6 Bioreactor Landfill

A further development in landfill technology is the bioreactor landfill. Bioreactor landfills are designed, constructed and operated to optimise moisture content and increase the rate of anaerobic biodegradation. The principal function that distinguishes bioreactor landfills from conventional landfills is leachate recirculation. The goal is to increase the rate of bio-degradation to achieve maximum gas generation rate and output so as to optimise recovery for energy production. This approach also aims to minimise the landfill stabilisation time and reduce the period of monitoring and liability retention. The bioreactor option is a direct result of engineering and building a new generation of environmentally sound landfills; it provides environmental security while permitting and encouraging rapid stabilization of the readily and moderately decomposable organic waste components [3].

6. Issues in MSW Management

6.1 Source Segregation, Collection

In India there is virtually no organized and scientifically planned source segregation except for industrial waste where due to organized nature of sector, segregation is sometimes practiced and for healthcare waste due to regulatory requirements. Sorting is mostly done by unorganized sector (scavengers and rag pickers) and rarely done by waste generators. Hence, the efficiency of segregation is quite low as the unorganized sector tends to segregate only those waste materials which have relatively higher economic return in the recycling market. The unsafe and hazardous conditions under which the segregation and sorting takes places are well known. The waste collection efficiency even in high income cities (i.e. Delhi) is rather low. Often a substantial amount of waste is left to rot on the streets and/or is dumped into low lying areas, canals, rivers etc. Several factors are responsible for such low collection efficiency; lack of appropriate collection systems, lack of and/or inadequate collection facilities such as waste disposal bins, collection vehicles etc., lack of funds, lack of and enforcement of appropriate regulations etc.

6.2 Treatment & Disposal

MSW is usually disposed as it is without any treatment. Most of MSW is still disposed off in dumps causing severe environmental and health risks. The progress in moving towards sanitary landfills and/or disposing through well designed and well operated incinerators is rather slow.

6.3 Resource Generation

Lot of materials can be recovered from waste for recycling which can then serve as an input for manufacturing. Of particular significance are cellulosic materials, plastic, metals and glass. Despite the absence of organized segregation systems, quite substantial amounts of clean plastics, cellulosic material, metals and glass are already recycled in India due to their increasing amount (Fig.5) which attracts economically. A large number of people ranging from rag pickers to primary dealers, secondary dealers and recycling industries earn their living out of waste recycling. In contrast, organic waste, which constitutes the largest proportion in the waste stream, is often disposed of rather than being segregated and converted into bio-gas, compost etc. Landfill gas is mostly unutilized. Only recently, some efforts have been started to recover energy from waste.

6.4 Policy Issues

A vigorous policy framework to give a direction and thrust to environmentally sound waste management does not exist in India. Policy measures to promote waste minimization, recycle and recovery are rather lean. No national targets have been set up to deal with overall issue of waste management in line with country's economic development programme. The environmental policies are 'discharge end control' based instead of shifting to 'source end control' based approach. The industrial policies continue to rely on manufacturing from virgin resources and a rational pricing mechanism and/or market based instruments to accelerate waste minimization and support greater use of recycled materials are not in place. Most of the current policies are in support of end-of-pipe approach creating huge burden on municipal authorities. There are no policies to promote segregation and reuse at source and conversion of waste into useful materials/energy .

6.5 Technology Issues

Launching targeted efforts for development/acquisition of technologies for material and energy recovery from waste is the need of the hour in India. To build confidence and test the application of such technologies in the context of developing countries pilot demonstration projects need to be established. This in turn will require extensive data collection on waste characterisation and quantification to facilitate assessment of recycling/recovery potential and design/development of technologies. Almost no effort seems to be taking place in this direction. Most of the work is focussed on augmenting waste collection and building disposal facilities.

6.6 Financing Issues

To support waste management one of the most pressing issues is the availability of funds. The local authorities are mostly in a dire financial situation and are barely able to maintain the basic jobs of waste collection and somehow dispose it. Municipal level waste management continues to be heavily subsidised by governments. Financing mechanisms to promote use of environmentally Sound Technologies, for technology development and demonstration are conspicuous by absence.

7. Future Challenges in MSW Management

A successful long term planning depends on the characteristics of the solid waste and estimation of future quantities. Decisions related to treatment choices and disposal options for solid waste management will get affected by the composition of solid waste in the future. Researchers have been reported for innovative and forward-looking solutions to address the issue of forecasting the quantities of municipal solid waste [48-52]. Although both planning and design of municipal solid waste management systems require accurate prediction of solid waste generation. Yet achieving the anticipated prediction accuracy with regard to the generation trends facing many fast-growing regions is quite challenging. A long time Forecast will be more meaningful if it gives the most optimistic, most pessimistic values and also the most likely values [53]. Most traditional statistical forecasting models, such as the geometry average method, saturation curve method, least-squares regression method, and the curve extension method, are designed based on the configuration of semi-empirical mathematical models. The structure of these models is simply an expression of cause-effect or an illustration of trend extension in order to verify the inherent systematic features that are recognized as related to the observed database.

Traditional forecasting methods for solid waste generation frequently count on the demographic and socioeconomic factors on a per-capita basis. The per-capita coefficients were taken as fixed over time or they may be projected to change with time. Grossman et al., (1974) [54] discussed such considerations by including the effects of population, income level, and the dwelling unit size in a linear regression model. The influence of per capita income, population density, persons per house, GDP and population on the composition of the solid waste using linear regression have been established by Khan and Burney (1989) [22]. For year 2025, using subjective judgment based on a single factor GDP of the nation, Gupta et al. (1998) [31] projected the quantity and characteristics of solid waste. However, the quantitative relationship between waste characteristics and GDP was not been established and a subjective judgement was used for prediction. Buenrostro et al. (2001) [55] reported relationship between solid waste composition and socioeconomic factors of community using expert judgements based on secondary data.

Dynamic properties in the process of solid waste generation cannot be fully characterized in those model formulations. Chang et al., (1993) [56] reported the econometric forecasting as one of the alternatives to static models, in which the future forecasts are derived from current forecasts of the independent variables themselves. It covers part of the dynamic features in forecasting analysis. When recycling impact is unparalleled, intervention analysis may account for the varying trends of solid waste generation under uncertainty [48]. The grey dynamic model was developed to resolve the data scarcity issue [57]. It is particularly designed for handling situations in which only limited data are available for forecasting practice and system environments are not well-defined or fully understood. Grey fuzzy dynamic model suitable for the situation when only very limited samples are available for forecasting practice, was demonstrated to handle the dynamic prediction analysis of municipal solid waste generation with reasonable accuracy by Chen and Chang, 2000 [50].

Dynamic MSW generation analysis has been done using time series data of solid waste generated quantities. Esbri J.N. et al., (2001) [58] proposed some tools for time series analysis and forecasting to study MSW generation. A prediction technique based on non-linear dynamics was proposed, comparing its performance with a seasonal Auto Regressive and Moving Average (ARIMA) methodology, dealing with short and medium term forecasting. Dyson B., et al., (2005) [59] presented a system dynamics modelling for the prediction of solid waste generation in a fast-growing urban area based on a set of limited samples. To address the impact on sustainable development city wide, the practical implementation was assessed by a case study in the city of San Antonio, Texas (USA). The analysis presents various trends of solid waste generation associated with five different solid waste generation models using a system dynamics simulation tool – Stella.

Srivastava et al., (2008) [52] reported using Fuzzy regression based approach for forecasting that the percentage of waste paper and food waste is expected to decrease from 29.50 to 24.58 and 36.37% to 27.55%, respectively, between years 2007 and 2024 for the solid waste composition of Delhi, India. On the other hand the waste plastic content is expected to increase from 2.74% to 3.55%. The most significant change is expected with respect to the percentage of metals and glass, which has been estimated to increase to triple and double, respectively. Srivastava et al., (2008) [52] also suggested that while planning the capacities of the solid waste management facilities, maximum possible values should be taken into account, whereas the economic viability of recycle/recovery and compost facilities should be evaluated based on the minimum possible values also the forecasting results signify the importance of controlling the calorific value of the waste so that it should not fall below the rated calorific value of incinerator. The trend of various components (%) of the municipal solid waste in Delhi can be identified from the available and projected data between years 1971 and 2024 (Fig. 12).It can be seen that inert materials and compostable matter are decreasing from 56% to 38.61% and 35.42% to 24.28% respectively while paper, glass and plastic showing increasing trend from 6.29% to 26.66%, 0.57% to 16.53 % and 0.85% to 5.48 % respectively. Kumar et al. (2011) [60] attempted to estimate the quantity of municipal solid waste that can be generated as 39,670 MT per year in municipal cooperation of ELURU city A.P, INDIA by 2026 considering four input variables Population, MSW generated, percentage of urban population of the nation and GDP per capita of the nation in the artificial neural network model.

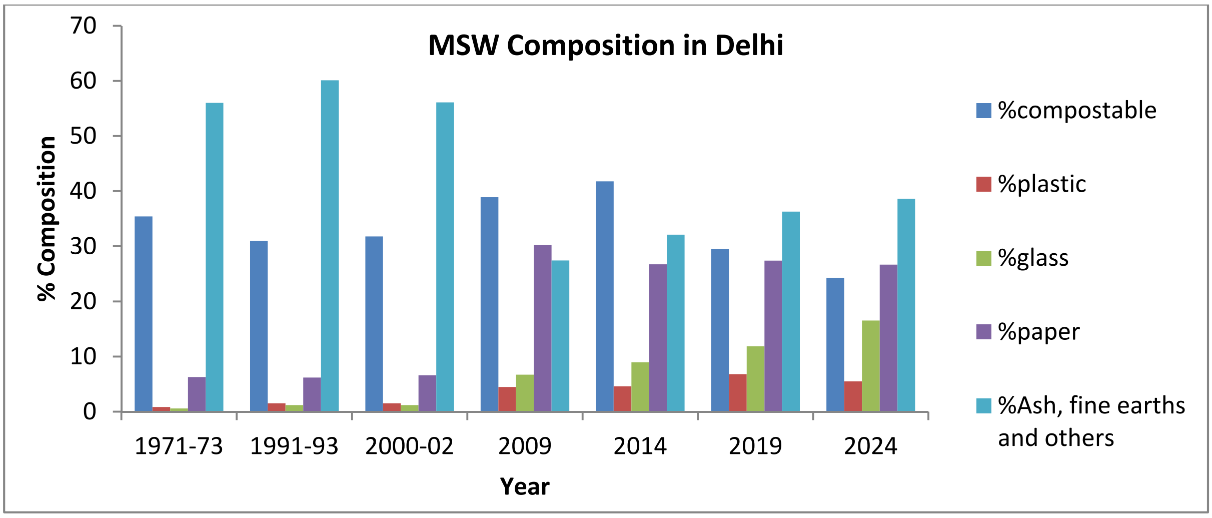

Figure 12

In India some of the future challenges for the management of solid waste are:

7.1 Increasing quantities and changing composition

Due to growth in population, changing lifestyles and consumption patterns, not only the quantity of waste generated is further increasing but quality and composition of waste is also changing particularly more and more hazardous and toxic waste is being generated both because of industrialization as well as end-of-life products. A noticeable change in composition is observed that as the standards of living improve the proportion of paper and plastics increases – in many developing countries it has doubled in one decade.

7.2 Increasing severity of adverse impacts

The negative impacts of wastes on the local environment (air, water, land, human health etc.) are becoming more acute often resulting in public outcries and demands for action. The impacts of inadequate waste management are not just limited to local level but are now crossing boundaries and due cases like methane emission are even affecting global environment. More and more water bodies (both surface waters as well as ground waters) are getting contaminated. The land under and around waste dumps are heavily polluted and will require tremendous efforts and resources for rejuvenation.

7.3 Increasing cost of waste management

Cost of waste management is increasing on several accounts. Firstly, because of the increase in quantity of waste being generated. Secondly, the changing composition of waste with increasing content of non-biodegradable and hazardous substances requires increasing complexity and sophistication in waste management techniques and technologies. Finally, with increasing environmental and health awareness the demands on safe and environmentally sound waste management require more careful and extensive waste management.

7.4 Limited policy framework

As already mentioned, national and local policies on waste management are not yet comprehensive to, cover all types of waste, and all aspects of waste management in India. Policy framework to support resource recovery from waste is still inadequate in India.

7.5 Lack of political priority

In India, waste management loses out to other political priorities of health, education, infrastructure development, job creation, poverty eradication etc. The realization that waste management could be supportive of these issues is often not there.

While these challenges may appear difficult to overcome and may dampen the required initiatives, in today's context, waste management also offers some exciting opportunities.

8. Opportunities from Waste Management

8.1 Waste minimization or waste reduction at source is increasingly being realized as a component for enhancing competitiveness. Many industrial firms make a special effort to minimize generation of waste so as not only to reduce their waste treatment and disposal costs but also improve their resource efficiency. However, small and medium sized industry experience difficulties in systematically integrating waste minimization actions into their overall management practices– largely as consequence of their time, expertise and money constraints.

8.2 Due to increasing energy and material costs, recovery of materials and energy from waste is becoming more and more economically viable. A whole new range of industrial sector can be developed based on recycling waste materials. The Government of Gujarat in India is already contemplating an idea of establishing a ‘Recycling industry park’. Apart from being free from the vagaries of price fluctuations and limitations in availability of virgin raw materials, recycling industries will also benefit from a cheap and perennial supply of input materials.

8.3 The current waste management cost can be reduced by designing the waste management systems, scientifically with focus on 3R .The volume of ‘residual waste’ after recovery / recycle of materials can be drastically reduced thus cutting down treatment and disposal costs. In studies conducted by UNEP it has been demonstrated that by adopting the Integrated Solid Waste Management approach the residual waste requiring disposal can be easily brought down to just 30-40%. In case the residual waste is sent to landfill, this would also mean that the life of existing landfills will be appreciably increased. Earnings from recovered materials and resources can further ease the budget requirements for waste management.

8.4 Recovering energy from waste can become an excellent source of renewable energy. Conversion of organic waste into useful materials (e.g. compost) and/or energy can apart from affecting a significant reduction in waste quantity can provide cheap and renewable energy. Other waste components which are not easily amenable to recycling (such as dirty plastic and paper) can also be converted into fuel, of course with due care for combustion related emissions.

8.5 The private sector is getting increasingly involved in waste management so it is not just a service to be provided by the government. In many cities the entire range of waste management services – collection, transportation, treatment and disposal are now provided by private sector. There is a huge potential for engaging private sector not only in recycling industry but also in establishing industry based on recycled material as input materials. This can have a snowballing effect in terms of directing private finances, job creation and industrial promotion. The beneficial environmental aspects in terms of reduced extraction of non-renewable resources are obvious.

8.6 Empowerment of the poor and employment generation are the major demands in developing countries. Waste management with focus on segregation and recycling can serve the twin objective of creating employment opportunities for the poor and thus enabling them to improve their life styles. It can be treated as a business opportunity with a good potential for job creation.

9. Summary

In this paper, an attempt has been made to study the changing trends of quantity and characteristics of MSW to find its impact on the performance and capacity planning of recovery/recycle, compost, incineration and landfill facilities. The changing pattern of waste composition emphasises the importance of segregation for successful operation of waste management facilities. Municipal authorities should maintain the storage facilities in such a manner that they do not create unhygienic and unsanitary conditions.

A new survey should be carried out on the generation and characterization of MSW in India. Since the MSW is heterogeneous in nature, a large number of samples have to be collected and analyzed to obtain statistically reliable results.

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