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Review Article

Environmentally Sustainable Municipal Waste Management Strategy- A Case of Jamshedpur, India

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Abstract

Municipal Solid Waste Management (MSWM) plays an important role in sustainable development. The motivation for the present study includes the abysmal state and challenges in MSWM in urban India. The concept of zero waste is a latest one for confounding waste problems of our society. Urbanization contributes to enhanced municipal solid waste (MSW) generation along with unscientific handling degrades the urban environment and causes health hazards. The expansion of urban areas, industrialization and changing patterns of consumption results in increased municipal waste generation which deteriorate the quality of environment, posing risk to the sustainable development. The seriousness of the problem increases in a scenario where natural resources are decreasing, and the traditional system of landfills still being practiced extensively for solid waste disposal. This paper addresses the issue of MSW by taking the case of Jamshedpur. It discusses the present municipal waste management system, new technologies, projected population, and solid waste generation. In an evolutionary approach, it points out the challenges that the sector is facing and makes an attempt to suggest a way forward through new technologies and estimation of value-added products that can be produced from the solid waste.

Keywords: Environment; sustainability; municipal sewage; management; generation trend; treatment options; economic viability

Introduction

Solid waste management includes seven principals which makes it environmentally sustainable, they are – Rethink, Refuse, Reduce, Repurpose and Repair, Reuse, Recycle and Rot. As far as, solid waste management is concerned worldwide. Globalization is one of the main reason which resulted into increase in the generation of Industrial and hazardous wastes. An estimate of 2 billion tons per year of municipal waste is produced worldwide and in the global scale 7–10 billion tons per year of 'urban' solid waste is being produced all over the world which includes wastes generated from households, commercial areas, industrial belts, and construction sites [1]. But with the rapid globalization the quantity of waste generated has gradually shifted from developed countries to developing countries. In Developing countries increase in population, migration from rural to urban areas, increase in the area and number of urban areas to fulfil the requirements are some of the basic interrelated reasons which leads to huge increase in the municipal solid waste generated and is expected to increase to a large amount at the end of a decade or two. By around 2050 the total waste generated might increase up to 70 % of the what is being generated presently and is being estimated to be nearly 3.4 billion tonnes per year [2]. Although Developing countries have made a significant progress in terms solid waste collection since 1990s, but still nearly 2 billion people at an average have no access to solid waste collection procedure [1]. In Developed countries there was an increase in the waste generation during the initialization of globalization and industrialization periods but gradually it got stabled and through certain waste management techniques. Compared to the developed nations, a major part of the population of the developing countries specially the ones which belong to the low-income groups are majorly effected by unsustainable management of solid wastes, nearly 90% of the wastes generated by the urban poor are disposed of in non-confined areas or randomly dumped or openly burned [2]. These practices have an adverse effect on the health and safety of livelihood and the environment as well. These effects not only lead to the spreading of various diseases but also one of the major factor responsible for climate change globally (methane release). Henceforth, proper waste management is one of the integral way to create a city which is sustainable and worth living. But, it still remains a challenge for developing countries as proper waste management is quite expensive and comprises of nearly 20 -50% of the entire municipal budget to make it happen [2].

In India, the population explosion and also the rapid increase in the population rate in the upcoming years is one of the reasons which is leading to huge amount of migration to urbanized areas. Thus, due to increase of urbanization and also the increase in the number of urban areas the amount of solid waste generated is also increasing at a very fast rate. More than 377 million urban people residing in 7,935 towns and cities generate an estimate of 62 million tonnes of solid waste per year, from which only 43 million tonnes of waste is collected. Out of the wastes collected only 11.9 million tonnes of wastes are being treated and 31 million tonnes of wastes are being dumped in landfill sites [3]. The landfill sites of India are one of the largest sites in the world and is the third highest emitter of greenhouse gases in the world [4]. In order, to reduce the load on the landfill sites, the biodegradable wastes need to be segregated and utilized to convert waste to compost and bio-methanation plants, and the amount of biodegradable wastes in India's total solid wastes is more than 50% [3].Thus, municipal bodies of various urban local bodies are implementing certain solid waste management techniques including the collection, transportation, disposal, and its treatment. Although, the results of these implementations have certain obstacles such as the waste producers, that is, the community residents, the commercial area owners or the hospitals do not segregate their wastes while disposing it off. But the problems are caused not only by the community, even the contractors who are responsible for collection and transportation of wastes cause problems as such, in order to get maximum of profits, the transportation costs are being reduced and thus the wastes are instead dumped in certain unauthorized areas without even segregating.

This paper includes a case study to give certain techniques as in how to make solid waste management environmentally sustainable, which is of the city Jamshedpur. Thus, we need to know some of the necessary things about Jamshedpur's solid wastes and its management. Depending on a survey conducted by CPCB with the help of NEERI on 59 cities, Jamshedpur produces wastes of 338 Tons per day at a rate of 0.31 kg/c/day [5]. The type of wastes of Jamshedpur mainely has high moisture content (48%) and has a high calorific value (1009 kcal/kg). Out of the total wastes of Jamshedpur collected, 43.36% of the wastes is worth composting and 15.69% of the wastes can be recycled. The Jamshedpur's solid wastes C/N ration is estimated to be 19.69 [5,6]. According to JUSCO who is responsible for the collection and transportation of solid wastes in areas of the city which are maintained by JUSCO has two dumping grounds as well, from these areas around 349 metric tonnes of wastes are generated and this is expected to rise to 749 metric tonnes by 2031 [7].

Literature Review

It is seen that the waste generation of a city, town or country is much dependant on the demographics and economic status of that place. As per collection of generated waste in developing countries is concerned, according to [8] the frequency of collection of waste by municipalities from commercial areas ranges from 14 times a week to once a week. Whereas the rate of collection of wastes in inner city areas varies from 4 times a week to no collection in the entire week. In regard to treatment, it is observed as per [8] in developing countries about 40% of the countries do not have compost while other 60% of the countries can do composting to some extent but not fully. There is a positive correlation between composting techniques and domestic burning. Although domestic burning is purposely adopted in areas which lack proper collection and also lack of infrastructures of treatment. As per types of waste is concerned one of the major type of waste generated in countries and cities are organic wastes. According to [9] it is observed that amount of generated wastes at an average increase with the decrease in the socio-economic status of the respective areas. Henceforth, a larger amount of organic waste is generated from rural households as compared to the urban households. The disposal and treatment of MSW in India involves mainly two principal techniques as per [9], they are Composting (involves aerobic composting and vermi-composting) and Waste – to – Energy (involving, palletisation, biomethanation). Although conversion of Waste – to – Energy is a yet new concept as per as disposal and treatment of municipal wastes in India is concerned. The final outcome is in the form of energy, i.e., Power, Biofuel and Compost. Although these mechanisms have given positive outcomes when it was applied in developed countries. But as far as developing countries like India is concerned it is one the initial stages of application because of the testing factors like financial viability and sustainability [10]. According to Municipal Solid Waste (Management and Handling) Rules 2000 have required steps and initiatives which have been taken by all Local Administrative Bodies in order to improve Solid Waste Management in India [11]. Some of the rules of MSW – Rules 2000 include regular door to door collection, provision of secondary storage for MSW before disposal and finally provision of recycling of wastes and recovery out of it through composting in the form of energy like Biofuel, electricity etc. But Financial constraints is a major factor and also lack of infrastructure and proper technology are the major factors which is responsible for the backdrop in solid waste management in India [11].

Technological Options for Transforming Waste to Value added Products

Table 1 describes the various technological options that can be used to convert waste to useful products that can also be used in various forms of energy as well [12-17].

A Case Study of Jamshedpur

In order to explain how revenue generation from useful products, generated from the municipal wastes, is a very big contributing factor to the sustainable ways of treatment of solid waste, this paper includes a case study of Jamshedpur. Jamshedpur is one of the prominent town of Jharkhand within the District of East Singhbum. It is an Industrial Town with various industries more significantly Tata Steel, Tata Motors etc. It has a population of 13,39,400 (as per census 2011) including the urban agglomeration as well. It is an industrial town including large scale as well as small scale industries. Thus, apart from domestic and commercial urban wastes a large amount of the type of solid wastes that are generated in this city are Industrial wastes. In order to make solid waste management sustainable we need to analyze the futuristic projection of the solid waste that is generated and the outcome which is projected so that it creates a sustainable and healthy environment for the projected future population.

The Future decadal population projection is calculated Mainly with 3 methods of calculation, that is through – Arithmetic progression (AP), Geometric progression (GP) and Incremental method.(as shown in Tables 1&2). The projected populations from 2021 – 51 helps to calculate the possible solid wastes generated in these upcoming years. Starting with the year 2021, the solid waste generated is 0.9 times the projected population of the years 2021. Further as the decadal population increases and the lifestyle changes in the upcoming years, the number of consumers increases which leads to the overall increase in the waste generated in the years ahead. Hence, 0.1 is added to 0.9 in each decade upto 2051. Also, the population of existing base year 2011 is less than the projected populations, so less waste is generated in 2011 as compared to that of from 2021 – 51, henceforth 0.1 is deducted from 0.9 to calculate the waste generated in 2011. In order to make the Solid waste management sustainable one of the essential steps would be to convert the solid waste that is generated into products or energies that would be useful for the society and the environment around. The solid wastes that are generated is mainely divided into two types of wastes, non-degradable and degradable. The non-degradable waste is being utilised mainely in the production of power or electricity. Whereas the degradable waste is used in the production of compost and biofuel. Overall, it is seen that out of the total solid waste that is generated 15% is non degradable wastes and 85% is degradable wastes. Thus, the Tables 3 & 4 below will show the amount of degradable and non-degradable wastes are generated in the upcoming years from 2021 – 51 and the amount of useful products extracted out of it which can be used in the form of energies (Figures 1 & 2).

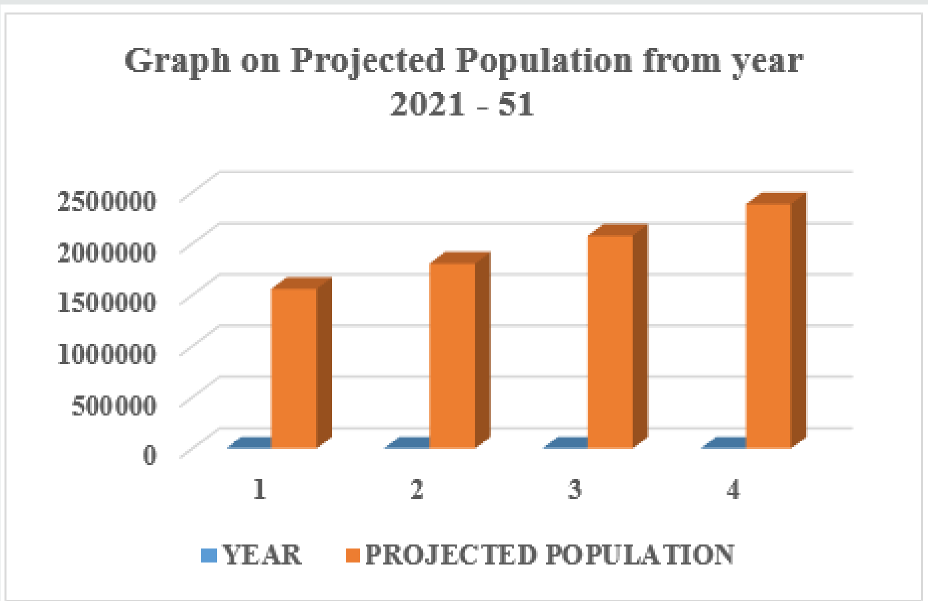

Figure 1: The Graph shows the decadal population projections from 2021 – 2051.

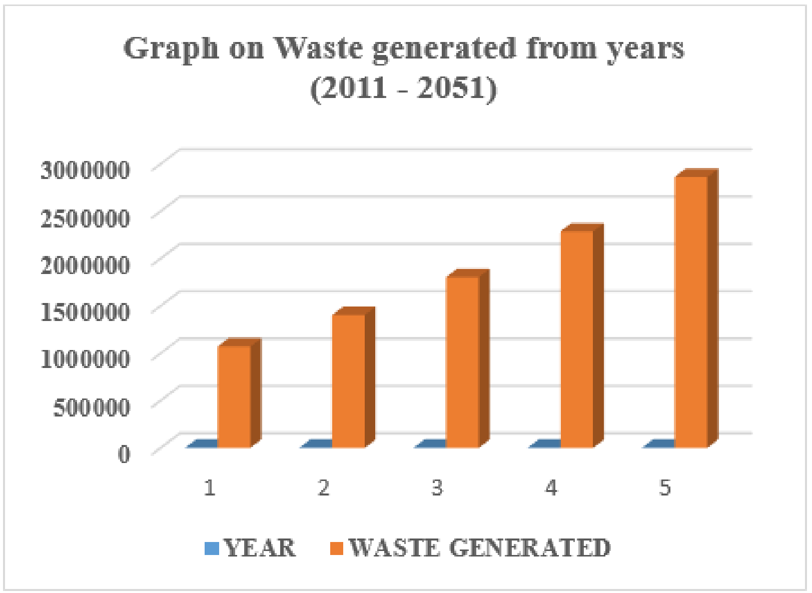

Figure 2: The Graph shows Solid waste to be generated from 2021 – 2051 including that of 2011.

Table 1: Technological Options. Describes the various technological options that can be used to convert waste to useful products that can also be used in various forms of energy as well.

Sr. No.	Technology [12]	Information about the Technology
1	Windrow Composting	Windrow composting is preferred in an area where higher ambient temperature is available. Organic matter (Wet waste) is converted into compost by aerobic decomposition. The aerobic microorganism oxidizes the wet waste into carbon dioxide and oxides of nitrogen. Carbon is used as an energy source and nitrogen is been recycled. Temperature of mass rises due to exothermic reaction. In this method, refused wet waste is delivered on the open land in about 20 windrows. The time required for windrow composting is approximately 4-8 weeks.
2	Vermicomposting	Vermicomposting is a process of converting organic matter into Bio-fertilizer using earth worms. These worms give out an excreta material in the form of 'vermicasts' when feed on the organic waste. this excreta material is rich in Nitrates, phosphorous, magnesium, calcium, and potassium. Thisis used as fertilizer and can be used to enhance the soil quality.
3	Bio methanation	Bio methanation is a process in which microorganism converts organic matter into biogas. It is a complex process leading to generation of methane and carbon dioxide. Bio methanation involves the process of Hydrolysis, acidogenesis, acetogenesis and methanogenesis.
4	RDF	Refused Derived Fuel (RDF) is a fuel derived from dry or non-biodegradable waste. It can be used to produce electricity or steam. Waste which has higher calorific value can be used to produce RDF. Dry solid waste with Caloric value 1500 Kcal/kg or more can be accepted in RDF plant. Process of conversion of dry waste into RDF include Screening, Coarse Shredding, bag splitting, shredding, Magnetic Separation and Refining Separation.
5	Incineration	Incineration involves burning of dry waste with energy recovery. But it will only disappear the solid waste problem and can leads air pollution. This is the most common method of waste to energy (WTE) around the world. It can reduce the volume of waste by 95-96%. Incineration process depends on composition and degree of recovery of material such as metals from ash for recycling.
6	Integrated system (Composting + RDF)	The aim of Integrated System is to achieve zero discharge. It could include composting of wet waste. Dry waste can be processed as RDF. Sanitary landfill can be included for refused waste coming out from Composting and RDF.
7	Sanitary Landfill	Sanitary landfill includes disposal of solid waste on land scientifically. The solid waste is either buried in underground or in large piles. The ground or base can be guarded with a thick plastic and a layer of clay which should be impervious. A collection system is there in the sanitary landfill to collect the leachate and gases coming out from the filled waste of sanitary landfill.

Table 2: Population Projection. Shows the decadal population projections from 2021 - 2051 by Arithmetic Progression, Geometric Progression, Incremental method and finally the average of it, depending on the existing population of 2011.

Year	Projected Population by AP	Projected Population by GP	Projected Population by Incremental Method	Average projected Population
2011	-	-	-	13,39,400(existing)
2021	1525800	1601458	1550680	1559313
2031	1712200	1914788	1786840	1804609
2041	1898600	2289421	2047880	2078634
2051	2085000	2737354	2333800	2385385

Table 3: Solid waste generated. Gives the total solid waste generated by the projected population from the year 2021 - 51 and of existing 2011 as well.

Year	Waste Generated	Unit
2011	1339400 x 0.8 = 1071520	Kg/Capita/Day
2021	1559313 x 0.9 = 1403381.7	Kg/Capita/Day
2031	1804609 x 1 = 1804609	Kg/Capita/Day
2041	2078634 x 1.1 = 2286497.4	Kg/Capita/Day
2051	2385385 x 1.2 = 2862462	Kg/Capita/Day

Table 4: Gives the amount of Non degradable waste that is generated out of the total solid wastes of 2021 - 51 and of existing 2011 as well and the power generated out of the non-degradable wastes.

Year	Non degradable Waste	Unit	Power Generated	Unit
2011	160.73	Ton/Capita/Day	1.6073	Megawatt
2021	210.51	Ton/Capita/Day	2.1051	Megawatt
2031	270.69	Ton/Capita/Day	2.7069	Megawatt
2041	342.98	Ton/Capita/Day	3.4298	Megawatt
2051	429.37	Ton/Capita/Day	4.2937	Megawatt

*Note: (Power generated = Non degradable waste generated / 100).

In order to make it more sustainable and encourage these above-mentioned processes of solid waste management to convert the wastes into useful products which can be used as certain forms of energies, it is very necessary to consider the factor of revenue generation from these processes. The cost generating factor would make the municipal bodies to adopt these processes of converting wastes into useful forms of energies more frequently as giving monetary outcome along with making it a better and clean environment increases its socio-economic value and sustainability (Figure 3). An approximate rate is assigned to each of the useful resultantused as energies derived from the wastes. The assumption is based on the concept that the rate increases with increase in the decadal years in future due to appreciation as the projected population appreciates in the upcoming years producing rate of increase in the waste generated as well. The increasing rate also increases the economic value of the wastes generated in the future years as well. As far as conversion of non degradable wastes into power is concerned the rate assigned to the power generated is uniform throughout each decade and that is Rs. 4000 (per megawatt). Hence, the economic value of converting non degradable wastes to power is shown in the Tables 5 & 6 below. The rates assigned for the conversion of degradable wastes into Biofuel is 45 rupees (per litre) for the first projected year (i.e., 2021) and is increased by 15 rupees with the increase of each decadal year upto 2051 and 15 rupees is reduced for the existing decadal year (i.e., 2011) as the population and the waste generated depreciates in this case, as per the Tables 7 & 8 given below. Lastly, the rates assigned for the compost generated from the degradable wastes is 5 rupees (per Kilogram) for 2011, which is the existing decadal year and is increased by 5 rupees with the increase of each projected decadal year upto 2051, as shown in the Table 9 below.

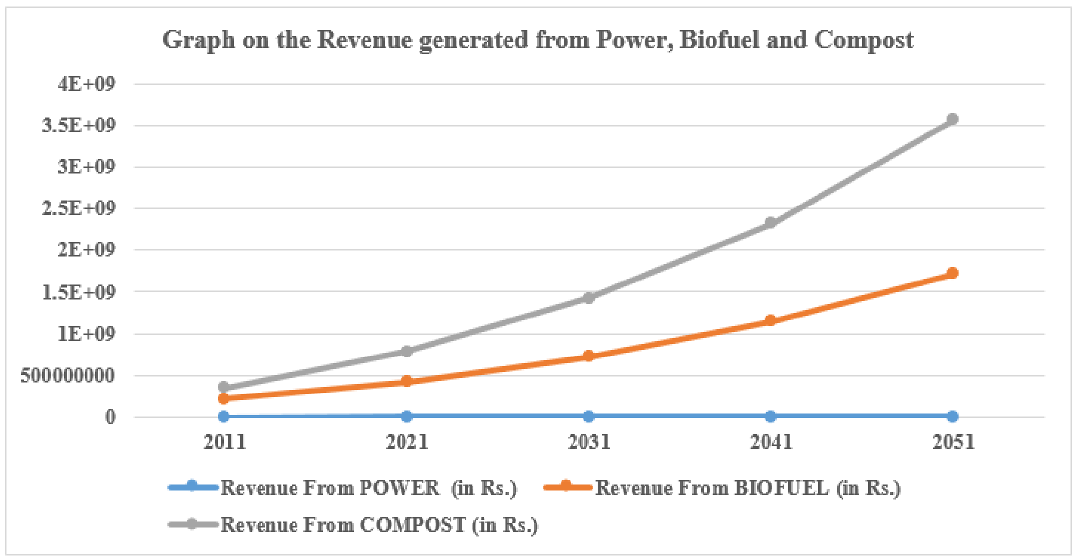

Figure 3: The above graph gives an idea of the result of converting waste to products which can be very useful sources of energy and the revenue collected from it if we add up the cost generating factor to it.

Table 5: Gives the amount of Degradable waste that is generated out of the total solid wastes of 2021 - 51 and of existing 2011 as well and the Biofuel generated out of the Degradable wastes.

Year	Degradable Waste	Unit	Biofuel Generated	Unit
2011	910.79	Ton/Capita/Day	19518.3	Litres
2021	1192.87	Ton /Capita/Day	25563.3	Litres
2031	1533.92	Ton /Capita/Day	32871.9	Litres
2041	1943.52	Ton /Capita/Day	41649.7	Litres
2051	2433.09	Ton /Capita/Day	52141.2	Litres

*Note: (Biofuel generated = Degradable waste generated*21.43).

Table 6: Gives the amount of Degradable waste that is generated out of the total solid wastes of 2021 - 51 and of existing 2011 as well and the Compost generated out of the Degradable wastes.

Year	Degradable Waste	Unit	Compost Generated	Unit
2011	910.79	Ton/Capita/Day	75595.7	Kg
2021	1192.87	Ton /Capita/Day	99008.6	Kg
2031	1533.92	Ton /Capita/Day	127315	Kg
2041	1943.52	Ton /Capita/Day	161312	Kg
2051	2433.09	Ton /Capita/Day	201947	Kg

*Note: (Compost generated = Degradable waste generated*83).

Table 7: Gives the revenue which can be generated when non degradable waste is converted into energy in the form of power per day and per year as well (expressed in Rupees).

Year	Cost From Power (Per Day) (In Rupees)	Cost From Power (Per Year) (In Rupees)
2011	6429.12	2346629
2021	8420.29	3073406
2031	10827.7	3952094
2041	13719	5007429
2051	17174.8	6268792

*Note: (Cost generated from Power per day = Non degradable waste generated*4000).

Table 8: Gives the revenue which can be generated when Degradable waste is converted into Biofuel which can be a great source of energy per day and per year as well (expressed in Rupees).

Year	Cost From Biofuel (Per Day) (In Rupees)	Cost From Biofuel (Per Year) (In Rupees)
2011	19518.27 x 30 = 585548.18	2.1E+08
2021	25563.299 x 45 = 1150348.471	4.2E+08
2031	32871.85 x 60 = 1972311.31	7.2E+08
2041	41649.69 x 75 = 3123727.004	1.1E+09
2051	52141.177 x 90 = 4692705.89	1.7E+09

Table 9: Gives the revenue which can be generated when Degradable waste is converted into Compost per day and per year as well (expressed in Rupees).

Year	Cost From Compost (Per Day) (In Rupees)	Cost From Compost (Per Year) (In Rupees)
2011	75595.736 x 5 = 377978.68	1.4E+08
2021	99008.579 x 10 = 990085.79	3.6E+08
2031	127315.165 x 15 = 1909727.474	7E+08
2041	161312.392 x 20 = 3226247.831	1.2E+09
2051	201946.694 x 25 = 5048667.353	1.8E+09

Conclusion

With the rapid pace of urbanization in India and migration of village workers to urban areas, the solid waste generation is increasing thereby posing serious threat to environment and human beings. Municipal Solid Waste Management (MSWM) in India started from 1960, but has still not achieved any great success. Enforcement of effective legislations on take-back obligations should be in place. Therefore, appropriate planning and implementation of MSWM is crucial for maintaining sustainable development. The present case study highlights the significance of decentralized MSWM for Jamshedpur district which provides different scenarios that already exists and new technologies that could be adopted. The solid waste generation for the projected population is calculated along with the quantity of value-added products that could be derived from this waste. These methods are not only minimizing environmental risks but have enough potential to maximize the economic and technical aspects of waste. It is acclaimed that segregation of waste, combining with electricity and biogas recovery would be the best option for Municipal SWM. Moreover, these practices avoid the potential materials loss from MSW that increases the environmental and economic impacts. The district of Jamshedpur needs to innovate and evolve an efficient MSWM system with enough incentives, economic inputs and provisions which should be viable as well as socially acceptable. Since the major concern is the nature of mixed waste in MSW and its segregation, reduction of such organic waste generation by effective separate collection should be seen as an alternative route for effective MSWM.

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