International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.02, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Municipal Solid Waste Generationand current Scenario of its Management in India

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ABSTRACT

India is one of the mega under developed country of the world with respect to population status and dynamics. The growing rate of population is a direct factor responsible for enhancement of municipal solid waste (MSW) generation. The main objective of this review research paper was to find out the current MSW generation and the possible problems associated with its management in India. The huge population of India is responsible for mammoth generation of MSW with daily rate of generation is 400g per capita. The constituents of MSW mainly comprise of compostable items (51-53%), followed by recyclable (17-18%) and having a moisture content of 46.76 %. The MSW generated contains C/N ratio approximately 32 with calorific value of about 1700-1800 Kcal/Kg. Only fraction (10-12%) of the total compostable waste was found to be used for composting. There are plenty of technologies available for generating energy and other useful substances from the MSW ecofriendly, but 60%- 90% of MSW generated in cities and towns are directly disposed off on or into land in an unsatisfactory manner. Therefore, the management of MSW generated in Indian cites has been found inadequate and challenging. This comprehensive review looks into various useful scientific alternatives that deal with the problems associated with MSW generation for protecting the environment from the long effects of MSW issues and suggests the remedial measures to cope with it.

Key Words: *Composting, India, Management, MSW, Recyclable*

I. INTRODUCTION

Waste is an unavoidable by-product of human activities. Economic development, urbanization and improved living standards in cities enhance the quantity and complexity of solid waste [18, 43]. Most of the cities in India are experiencing unplanned urban sprawl and heavy pressure of population. The net result is an enormous generation of solid wastes. The quantity of generated solid waste mainly depends on population, economic growth, and the efficiency of the reuse and recycling system. Municipal Solid Waste is generally a combination of household and commercial refuse which is generated from the living community [22, 42], it includes degradable; paper, textiles, food and vegetable waste [33], moderately degradable (cardboard and wood) and materials of non-degradable; leather, plastics, rubbers, metals, glass and electronic waste[1-2]. The MSW composition in most developing countries is highly degradable [10, 32], mainly composed of an organic fraction with high moisture content. Rapid industrialization and population explosion in India has led to the migration of people from villages to cities, which enhanced thousands of tons of MSW daily Rapid population growth and expanding urbanization have caused a drastic increase of the municipal solid waste generation and the variety of the waste composition [23]. Indian mega-cities (Delhi, Mumbai, Kolkata and Chennai) are top producer of MSW in India due to high density of residential and floating population, from households, offices, trade/commercial activities, industries and health care centres [7-8].Solid waste management involves activities associated with generation, storage and collection, transfer and transport, treatment and disposal of solid wastes. But in most Indian cities, the municipal solid waste management system comprised only four activities, i.e., waste generation, collection, transportation and disposal. The management of MSW is going through a critical phase, due to unavailability of suitable facilities to treat and dispose of the larger amounts of MSW generated daily in metropolitan cities [29]. Poor collection and inadequate transportation are responsible for the accumulation of MSW at every nook and corner [17, 21, 27, 28]. Due to improper solid waste management, waste has become one of the pollution sources and caused diverse environment impact as well as detrimental towards human health and safety [45] and often production of solid waste is the most serious threat to the fragile ecosystem [5]. Ecological impacts such as land degradation, water and air pollution are related to improper management of municipal solid wastes [4].

II. QUANTITY AND QUALITY OF MSW GENERATED IN INDIA

The quantity and quality of solid waste vary from place to place. Factors that influence the quantity and composition are the average income level [3, 48], the sources [1, 8], the population [23], social behavior and climate [35], industrial production [8] and the market for waste materials [12-13]. Quantity of solid waste generated in Indian cities has increased from 6 million tons in 1947 to 48 million tons in 1997 with an annual growth rate of 4.25%, and it is expected to increase to 300 million tons by 2047 [19]. Central pollution control board (CPCB) with the support of NEERI has conducted survey of solid waste managing in 59 cities (35 metro cities and 24 state Capitals: 2004-05). Quantities and quality of generated MSW are depicted in Table1. In the last few decades, the amount of waste generated per capita has recorded an annual increase at a rate of 1% to 1.33% [6]. If this rate of increase continues, India will probably experience a rise in waste generation from less than 40,000 tons per year to over 125,000 tons by 2030 [44]. Furthermore, the per capita generation rate is high in some cities (Port Blair, Kochi, Chennai, Vishakhapatnam, Pondicherry, Kolkata, Jammu, Delhi and Hyderabad). This may be due to high living standards, the rapid economic growth and the high level of urbanization in these cities. Increases in waste generation are often associated with economic growth, higher industrialization, rise in population and higher standards of living [48]. However, the per capita generation rate is observed to be low in other cities Nashik, Imphal, Rajkot and Guwahati). The composition and volume of wastes varies from one city to another, and that these variations are due to the different patterns of consumption, wastes production index, composition of the population, socioeconomic and cultural level and in large measure to the influence of the consumption patterns [7, 24]. The differences in the municipal solid waste quality indicate the effect of urbanization and development. In urban areas, the major fraction of municipal solid waste is compostable materials (40-60%) and inerts (30-50%). The major fraction of MSW comprised of organics (44%) followed by recyclables viz., paper, plastics, glass and metals [30, 40]. Recyclable materials contributed most in MSW [30]. Food is the lifeline to every form of life and is the most important consumable on daily basis; with the result it contributes lot to the MSW. Food waste is a major constituent with high percentage among the all constituents of MSW [25, 34].

III. COMPOSITION OF MUNICIPAL SOLID WASTE

The growing population levels, flourishing economic conditions, swift urbanization and the rise in community living values have greatly accelerated the municipal solid waste production rate in developing countries [48].The composition of MSW depends on a wide range of factors such as food habits [25, 34], cultural traditions, climate and income, etc [35, 37]. Various categories of MSW are found such as commercial waste, food waste, institutional waste, street waste, industrial waste, construction and demolition waste, and sanitation waste. The higher income generate cities in India were found to generate more MSW per capita per day basis and their waste have higher portions of packaging materials and recyclable wastes, while in case of developing cities, the proportion of compostable and recyclable wastes are very low. MSW includes degradable (paper, textiles, food waste, straw and yard waste), partially degradable (wood, disposable napkins and sludge, sanitary residues) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods, dust and electronic waste) [1]. The food wastes bears lot of moisture that contributes to the MSW to a great extent [25, 26, 29, 39], reported that in most developing countries the highest percentage (40–70%) of MSW consists of organic matter, which is able to retain a high moisture content. The C/N ratio ranges between 800 and 1000 kcal/kg [20, 29] .

International Journal of Advance Research in Science and Engineering
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www.ijarse.com
IJARSE
ISSN: 2319-8354

Table-1: Quantity and Quality of Municipal Solid Waste generated at different cities in India [12]

S. No.	City	Population	Area (Km^2)	Waste Quantity (TPD)	Waste Generation Rate (kg/c/day)	Compostable (%)	Recyclables (%)	C/N Ratio	HCV* (Kcal/kg)	Moisture (%)
1	**Kavaratti**	10119	4	3	0.30	46.01	27.20	18.04	2242	25
2	**Gangtok**	29354	15	13	0.44	46.52	16.48	25.61	1234	44
3	**Itanagar**	35022	22	12	0.34	52.02	20.57	17.68	3414	50
4	**Daman**	35770	7	15	0.42	29.60	22.02	22.34	2588	53
5	**Silvassa**	50463	17	16	0.32	71.67	13.97	35.24	1281	42
6	**Panjim**	59066	69	32	0.54	61.75	17.44	23.77	2211	47
7	**Kohima**	77030	30	13	0.17	57.48	22.67	30.87	2844	65
8	**Port Blair**	99984	18	76	0.76	48.25	27.66	35.88	1474	63
9	**Shillong**	132867	10	45	0.34	62.54	17.27	28.86	2736	63
10	**Shimla**	142555	20	39	0.27	43.02	36.64	23.76	2572	60
11	**Agartala**	18998	63	77	0.40	58.57	13.68	30.02	2427	60
12	**Gandhinagar**	195985	57	44	0.22	34.30	13.20	36.05	698	24
13	**Dhanbad**	199258	24	77	0.39	46.93	16.16	18.22	591	50
14	**Pondicherry**	220865	19	130	0.59	46.96	24.29	36.86	1846	54
15	**Imphal**	221492	34	43	0.19	60.00	18.51	22.34	3766	40
16	**Aizwal**	228280	117	57	0.25	54.24	20.97	27.45	3766	43
17	**Jammu**	369959	102	215	0.58	51.51	21.08	26.79	1782	40
18	**Dehradun**	424674	67	131	0.31	51.37	19.58	25.90	2445	60
19	**Asansol**	475439	127	207	0.44	50.33	14.21	14.08	1156	54
20	**Kochi**	595575	98	400	0.67	57.34	19.36	18.22	591	50
21	**Raipur**	605747	56	184	0.30	51.40	16.31	223.50	1273	29
22	**Bhubaneswar**	648032	135	234	0.36	49.81	12.69	20.57	742	59
23	**Tiruvanantapuram**	744983	142	171	0.23	72.96	14.36	35.19	2378	60
24	**Chandigarh**	808515	114	326	0.40	57.18	10.91	20.52	1408	64
25	**Guwahati**	809895	218	166	0.20	53.69	23.28	17.71	1519	61
26	**Ranchi**	847093	224	208	0.25	51.49	9.86	20.23	1060	49
27	**Vijaywada**	851282	58	374	0.44	59.43	17.40	33.90	1910	46
28	**Srinagar**	898440	341	428	0.48	61.77	17.76	22.46	1264	61
29	**Madurai**	928868	52	275	0.30	55.32	17.25	32.69	1813	46
30	**Coimbatore**	930882	107	530	0.57	50.06	15.52	45.83	2381	54

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IJARSE
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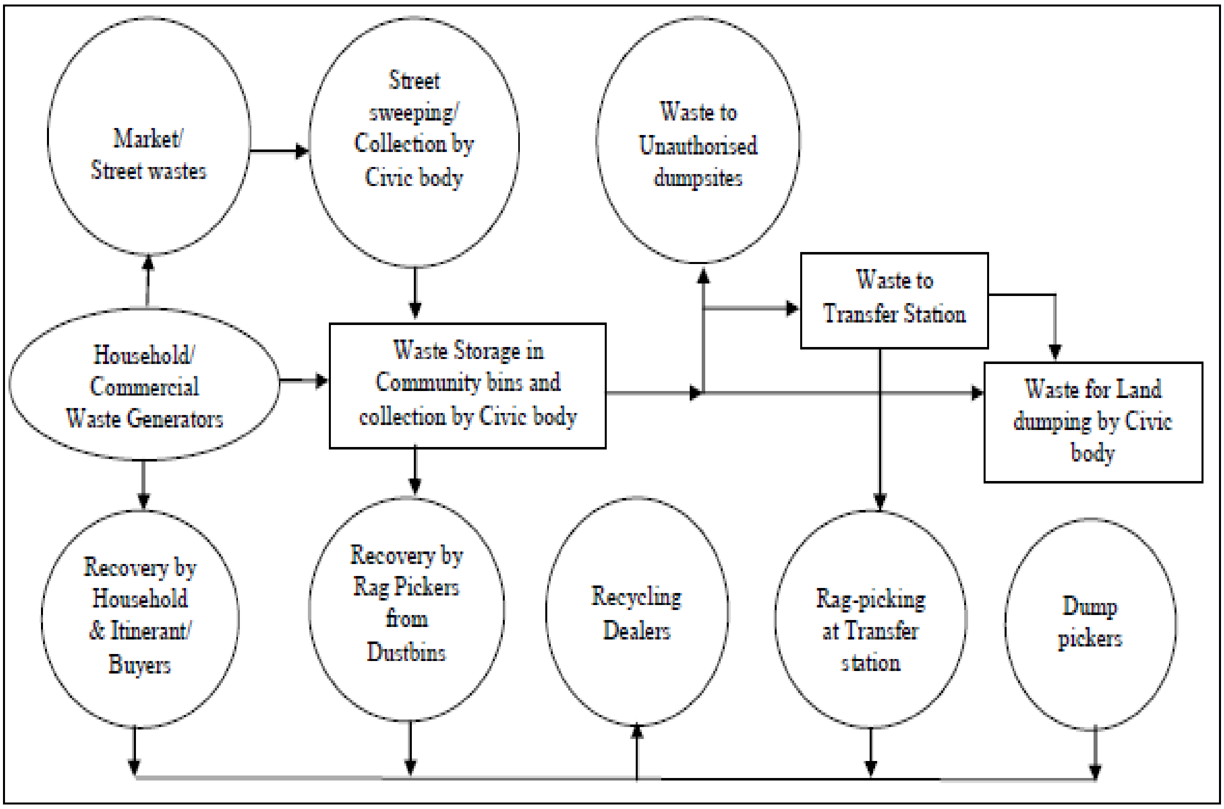
31	**Jabalpur**	932484	134	216	0.23	58.07	16.61	28.22	2051	35
32	**Amritsar**	966862	77	438	0.45	65.02	13.94	30.69	1836	61
33	**Rajkot**	967476	105	207	0.21	41.50	11.20	52.56	687	17
34	**Allahabad**	975393	71	509	0.52	35.49	19.22	19.00	1180	18
35	**Vishakhapatnam**	982904	110	584	0.59	45.96	24.20	41.70	1602	53
36	**Faridabad**	1055938	216	448	0.42	42.06	23.31	18.58	1319	34
37	**Meerut**	1068772	142	490	0.46	54.54	10.96	19.24	1089	32
38	**Nashik**	1077236	269	200	0.19	39.52	25.11	37.20	2762	62
39	**Varanasi**	1091918	80	425	0.39	45.18	17.23	19.40	804	44
40	**Jamshedpur**	1104713	64	338	0.31	43.36	15.69	19.69	1009	48
41	**Agra**	1275135	140	654	0.51	46.38	15.79	21.56	520	28
42	**Vadodara**	1306227	240	357	0.27	47.43	14.50	40.34	1781	25
43	**Patna**	1366444	107	511	0.37	51.96	12.57	18.62	819	36
44	**Ludhiyana**	1398467	159	735	0.53	49.80	19.32	52.17	2559	65
45	**Mumbai**	1437354	286	574	0.40	52.44	22.33	21.58	1421	43
46	**Indore**	1474968	130	557	0.38	48.97	12.57	29.30	1437	31
47	**Nagpur**	2052066	218	504	0.25	47.41	15.53	26.37	2632	41
48	**Lucknow**	2185927	310	475	0.22	47.41	15.53	21.41	1557	60
49	**Jaipur**	2322575	518	904	0.39	45.50	12.10	43.29	834	21
50	**Surat**	2433835	112	1000	0.41	56.87	11.21	42.16	990	51
51	**Pune**	2538473	244	1175	0.46	62.44	16.66	35.54	2531	63
52	**Kanpur**	2551337	267	1100	0.43	47.52	11.93	27.64	1571	46
53	**Ahmedabad**	3520085	191	1302	0.37	40.81	11.65	29.64	1180	32
54	**Hyderabad**	3843585	169	2187	0.57	54.20	21.60	25.90	1969	46
55	**Bangalore**	4301326	226	1669	0.39	51.84	22.43	35.12	2386	55
56	**Chennai**	4343645	174	3036	0.62	41.34	16.34	29.25	2594	47
57	**Kolkata**	4572876	187	2653	0.58	50.56	11.48	31.81	1201	46
58	**Delhi**	10306452	1483	5922	0.57	54.42	15.52	34.87	1802	49
59	**Greater Mumbai**	11978450	437	5320	0.45	62.44	16.66	39.04	1786	54

IV. CURRENT SCENARIO OF MSW MANAGEMENT IN INDIA

A. COLLECTION AND STORAGE OF MSW

Significantly, most of the urban areas are lacking in MSW storage at the source in India and the bins are common for both decomposable and non-decomposable waste (no segregation of waste is performed) and the waste is disposed at a communal disposal center. Storage bins can be classified as movable bins and fixed bins. The fixed bins are more durable but their positions cannot be changed one they have been constructed, while the movable bins are flexible in transportation but lacking in durability [20, 29, 47]. The MSW management steps are depicted in **Figure1**.



Source: Joseph, 2002

Figure1: Schematic Flow Chart of Common MSW Management Process

B. TREATMENT AND DISPOSAL

India is facing the lacking of resources or the technical expertise necessary to deal with the disposal of Municipal Solid Waste [29]. The two foremost pioneering mechanisms of waste disposal being adopted in India include composting (aerobic composting and vermi-composting) and waste-to-energy (WTE) (incineration, pelletisation, biomethanation). WTE projects for disposal of MSW are a relatively new concept in India. Although these have been tried and tested in developed countries with positive results, these are yet to get off the ground in India largely because of the fact that financial viability and sustainability is still being tested [20]. A waste-to-energy plant established at Vijaywada by Shriram Energy Systems, Ltd., Hyderabad, with a capacity of about 500 TPD of MSW and a power generating capacity of 6 MW, has been in operation since December 2003 [14, 16]. Another plant, with a capacity of about 700 TPD of MSW with a power generating capacity of 6.6 MW, established by M/s SELCO International, Ltd., at Gandhamguda near Hyderabad has been in operation since November 2003. M/s Shriram Energy Systems, Ltd., Hyderabad, will commission a third waste-to-energy plant at Vishakhapattanam. A waste-to-energy plant (600 TPD capacity) is also underway at Chennai [37].

C. COMPOSTING

Composting is the aerobic and thermophilic decomposition of organic matter present in the waste, by micro-organisms. The organic matter is transformed into a stable humus-like substance which can be used as a manure and soil conditioner, during this process [15]. It is the second preferred method of solid waste, mainly due to high percentage of organic material in the waste composition [11]. Composting has a long history particularly in rural India and it is a difficult process because the waste arrives in a mixed form and contains a lot of non-organic stuff. When mixed waste is composted, the end product is of poor quality. The existence of plastic objects in the waste stream is principally 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 [29] and 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, Ahmedabad, Hyderabad, Bhopal, Luknow and Gwalior. Many other cities have either signed agreements or are in the process of doing so to have composting facilities very soon [20, 29]. In India, composting is used around 10-12% because composting needs segregation of waste and sorting is not widely practiced [19, 29, 33].

D. VERMICOMPOSTING

Vermicompost is an organic manure (bio-fertile) produce as the vermicast by earthworm feeding on biological waste material; plant residue [37-38]. Vermicomposting involves stabilization of organic waste through the joint action of earthworms and aerobic microorganisms. Initially, microbial decomposition of biodegradable organic matter occurs through extra cellular enzymatic activity (primary decomposition). Earthworms feed on partially decomposed matter, consuming five times their body weight of organic matter per day. The ingested food is further decomposed in the gut of the worms, resulting in particle size reduction. The worm cast is a fine, odorless and granular product. This product can serve as a biofertilizer in agriculture. Vermicomposting has been used in Hyderabad, Bangalore, Mumbai and Faridabad. Experiments on developing household vermicomposting kits have also been conducted. However, the area required is larger, when compared to dry composting [20].

E. BIOMETHANATION (ANAEROBIC DIGESTION)

Solid wastes can be used for production of Biogas. Biogas comprises of 68% methane, 31% CO_2, 1% nitrogen and gives calorific value of 5871 kcal/m3 [15]. If the organic waste is buried in pits under partially anaerobic conditions, it will be acted upon by anaerobic microorganisms with the release of methane and carbon dioxide; the organic residue left is good manure. This process is slower than aerobic composting and occurs in fact naturally in landfills. However, thermophillic digestion for biomethanation is much faster and has been commercialized. Anaerobic digestion leads to energy recovery through biogas generation. The biogas, which has 55–60% methane, can be used directly as a fuel or for power generation. Anaerobic digestion in controlled manner of one ton MSW produces 2.5 to 4 times CH_4 in 21 days of time span in comparison to one ton of MSW in landfill i.e., 6 to t years [20].

F. INCINERATION

Incineration is the most common thermal treatment of MSW to reduce the volume of MSW and generate significant amount of energy from collected wastes. It involves combustion of MSW at very high temperature (more than 1000 °C) in the presence of oxygen. After incineration, the wastes are converted to CO_2, H_2O vapour and ash. This method may be used as a means of recovering energy to be used in heating or the supply of electricity. In addition to supplying energyincineration technologies have the advantage of reducing the volume of the waste, rendering it harmless, reducing transportation costs and reducing the production of the greenhouse gas methane. Unfortunately, In India the incineration is a poor option. This may be due to the high organic material (40–60%), high moisture content (40–60%), high inert content 30–50% [34] and low calorific value content (800–1100 kcal/kg) in MSW. The first big MSW incineration plant was established at Timarpur (New Delhi in 1987) of 300 t/day capacity and the cost for installation was about Rs. 250 million (US$5.7 million). The other incineration plant was constructed at Trombay (Mumbai) for burning only the institutional waste, which includes mostly paper and other related wastes [29]. In many cities, small incinerators are used for burning hospital waste [20].

G. PYROLYSIS AND GASIFICATION

Pyrolysis and Gasification are related processes because both requires high temperature to decompose organic waste but at low amounts of oxygen. Technically gasification very low concentration of oxygen supply while as pyrolysis is an oxygen free burning process. Gasification has advantages since it allows for the incineration of waste with energy recovery and without the air pollution that is characteristic of other incineration methods. In India, there are 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 inerts and shredding for size reduction. Two different designs of gasifiers exist in India. The first gasification plant for burning the MSW was installed at Nohar, Hanungarh, Rajasthan by Narvreet Energy Research and Information (NERI). The wastes usually burn in Nohar gasification plant are 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. The second unit is the TERI gasification unit installed at Gaul Pahari campus, New Delhi by Tata Energy Research Institute (TERI) [20, 29].

H. LANDFILLING

A landfill is an area of land onto or into which waste is deposited. It is divided into a series of individual cells and only a few cells of the site are filled with trash at any one time. In India inadequate, crude dumping and poorly managed MSW is commonly experienced, giving rise to grave environmental deprivation. About 60 to 90 % of MSW generated in cities are unswervingly disposed off on open land in unscientific manner. 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 [32]. The pollution of groundwater, though largely unassessed, is definitely a threat posed by the dumping of wastes [9, 27, 31]. 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. In India, for safeguard of environment, there will be definitely some improvement in the aspect of landfilling and final disposing of MSW and 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 [20, 29, 46].

I. BIOREACTOR LANDFILL

A further development in landfill technology is the bioreactor landfill. The Bioreactor landfills use enhanced microbiological processes to accelerate the decomposition of waste. The main controlling factor is the constant addition of liquid to maintain optimum moisture for microbial digestion. This liquid is usually added by re-circulating the landfill leachate. In cases where leachate is not enough, water or other liquid waste such as sewage sludge can be used. The goal is to increase the rate of bio-degradation to achieve recovery for energy production. This approach also aims to minimize the landfill stabilization 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 [29, 36].

V. INTEGRATED SOLID WASTE MANAGEMENT (ISWM)

Integrated Solid Waste Management (ISWM) provides a framework for the development of a sustainable MSW service, which can take place with the use of a range of collection, transport and treatment options [10-11]. It takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. ISWM system involves the use of number of special handling and treatment techniques, and functioning of such a systems for the collection and sorting of the waste. One important and adequate treatment method can manage all the generated MSW in an environmentally sound manner. For restricting further damage of environment with MSW pollution, the need of hour is to employ those available treatment and disposal options that must be the best combination of the available options suited to the particular community chosen. Effective management schemes therefore need to operate in ways which best meet current social, economic, and environmental conditions of the municipality.

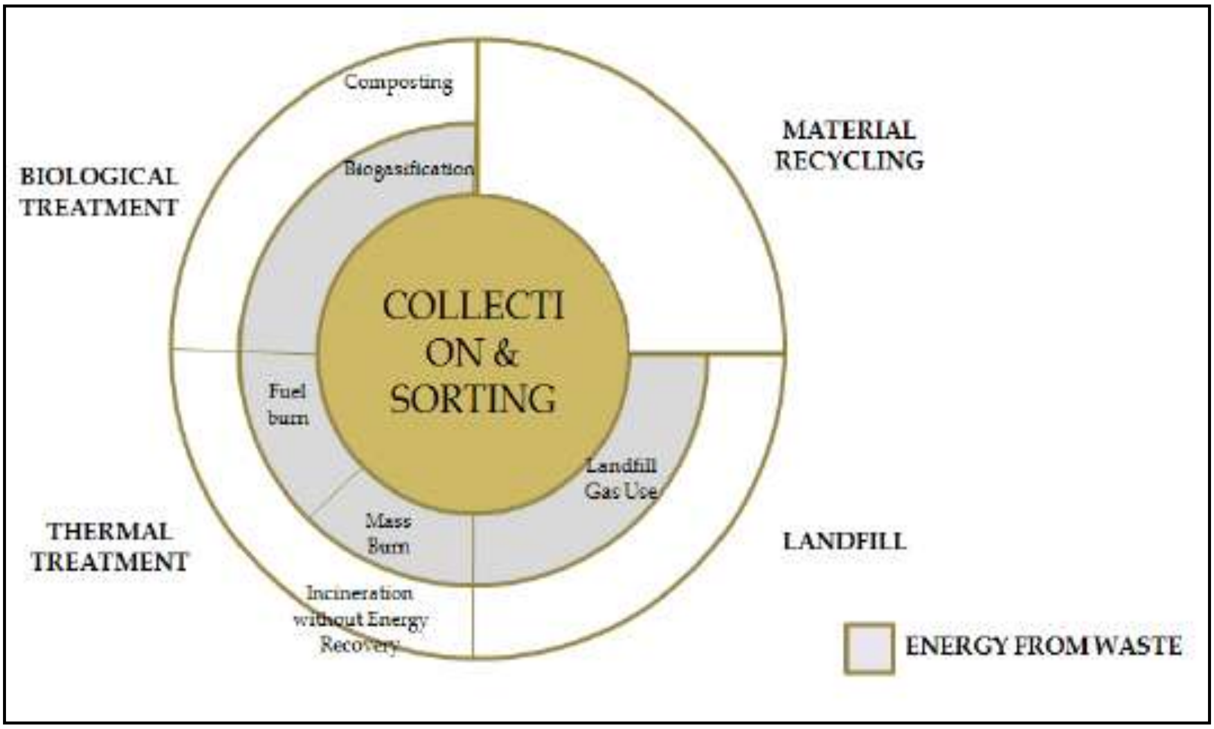


Figure-6: Elements of Integrated Solid Waste Management [41]

VI. CONCLUSION

The changing trends of quantity and characteristics of MSW is a growing challenge for the authority that has the mandate for MSWM. Furthermore, the changing pattern of waste composition emphasizes the importance of segregation for successful operation of waste management facilities. For managing the MSW, the authorities should endorse the collection, storage, segregation of waste in such a manner that they do not create any unhygienic and unhealthy conditions. A new survey should be carried out on the generation and characterization of MSW in India.

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