Biological treatment of solid waste management in ULBs

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Abstract

In India, MSWM is governed by MSWR. However, majority of ULBs do not have appropriate action plans for execution and enactment of the MSWR. Unfortunately, no city in India can claim 100% segregation of waste at dwelling unit and on an average only 70% waste collection is observed, while the remaining 30% is again mixed up and lost in the urban environment. Out of total waste collected, only 12.45% waste is scientifically processed and rest is disposed in open dumps. Environment friendliness, cost effectiveness, and acceptability to the local community are major attributes to achieve efficient solid waste management system. Environmentally benign practices are the need of the hour to cope with the almost exponential growth of MSW. For this, appropriate technological solutions through PPP are required. However, lack of competency and insufficient financial support are major threats to ULBs for development of MSW infrastructure. There is need for PPP to implement management and handling with the latest technology/ know-how with the subject experts firms and companies. Establishment of the good public governance in compliance with secured regulatory framework and appropriate financial support and strict contract implementation is required for the success of PPP. Capacity building and availability of skilled labor, familiarity with new and as well as best practices available for SWM, financial incentives for identifying new techno-feasible solutions, appropriate and quick decision at ULBs level for smooth implementation are real challenges. India is still struggling to make waste-to-energy project a success story.

Key words: 1.MSWM, 2.SWM, 3.ULBs

Introduction

The world cities generate 1.3 billion tons of solid waste/year, which is estimated to be about 1.2 kg/capita/day. It is projected that waste generation would be about 2.2 billion tons per year by the year 2025. The per capita waste generations by North America for Economic Co-Operation and Development countries are found to be on the higher side. On the other hand, most of the African and Asian cities have a lower waste generation rate, although experiencing some changes in recent years with changes in their level of income, increased urbanization and consumption habits. Although, South Asian region compared to OECD, European Union and even South East Asian countries produces a lower amount of solid wastes, it is expected that waste generation by many Asian countries, including South Asian region (SAR), would keep on accelerating with changes in their level of income, faster GDP growth, and growth in urbanization and change in consumption pattern. Most mega-cities in Asia still produce lower/capita municipal waste compared to most other regions (OECD, MENA and Latin American regions (LCR)). But with changes in level of income, availability of consumer goods, consumption habits and people‘s lifestyles, generation of solid wastes are expected to amplify with time across the Asian cities. It is reported that by 2025 daily municipal solid waste generation by Asia alone would be 1.8 million tons/day. This may raise its per capita waste generation between 1.2 kg to 1.4 kg per day/person. It is postulated that solid waste generation has a strong and positive relationship with family income level as income largely determines people‘s consumption pattern. Based on this understanding, generation of solid waste by different income earning countries (i.e. high income, upper middle income, lower middle income and lower income earning countries) has also been analyzed. Estimated current/day/capita average solid waste generations by the four income earning country groups are found to be 2.1, 1.2, 0.79 and 0.60 kg. Solid waste management through proper waste collection, segregation, transportation, land-filling or recycling services depend much on a country‘s economic and technological capabilities. It also depends on relevant policy and legal frameworks and their implementation efficiency. A high waste collection efficiency can be observed across the developed and upper income earning countries, while a lower efficiency is recorded by most of the low and lower middle income earning countries like India, although things are expected to be changed with time in many countries. Evidences show that waste collection efficiency ranges from 46 percent in African region (AFR) to 98 percent by OECD countries. In case of waste composition, low income earning regions like AFR, EAP and SAR are found to have lower inorganic waste components in their daily wastes generations compared to the high income earning OECD countries. This ranges from 38 percent in EAP region to 73 percent for OECD countries. A similar trend is thought to be followed by these income earning groups even until 2025. Furthermore, an increasing ratio of inorganic to organic solid wastes by most municipal corporations across the lower and lower middle income countries is expected to increase in Asia and Africa.

Review of Literature

According to (NIUA, 2015), there are 5034 towns in India, wherein 4003 urban local bodies (ULBs) have been constituted. They play a crucial role in municipal solid waste management system. The average municipal solid waste generation in India, according to (Annepu and Kharvel 2012), which was a sharp increase within a period of just five years. It is also expected that this might experience some further surge in the coming decades. A study on a comprehensive dataset of 366 Indian cities by (Annepu and Kharvel 2012) revealed that by the time period of 2001 to 2021, per capita solid waste generation in India would increase from 0.50 kg/day to 0.57 kg/day. Annual waste generation by the 366 Indian cities is expected to increase from 47.3 million tons in the year 2011 to 71.2 million tons in 2021. Similarly, for the same time period waste generation by entire urban Indian is expected to be from 1.85 lakh tons to 2.78 lakh tons daily, which comes out to be 67.6 million tons to 101.6 million tons annually, respectively. This implies that in between 2011 to 2021, total (cumulative) municipal solid waste generation by 366 Indian cities would be 643.5 million tons, while the entire urban India might experience producing a huge amount of 919.3 million tons of solid wastes by the same timeline. Another study (JnNURM, 2014) reported that by 2031 urban India is projected to generate 165 million tons of waste annually and by 2050 it could reach 436 million tons. To accommodate this amount of waste generated by 2031, about 23.5 × 107 cubic meter of landfill space is required and in terms of area it would be 1,175 hectare of land per year. The area required from 2031 to 2050 would be 43,000 hectares for landfills piled in 20 meter height. These projections are based on 0.45 kg/capita/day waste generation.

Methods for Solid Waste Management

Solid Waste Management is a science associated with the management of generation, storage, collection, transportation, processing and disposal of solid waste using the best principle and practices of public health, economics, engineering, conservation, aesthetics and other environmental conditions. Solid Waste Management is one of the important obligatory functions of urban local bodies in India. Solid waste management reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal.

Non-engineered disposal

This is the most common method of disposal in low-income countries, which have no control, or with only slight or moderate controls. They tend to remain for longer time and environmental degradation could be high, which include mosquito, rodent and fly breeding, air and water pollution, and degrading of the land. In many Indian cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation.

Land filling

Sanitary land filling is an acceptable and recommended method for ultimate disposal of MSW. It is a necessary component of MSWM, since all other options produce some residue that must be disposed of through land filling. However, it appears that land filling 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 land filling. Sanitary landfill is a fully engineered disposal option, which avoids harmful effects of uncontrolled dumping by spreading, compacting and covering the wasteland that has been carefully engineered before use. The compact layer of soil restricts continued access to the waste by insects, rodents and other animals. It also isolates the refuse, minimizing the amount of surface water entering into and gas escaping from the waste. Sanitary land filling is a necessary component of solid waste management, since all other options produce some residue that must be disposed off through land filling.

Recycling of organic waste

If the organic waste is left unattended, it will tend to decompose by natural process giving rise to odours, hosting and feeding a variety of insects and pests, which in turn, form the carriers of disease creating severe health problems. The segregation, decomposition and stabilization of the organic waste by biological action forms the basis of recycling through different natural cycles.

Treatment of MSW

Aerobic composting

Composting is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moisture and organisms in the waste themselves that convert waste into humus like material by acting on the organic portion of the solid waste. If carried out effectively, the final product is stable, odour free, does not attract flies and is a good soil conditioner. Composting is considered when biodegradable waste is available in considerable fraction in the waste stream and there is use or market for compost. This is a popular technique in Europe and Asia, where intense farming creates a demand for the compost**.** Centralized composting plant for sector may only be undertaken if adequate skilled manpower and equipment are available, hence at household level and small level composting practices could be effective which needs the people's awareness. Many large-scale compost plants with capacities of ranging from 150 to 300 tonnes/day were set up in the cities of Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur and Kanpur during 1975-1980**.** Now, about 9% of solid waste is treated by composting. Composting was encouraged in the early initiatives of the Government of India (GOI) regarding MSWM focused primarily on promoting composting of urban MSW. In the 1960s, the Ministry of Food and Agriculture offered soft loans to urban local bodies for this purpose. The 4th 5-year plan (1969–1974), block grants and loans were provided to state governments for setting up MSW composting plants. Finally, in 1974, GOI introduced modified scheme to revive MSW composting, particularly in cities with a population over 0.3 million. As far as large-scale composting is concerned, many mechanical compost plants with capacities ranging from 150 to300 t/day were set up in the cities of Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur and Kanpur during 1975–1980 under the central scheme of MSW disposal. Indore city was a famous centre for from MSW was not used for soil enrichment due to many problems. 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 (US$0.046/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, Lucknow and Gwalior.

Vermicomposting

Vermicomposting involves stabilization of organic waste through the joint action of earthworms and aerobic micro organisms. 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, odourless 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. Municipal solid waste is highly organic in nature, so vermicomposting has become an appropriate alternative for the safe, hygienic and cost effective disposal of it. In this method earthworms feed on the organic matter present in the solid waste and convert into casting (ejected matter) rich in plant nutrients. Vermicomposting has been used in various cities of India like Hyderabad, Bangalore, Mumbai and Faridabad.

Anaerobic digestion

Recently, the organic fraction of solid waste has been recognized as a valuable resource that can be converted into useful products via microbially mediated transformations. There are various methods available for the treatment of organic waste but anaerobic digestion appears to be a promising approaches. Anaerobic digestion involves a series of metabolic reactions such as hydrolysis, acidogensis and methanogensis. Anaerobic digestion represents an opportunity to decrease environmental pollution and at the same time, providing biogas and organic fertilizer or carrier material for biofertilizers. The anaerobic treatment of solid organic waste is not as widespread as the aerobic process, mainly due to the longer time required to achieve biostabilization. The process is also sensitive to high levels of free ammonia resulting from anaerobic degradation of the nitrogen rich protein components. The specific activity of methanogenic bacteria has been found to decrease with increasing concentrations of ammonia.

Recovery of recyclable materials

A number of recyclable materials, for example paper, glass, plastic, rubber, ferrous and non-ferrous metals present in the MSW are suitable for recovery and reuse. It has been estimated that the recyclable content varies from 13% to 20% (for example, in Mumbai 17% and in Delhi 15% of MSW is recyclables). A survey conducted by CPCB during 1996 in some Indian cities revealed that rag pickers play a key role in SWM. They work day and night to collect the recyclable materials from the streets, bins and disposal sites for their livelihood, and only a small quantity of recyclable materials is left behind them. In India, about 40–80% of plastic waste is recycled compared to 10–15% in the developed nations of the world. However, the recovery rate of paper was 14% of the total paper consumption in 1991, while the global recovery rate was higher at 37%. The role of governments in recovering secondary materials is small compared to the informal sectors. In Delhi, there are more than 100,000 rag pickers and the average quantity of solid waste materials collected by one rag picker is 10–15 kg/day. About 17% of Delhi waste handling is done by rag pickers, who collect, sort and transport waste free of cost, as part of the informal trade in scrap, saving the government Rs 600,000 (US$13,700) daily. In Bangalore, the informal sector is attributed with preventing 15% of the MSW going to the dumpsites. The municipalities in Pune save around Rs. 9 million/yr (US$200,000) on account of waste pickers. In Hyderabad, the cost of MSWM per ton is less in the areas where THE private sector participated compared to the areas serviced by municipality. In Mumbai, it is found that the cost of per ton of MSWM is US$35 with community participation, US$41 with public private partnership (PPP) and US$44 when only Municipal Corporation of Greater Mumbai (MCGM) handles the MSW. Hence, community participation in MSWM is the least cost option and there is a strong case for comprehensively involving community participation in MSWM. Many other studies that have been undertaken by different institutes and authorities revealed that the role of the informal sector in MSWM is very important because it provides a livelihood to many immigrants and marginalized people. The informal collection avoids environmental costs and reduces capacity problems at dumpsites; also, rag pickers can provide excellent segregation of MSW.

Composition of Pretreated Solid Wastes

S. No	Month	Organic Material (%)	Plastic (%)	Glass (%)	Stone (%)	Other inert material (%)	Total (%)
1	January (2022)	50.95	9.61	2.64	5..20	28.53	96.93
2	February (2022)	34.49	8.04	3.62	9.68	42.66	98.49
3	March (2022)	45.03	8.71	2.59	9.42	32.25	98.01
4	April (2022)	37.4	10.69	1.7	10.28	37.48	97.55
5	May (2022)	36.3	10.93	2.12	7.55	39.84	96.74
6	June (2022)	37.34	7.92	3.55	9.03	40.3	98.14
7	July (2022)	42.7	10.21	2.12	6.16	31.35	92.54
8	August (2022)	41.55	12.44	1.4	8.54	32.01	95.94
9	September (2022)	42.42	10.08	2.33	10.8	27.5	97.13
10	October (2022)	39.8	8.03	2.3	10.3	34.8	95.23

Treatment and disposal of (MSWP) plastic wastes

Plastic bricks and tiles:

The table below deals with results on recycling of MSWP in the form of plastic bricks and tiles. Plastic bricks and tiles can be made by melting plastics along with tar in the ratio of 1: 1, 2:1and 3:1. However, our attempts for addition of coir waste along with MSWP and tar mixture in the ratio of 1:3:2 and 1:2:2 were failed to mould the plastics in the form of stable bricks and tiles. However, 1:3:3 ratio combinations of coir waste, MSWP and tar has yielded stable form of plastic bricks and tiles.

Preparation of plastic brick on MSWP

S. No	Tar (g)	Plastic (g)	Coir waste(g)	Initial weight(g)	Molded in brick	Final weight(g)
1	100	100	-	200	Brick	176
2	100	200	-	300	Brick	196
3	100	300	-	400	Brick	240
4	300	450	150	900	UMB	570
5	400	400	200	1000	UMB	630

UMB: Unable to mould in to bricks

Recycling of plastic waste in the form of fuel gas

S. No	Initial weight of Plastic + Tar (g)	Total heating time/ minutes	Amount of fuel gas (g)	Weight of plastic residues (Tar) (g)
1	50 + 0	16	18	27
2	50 + 50	25	36	55
3.	200+ 100	32	47	132
4.	300 +100	62	116	167

Plastic briquettes and its Calorific value

S. No	Amount of substrate *MSWOM: FSD	Average weight and size of briquettes		Total No. of briquet tes	Bulk density Kg/ m3	Calorific value KaCl/ kg
		Size (l × w × h)	Weight (g)			
1.	150 + 50	7.0 × 7.5 × 7.5	164.2	1	1234.28	2179.71
2.	200 + 00	9.2× 7.5 × 7.5	153.6	1	1003.4	2641.94

MSWPR: Municipal solid waste plastic residue, FSD: Fermented saw dust

Discussion

During various industrial, mining agricultural and domestic activities India produces 960 MT of solid waste. Which is a major environment and ecological problem besides occupying a large area of land for their storage and disposal? Waste treatment technologies like land filling, incineration (Thermal treatment), recovery and recycling, composting (aerobic and vermicomposting), biomethanization, pellatisation are being used for municipal solid waste management, out of these, recycling of waste is restricted to only reusable wastes, while composting is restricted to biodegradable solid wastes majority of waste are preferably land filled.

Thermal treatment and Land filling:

Thermal treatment of MSW can be accomplished by incineration, pyrolysis, and plasma Arc gasification. , If MSW has high dampness or has low calorific value, incineration is not feasible. Incineration of Indian MSW is not suitable as the MSW has high organic constituents, moisture content or inert content in the waste in the range of 30% - 60% each and calorific value in the range of 800-1,100 kcal/ kg in MSW. It is a cheap and simple method. However, land filling requires a huge land which lead strain on land resources.

Aerobic composting:

Composting is a phenomenon under which biological conversion of organic matter existing in MSW takes place in the presence of air under humid and warm environment composting could be either labor intensive or mechanical. In smaller town labor intensive composting is carried out. Reservation to use compost generated from MSW by farmers lack of appropriate market policy for use of RDF and compost makes such a project economically non- viable, India is still struggling to make waste - to - energy project a success story. There is need to import economically feasible and proven technologies. Environmentally benign practice is the need of the hour to cope with almost exponential growth of MSW. The waste generated in India has more organic content about 50% -as compared to 30% generated by developing countries. Further, to effectively utilize the biodegradable organic wastes of MSW, suitable methods will be adopted and emphasis should be made on innovative techniques, cost benefits and analysis, life cycle assessment etc. so, that the waste can be managed in an eco - friendly manner. By considering all the above facts and current status of MSW management in our country, an attempt was made to introduce solid state fermentation as a technology to treat and dispose MSWOM in an eco - friendly manner. Similarly, we have applied aerobic composting on MSWOIM to convert them in to useful products.

Pyrolysis:

Plastic are non-degradable polymers which contain carbon, hydrogen and others elements (chlorine, nitrogen, etc.). Due to its non biodegradable nature, this compound contributes several problems to waste management. There are different environmentally friendly ways of recycling plastic waste compared with incineration and disposal in landfills. ASTM D7209-06 indicates that the plastics can be recycled using four types of methods. One of them being the chemical recycling. In this method, chemical degradation leads to production of liquid fuels and chemicals with high added value from waste plastic fragments. Pyrolysis is the thermal decomposition of long chained hydrocarbon compounds into smaller ones in absence of oxygen at temperatures above 500°C generating gaseous and liquid product. Therefore, in this investigation we have made an attempt to recycle the non-recyclable plastics in the form of bricks and fuel gas.

Disposal and treatment of MSWOIM by aerobic composting:

It was reported that about 12 million tons of inert wastes were generated in India, annually. It occupies about one third of total MSW. we have recorded an annual average of 35.95%, inert materials in MSW of Madurai corporation. This is the second majour portion of MSW in not only in Madurai, but also in many Indian cities. Therefore, in this present investigation attempt made to convert it to compost and use them as plant growth media. In order to test their suitability for plant growth media, seed germination test were conducted with five different crop plants such as pulses, vegetables and cereals. Results indicated that compost was not supported the germination of seeds of Vigna radiate and Abelmoscus esculandus at its 100% concentration. Therefore, various % of compost concentration were prepared by mixing compost with red soil (garden soil). The resultant compost mixtures were tested for seed germination. The results revealed that the compost mixture support better seed germination in its lower concentrations particularly at its 10% concentration in all crop seeds which were used for the experiments.

Disposal and treatment of MSWP:

According to the World Bank, plastic waste accounts for 8–12% of the total municipal solid waste (MSW) worldwide, while it is estimated to increase to 9–13% of the MSW by 2025. The increasing availability of such waste material in local communities, coupled with the high energy density, render waste plastics one of the most promising resources for fuel production. The pyrolysis of plastics and other MSW for fuel production is practiced by several small-size companies worldwide, especially those of emerging economies, where industries such as cement, glass, and other energy-intensive sectors represent the reference market for this type of fuel (diesel-range hydrocarbons produced via the pyrolysis of plastics and MSW). The pyrolysis of plastics yields on average 45–50% of oil, 35–40% of gases, and 10–20% of tar, depending on the pyrolysis technology. According to previous research, there are some cases where a high amount of liquid yield, more than 80 wt %, could be produced in the pyrolysis of individual plastic, which is higher than the pyrolysis of wood-based biomass in general. The pyrolysis oil can be valorized better if separated into separate fractions with different boiling point ranges, e.g., light (0–170 _C), mid-distillate (170–370 _C), and heavy (>370 _C) fractions. The total pyrolysis oil or fractions of it can be further upgraded via suitable conversion processes, such as catalytic hydro treatment, to meet market fuel standards. A two- stage pyrolysis-catalysis of high-density polyethylene has been investigated, with the pyrolysis of the plastic in the first stage followed by the catalysis of the evolved hydrocarbon pyrolysis gases in the second stage leading to gasoline range hydrocarbon oil (C8–C12), by the results showed that, using the staged catalysis, a high yield of oil product (83.15 wt %) was obtained from high- density polyethylene. In the last years, the use of pyrolysis oil as a diesel fuel has been of main importance, and there are some latest references where they study the potential of using oils that have been derived from the pyrolysis of plastics at different temperatures in diesel engines. Plastic wastes were chopped, cleaned. Known amount of well cleaned plastic wastes was added along with boiled tar liquidThe performance of later was not up to our satisfaction. Though, the single chambered gasification converted the waste in to fuel gas, oil and residues. It needs further investigation to improve its performance. The plastic residue collected from the gasifier was mixed with fungal fermented MSWOM and pressed into briquettes to be used as fuel.

Summary

MSWM comprises segregation, storage collection, relocation, carry-age, processing, and disposal of solid waste to minimize its adverse impact on environment. Unmanaged MSW becomes a factor for propagation of innumerable ailments. In the developed countries, solid waste management belongs to prominent thrust areas for pursuing research and economic and technological advancements have initiated responsiveness of stakeholders towards it**.** High population growth rates, rapidly varying waste characterization and generation patterns, growing urbanization and industrialization in developing countries are the important reasons for paying attention towards MSWM, as more area is required to accommodate waste. In India 12 million tons of inert waste is generated in India from street sweeping and construction and demolition debris waste and in the landfill sites, it occupies about one-third of total MSW. In India, MSWM is governed by implementation of MSWR is a major concern of urban local bodies across the country.

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