

Avenues of Collection and Disposal of Municipal Solid Wastes Management in India -A Review

Pradip Kumar¹, Rajendra Kumar Kaushal²

¹M.Tech. Student, ²Assistant Professor at Bundelkhand Institute of Engineering and Technology (BIET), Jhansi, Uttar Pradesh (UP), India

¹pradip86kumar@gmail.com Tel: +918574747681, ²rajendra.kaushal02@gmail.com, Tel: +919721880550

Abstract- Solid waste management is the one thing about each and every city government provides for its residents. Solid waste management is arguably the most important municipal service while service levels, environmental impacts and costs vary in a very dramatically manner. As the cities hurtle towards its urban future, the amount of municipal solid waste is growing even faster than the rate of urbanization. Municipal solid waste management has become an acute problem as consequence of enhanced economic activities and rapid urbanization. Due to high moisture and organic nutrient rich solid waste provide renewable biogas as predicted with high methane potential and organic manure. The aim of this review is to determine the most environment friendly option of MSW management system.

Key Words: Energy recovery, Life cycle assessment, composting, Material recovery facility, and MSW

1-INTRODUCTION

Rapid industrialisation, population explosion, urbanisation and economic growth in India led to the migration of rural people to cities, a trend of significant increase in municipal solid waste generation has been recorded around the whole country. Solid waste generation is a natural phenomenon of human life [1]. Municipal solid waste generation shows a positive correlation with the economic growth of people in terms of kg/capita/day as a consequence of improved life style and social status [2].

From the past decades per capita solid waste generation increased from 250-350 gm/day to 320-530 gm/day in mid-seventies and late eighties respectively [3]. In India, it is estimated that the rate of increase of solid waste generation is 1 to 1.5 % annually [4,5]. Due to the enormous increase in solid waste generation, cumulative requirement of land for solid waste disposal is about 1400 km² by 2047 in India [6], which imposes pressure on nation, issues of sustainable disposal of these solid waste generated have become highly challenging [7]. India as a growing country has population of

1.21 billion accounts for 17.5% of the total world population (Census of India 2011) out of these population 377 million people belongs to urban area, which is 31.16% of the Country's total population.

At present, Solid waste management has become eve to each city as it is a complex and multidisciplinary environmental problem that must be considered from technical, economic, environmental and social aspects on a sustainability basis. To sustain a healthy and good environment, both municipal and industrial waste must be managed according to the solid waste management hierarchy i.e. prevention, minimization, recovery, incineration and landfilling. For this purpose, latest management technique can be used. Life cycle assessment analyses the environmental aspects and potential impact throughout waste life cradle to grave from raw material acquisition through production, use, and disposal [5]. One of the most municipal solid waste management techniques is agriculture application of municipal solid waste as it is rich in nutrient sources for plants and as soil conditioner and also meets the challenge of land requirement [9]. Due to presence of heavy metals, organic pollutants and pathogens agriculture application of municipal solid waste may pose a potential threat to environment. Application of municipal solid waste as compost in agriculture fields can improve soil physical-chemical properties i.e. soil structure, water retention capacity, buffering capacity and nutrient status [10]. Among all solid waste management strategies composting is gaining interest as a suitable alternate for chemical fertilizers with environmental profit as this process eliminate or decreases the toxicity of municipal solid waste [11, 12, 13]. The current municipal solid waste management system has different alternative

as reported earlier. The material recovery facility is being the most prominent method among other methods such as source reduction, reuse, recycling, composting, incineration, energy recovery, on-site burial, open burning and bioremediation, as it reduces the amount of fresh raw material resources for production [14].

2-COMPOSITION OF SOLID WASTE

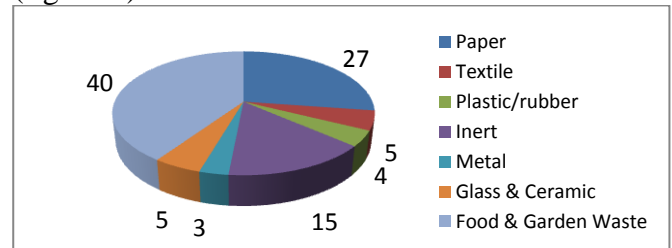
The municipal solid waste composition is influenced by many factors such as culture, economic development, climate and energy sources. Although waste composition, usually provided by weight, impacts how often waste is collected and disposed off especially with regard to collection: organics and inert generally decreases in relative terms, while increasing paper and plastic increases overall waste volumes. The municipal solid waste is broadly classified into organic and inorganic, however six categories i.e. organic, paper, plastic, glass, metals and others (table-1), are usually sufficient for general purpose solid waste planning. Construction and demolition (C & D), and industrial, commercial and institutional (ICI) waste become important components that need further refinement. In some cities construction and demolition represent as much as 40% of the total waste produced. Most of the solid waste management plans, industrial by products are not included in waste composition analysis, while household and general waste may be included since it is usually disposed at common facilities. Generally, low and middle-income cities have a high percentage of organic matter in the solid waste ranging from 40 to 60% of the total while paper (3 to 6%), earth material (30 to 40%) and plastic, glass, and metal fractions (<1%) increases in the waste produced [15].

Type	Sources
Organic	Food scraps, yard (leaves, grass, and brush) waste, wood, process residues.
Paper	Paper scraps, cardboard, newspaper, magazine, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cup. Strictly speaking papering

	organic but unless it is contained by food residue, paper is not classified as organic.
Plastic	Bottles, packing, containers, bags, lids, cups.
Glass	Bottles, broken glassware, light bulbs, coloured glass.
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railing.
Other	Textiles, leather, rubber, multi-laminates, e-waste, appliances, ash, other inert materials

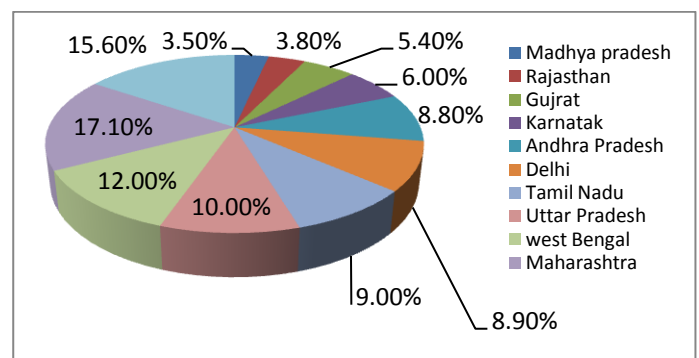
* World Bank publication/Urban Development & Local Government Unit

There are many sources through which solid waste are generated, some of these are bio-medical waste, industrial waste, residential population, commercial establishments, public and private institutions and agriculture waste of heterogeneous in nature [1]. The average proportion reaching a disposal site given by CPHEEO is shown in figure-1 and contribution of state in solid waste generation (figure-2).



(Figure-1) Composition of municipal solid waste

* CPHEEO Manual on MSW, 2005.



(Figure-2) Share of States and Union Territories in urban MSW Generation
 *[48] Earth Engineering centre at Columbia University.

3-MUNCIPAL SOLID WASTE QUANTITY

The quantities of municipal solid waste generation rate are greatly influenced by economic

development, the degree of industrialization, public habits, and local climate. Due to higher economic development income level enhance, as income level and urbanization are highly correlated and as disposable income and living standards increase, consumption of good and services consequently increases, as does the amount of waste generated. In India, the present solid waste generation is approximately 48 million tons per year and this figure seems to exceed to 300 million tons per year by the year 2047 and also shows a growth of per capita solid waste generation from 490 gm. per capita to 945 gm. per capita respectively. Such enormous increase of solid waste generation poses land requirement of 169.6 km² for disposal in 2047 as against 20.2 km² in 1997 (CPCB 2000). The rate of rise of urban population in Indian cities lies between 3 to 3.5 % per annum and hence per capita generation of solid waste rises by 1 to 1.33% [16,17]. In a low or middle income country like India the rate of per capita solid waste generation, in small towns are less than those of metro cities, ranges from 0.2 to 0.5% kg/day. A survey on solid waste management conducted by Central pollution control board in 299 cities provides data for solid waste generation in different cities (Table-2,3).

		Waste Generation (TPD)		Per Capita Waste Generation (kg/day)	
		Low	High	Low	High
Metros	Value	3344	11520	0.445	0.708
	City	Greater Bengaluru	Greater Kolkata	Greater Bengaluru	Chennai
Class-1 Cities	Value	317	2602	0.217	0.765
	City	Rajkot	Pune	Nashik	Kochi
All Cities	Value	5	11520	0.217	0.616
	City	Kavarati	Kolkata	Kohima	Port Blair
States	Value	19	23647	0.217	0.616
	State	Arunachal Pradesh	Maharashtra	Manipur	Goa
Union Territories (UT)	Value	5	11558	0.342	0.867
	UT	Lakshadweep	Delhi	Lakshadweep	Andaman &

					Nicobar
Regions	Value	696	88800	0.382	0.531
	Region	East	West	East	West

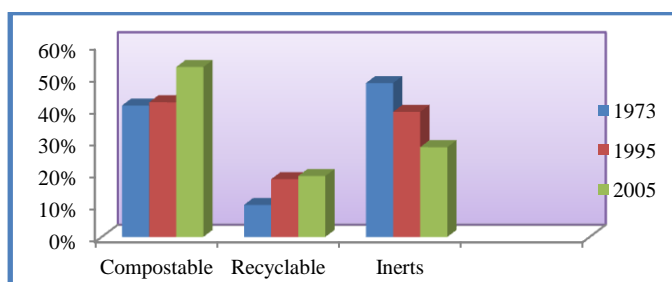
* [48] Earth Engineering centre at Columbia University.

Region/City	MSW (TPD)	Composition (%)	Recyclable (%)	Inert (%)	Moisture (%)	Cal. Value (MJ/kg)	Cal. Value (kcal/kg)
Metro	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	1,627
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

*[48] Earth Engineering centre at Columbia University.

4-IMPACT OF ECONOMIC GROWTH AND CHANGE IN LIFE STYLES ON MSW

Since last few years, India has undergone unprecedented economic growth as a result of which considerable change in lifestyle and per capita waste generation seen, per capita waste generation increased from 440 gm/day to 500 gm/day at a decadal per capita waste generation growth of 13.6%. A decreasing trend in inert of municipal solid waste is found, from 1973-1995 and 1995 to 2005 by 9% to 11% respectively due to improvement in collection, where as an increasing trend is observed in organic and recyclable matter for the time period 1973-1995 and 1995-2005 by 1% to 10% and 8% to 8% to 1% respectively (Figure-3).

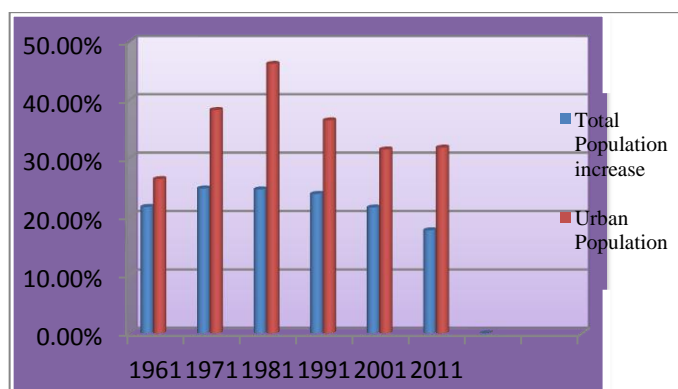


(Figure-3 Change in Composition of Indian MSW since 1973, through 1995 and 2005).

*[48] Earth Engineering centre at Columbia University.

5- IMPACT OF POPULATION GROWTH

Indian population increased by more than 181 million during last census period with a growth rate of 17.64% almost as much as population of Brazil. As a result of rapid urbanisation, In India growth rate of urban population is always greater than overall population growth (Figure-4). A survey conducted in 366 cities of India shows that these cities 31.6 million tons of solid waste in 2001 and 47.3 million at present with a 50% increase in one decade [18 19]. It is predicted that these cities will be generating 47.3% million tons of solid waste by the year 2047, Hence total urban municipal solid waste generation in 2041 will be 230 million tons per year (Table-4).



(Figure-4 Trend of Urbanisation in India)

*[48] Earth Engineering centre at Columbia University.

(Table-4 Population growth and impact on Overall Urban waste Generation and Future Prediction 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	0.741	160.96

*[48] Earth Engineering centre at Columbia University.

6-CLASSIFICATION OF WASTE

The waste does not exist in nature, the act of wasting is human interventions for short term convenience.

In different text have different view for classification of solid waste, following classification appear appropriate.

6.1-BIODEGRADABLE WASTE

It consist of garden or park waste , grass, flower cutting and hedge trimming, animal carcasses, parts from slaughter houses not intended for human consumption, leftover and spoiled food , residue from food/fruit/vegetable processing industry, human excreta, cattle dung, sewage etc., generally these waste are produced microbial, plants and animal sources.

6.2-HAZARDOUS WASTE

Typically, hazardous waste originate form medicines, dispensary waste, paints, chemicals, light bulbs, fluorescent tubes, fertilizer/pesticide container, spray canes and batteries etc.

6.3-RECYCLABLE WASTE

Those waste which are used for production fresh product comes under this list, it comprise of paper, glass bottles, ceramics, plastic and metal scrap etc.

6.4-Inert waste

Waste produced from construction and demolition, dirt, rocks and debris etc. comes in this category, with relatively lower impact on environment due to non-biodegradability nature.

6.5-COMPOSITE WASTE

It comprises of waste clothing, tetra packs and waste plastics such as toys etc. The sources of solid waste, waste generator and solid waste contents can be tabulated as bellow Table-5[20, 21].

Source	Typical waste generators	Solid waste contents
Residential	Single and multifamily dwelling	Food waste, paper, cardboard, plastics, textiles, yard waste, wood, glass, metals, ashes, special wastes (e.g., Bulky items, consumer electronics, batteries, oils, tires), and household hazardous wastes.
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packing, food waste, construction and demolition materials hazardous waste, ashes, special waste
commercial	Stores, hotels, restaurants, markets, office building etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous waste.
Institutional	Schools, hospitals, prisons, government centres.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous waste
Construction and Demolition	New construction sites, Road repair, renovation Sites, demolition of Buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, Landscaping, parks, Beaches, other recreational Areas, water and Wastewater treatment Plants	Street sweepings; landscape and tree Trimmings; general wastes from parks, Beaches, and other recreational areas; Sludge
Process (Manufacturing etc.)	Heavy and light Manufacturing, refineries, Chemical plants, power Plants, mineral extraction And processing.	Industrial process wastes, scrap Materials, off-specification products, Slay tailings
Agriculture	Crops, orchards, vineyards, Dairies, feedlots, farms.	Spoiled food wastes, agricultural Wastes, hazardous wastes (e.g., Pesticides).

*CPCB

7-SOLID WASTE MANAGEMENT

In most of the Indian cities, the primary responsibility of solid waste management is handed to the municipality, urban local bodies and NGOs, includes predominately solid/semi-solid domestic and commercial waste collected within an area. In low income cities where proper management for solid waste are not available they often practise illegal means of disposal and throw away their waste near their surroundings due to which heaps of un-disposed wastes, rotting around industrial site, sides of highway and corner of residential/market area give ugly view, apart from causing health and pollution problems as a result of putrefaction and

tends to proliferation of vector and pathogens, as well as greenhouse gas emission.

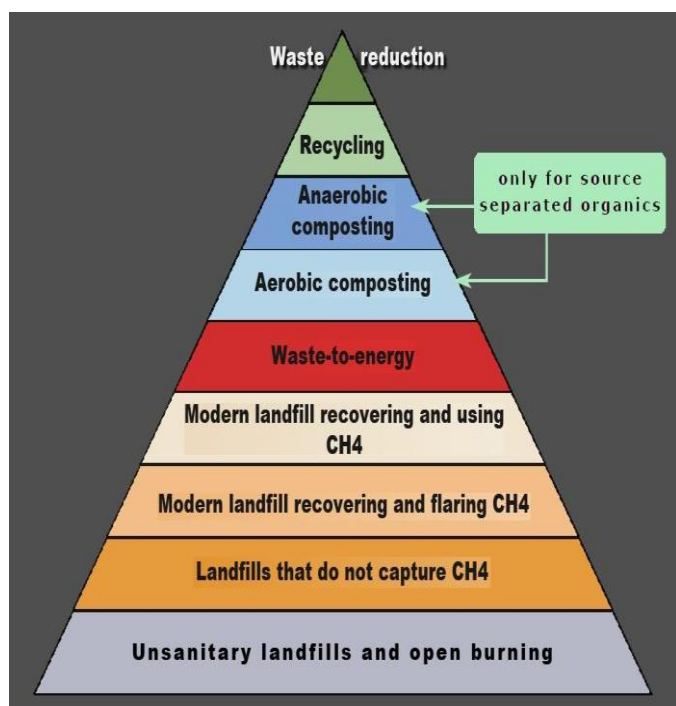
7.1-COLLECTION AND STORAGE

At present, in most of the Indian cities adequate facilities for solid waste collection is provided under the 'Clean India Campaign' with the assistance of corporate and semi-corporate organisation. Generally, in most of the cities collection of solid waste is done by fixed and movable bins at various points along the roads, inside in commercial and institutional area, and sometimes leads to the creation of unauthorized open collection points. The fixed bins are constructed where production of solid waste are more and have more durability but are not flexible for transportation facility while moveable bins are more flexible for transportation but lack of durability [22,23]. Now a day's door to door collection of solid waste with the assistance of local bodies are practised in mega cities and small urban areas also with specified monthly payment. After this attempt of solid waste management, collection of solid waste is almost done in common, decomposable and non-decomposable, bins and disposed off at a community disposal centre without segregation. In cities where public participation, private contractors and NGOs are employed for collection and transportation of solid waste have collection efficiency about 72% while this figure is low in other cities due to insufficient waste collection services [24,25,26]. These collected wastes are transported for secondary transportation communal bins to the disposal sites by contractor. Survey conducted by CPCB in 299 class-1 cities of India has found that manual collection comprises 50%, collection and by truck 49% [27].

7.2-HIERARCHY OF SUSTAINABLE SOLID WASTE MANAGEMENT

The most environmental friendly hierarchical solid waste management system recognises that reducing the use of materials and reusing them, such approach of source reduction begins with reducing the amount of solid waste, until end of use, generated and reusing them

prevent it from reinterring the solid waste [28]. The most effective way of handling solid waste is material recovery in the form of recycling and composting, in addition to this there must be provision to handle non-recyclable wastes that will be generated in future [29]. Energy recovery from solid waste is a sustainable solution to handle non-recyclable waste. Open dumping or unsanitary landfilling of municipal solid waste is generally considered as burying natural resources which may be used as secondary raw material or source of energy. Sustainable hierarchal approach of solid waste management is shown in figure-5.



(Figure-5 Hierarchy of sustainable waste management)

*[48]Earth Engineering centre at Columbia University.

7.3-MATERIAL RECYCLING/ RECOVERY

The process of recycling is the recovery of the useful material from solid waste, these includes paper, glass, plastic, and metals, and are easily used to produce virgin product reducing the amount of fresh raw materials required of production. In all scenarios relevant to the solid waste management recycling has positive effect where net effect is an ecological benefit. Production of material from recycled material reduces considerable amount of

resources as compared to production from fresh material such as coal, oil fuel, electricity etc.[14].

7.4-SEPARATION

Generally, municipal solid waste is heterogeneous in nature that why separation of solid waste into relatively homogeneous category is being necessary prior to treatment and disposal point of view, further adds to the cost. Due to its high biodegradability and methane potential, it seems to be promising feedstock for biogas generation plants [30]. This provides an enthusiastic economic way to handle localized specific wastes contributing to environment friendly disposal, avoid potential health hazards of no or delayed disposal is to intercept a biodegradable waste at the point of generation before it is being mixed with other wastes. This method has more scope in house hold wastes.

7.5-COMPOSTING

Composting is a simple microbial based aerobic process which is considered as environmental friendly way to reduce organic waste and produces fertilizer or compost [30]. Composting is gaining interest as suitable option for recycling among all the solid waste management techniques [12]. As wastes are collected in mixed form in India and contain both organic as well as non-organic materials, in such situation composting method generally seems to be difficult, traditionally used particularly in rural areas [31]. The efficiency of composting have strong correlated with segregation, in the absence of segregation performance of plant is rendered due to presence of non-degradable material in the waste such as plastic, glass and metals etc. In 1992 India established first composting plant, with designed capacity 500 t/day but actual utilisation is 300t/day due certain limitations, running successfully providing desired result. At this time nearly 175 industries running successfully making composting up to commercial scale by using available wide variety of waste to generate organic manure, these compost represent rich source of nutrients which is useful for maintaining and restoring soil fertility and are of great values these days, particularly

where the soil have low organic contents [32]. Uncontrollable release CO₂ in the atmosphere without capturing energy is somewhat noticeable [33,34]).

7.6-LANDFILLING

In India landfills are broadly practiced in urban areas where huge amount of solid waste is generated daily, located nearby rural areas. Similar to open dumping, landfill is a pit that is dug in the grounds into which solid wastes are disposed, increasing possibility of ground water pollution through leachate during rainy seasons, aiming to avoid direct contact between the waste and the surrounding environment. An alarming situation is created to environment due to rise in leachate and biogas emission [35], causes noxious odour as it decomposes, attracts flies and add chemical oxygen demand to the leachate. In most part of the India landfilling is done in low lying area or river basin in a haphazard manner as a result of which there is large possibility of heavy metal leachate into water resources through leachate. In spite of facing problem of landfill site (Table-6) and leachate problem, landfilling is widely practiced in India [36,37].

landfill fires area also become common to most of landfill site, the fire may be due to waste-picker or by municipal worker. Incineration of municipal solid waste in India is not a suitable option as waste contains high moisture 40-60%, high organic matter 40-60%, high inert substance 30-50%, and low calorific value 800-1100 kcal/kg, as a result of which installation and running cost of plants are high [39], while small incinerators are successfully running for incinerating hospital waste in many cities of India [40,41,42].

7.8-AGRICULTURE APPLICATION

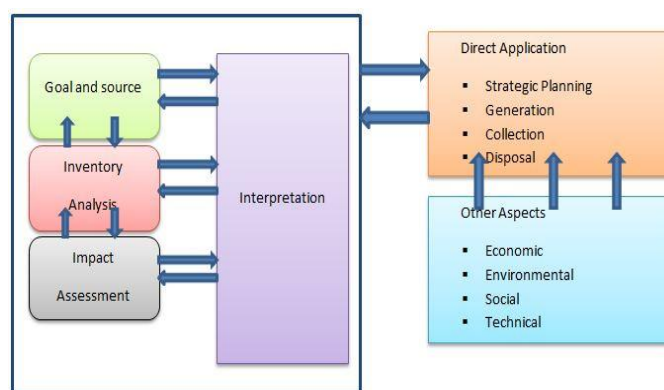
Application of municipal solid waste in agriculture as source of nutrient is seen as most cost effective municipal solid waste disposal option over traditional means of disposal technique such as landfilling, incineration, this is justified by the need of finding an appropriate destination for recycling. Due to presence of pathogens and several heavy metals application of municipal solid waste as compost create a new threat to environment, such toxic elements enters in the food chain through food crops to which waste applied for fertilizer [43]. But some research shows that appreciable amount of heavy metals in municipal solid waste compost have no adverse effects on microbial biomass and enzyme activity of soil under consideration.

Year	Area of Land occupied/required for MSW disposal (sq.km)	City Equivalents
1947-2001	240	50% of Mumbai
1947-2011	380	905 of Chennai
1947-2021	590	Hyderabad
2009-2047	1,400	Hyderabad+Mumbai+Chennai

*[48] Earth Engineering centre at Columbia University.

7.7-INCINERATION

Through over India, incineration of residual municipal solid waste is generally practiced, most of the time open burning, resulting products of combustion are emitted directly into the ambient air without passing through an adequate stack, dust or chimney [38], in India spite of the open burning,



(Figure-6 Component of Life cycle assessment for solid waste)

SUMMARY

In this Paper, an attempt has been made to study the heterogeneous nature and changing trends of municipal solid waste to find out its adverse impact on atmosphere, impact on the performance

and planning suitable municipal solid waste management strategy. The study shows that the material recovery and composting is the more environmentally preferable option for solid waste management other technique. LCA helps in comparing different solid waste management technique such as recycling, landfilling, composting and incineration etc. It is found that open burning/incineration is not suitable option for solid waste management from environmental point of view as it has highest toxic effect due to nitrogen oxide. At present there is urgent need of survey for collection of data regarding generation and composition of municipal solid waste. The aim of sustainable disposal of municipal solid waste can be achieved by analysing large number of samples, and information collected from these samples should be used for planning new solid waste management strategy.

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