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Municipal Solid Waste Management (MSWM) Treatment Techniques: A Case Study of Chh. Sambhajinagar, Maharashtra, India

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ABSTRACT

Municipal solid waste management possess significant environmental challenges worldwide, and improper management can lead to public health hazards. The pattern and composition of waste generated vary by lifestyle and urbanization rates. Effective solid waste management can enhance living standards in developing urban areas by improving health and sanitation. Studies indicate that 90% of municipal solid waste issues stem from the poor management of open dumps and landfills. However, as a result of modernization and population growth, the municipal solid waste increased tremendously—one of the cities with the fastest rate of development, Chh. Sambhajinagar produces between 450 to 500 metric tons of waste every day. The city's population has grown from 1,177,330 in 2011 to over 1,683,000, with projections indicating it will exceed 1.8 million by 2026. This growth has led to significant waste accumulation and an urgent need for efficient waste management. In Chhatrapati Sambhajinagar Municipal Corporation, solid waste management employs an integrated strategy starting with source segregation and mechanical sorting. Biodegradable waste is processed through composting and bio-methanation, yielding manure and biogas; non-biodegradable waste is transformed into Refuse Derived Fuel (RDF). Recyclables like plastics, metals, and paper are redirected to recycling streams. The article reviews advancements in municipal solid waste management technologies and evaluates the city's current practices, emphasizing the importance of effective waste management for sustainable urban development.

Keywords Municipal solid waste management (MSWM), Landfill, Treatment technologies, Sustainable urban development.

INTRODUCTION

Municipal solid waste management (MSWM) is a major worldwide concern, especially in rapidly growing urban areas. Increasing population, urbanization, and economic development have led to higher waste generation, creating environmental and public health challenges. Waste management systems in India suffered from various drawbacks such as insufficient awareness among the public, improper

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waste segregation, substandard waste collection and transportation services, insufficient treatment facilities and financial limitations. Therefore, most municipal solid waste was not being treated. MSW is a mixed stream of recyclable, compostable, and non-recyclable materials, and its quantity and composition are influenced by factors such as population, income level, lifestyle, climate, and economic activity (Bamne and Mhatre 2019). According to the CPCB (Central Pollution Control Board), 34 states and union territories produced 1, 43,449 TPD (Tons per day) of MSW in 2013–2014. According to this data, India generates an average of 0.11 kg of waste per capita per day. About 1, 17,644 TPD (82%) of the waste produced was collected, and 32,871 TPD (22.9%) was processed or treated (CPCB 2013).

India's urban areas produce over 45 million tonnes of solid waste annually, which was improperly collected, transported, and disposed in 2025. The generation was predicted to produce 125 million tonnes annually. The Government of India's, Ministry of Urban Affairs estimated that the country produces about 1, 00,000 metric tons of solid waste per day, of which 90% was disposed of outdoors (Bhalla *et al.* 2013). If ULBs (Urban Local Bodies) in India continue to depend on landfills for MSW management, the country's population was expected to reach 1,823 million by 2051, producing about 300 million tons of MSW annually, which will require about 1,450 km^2 of land to dispose of systematically (Position paper on solid waste management sector in India 2009). Therefore, the amount of landfill space needed for waste disposal could be many times greater if per capita generation grows at 5% annually (CPCB 2013).

Review of literature

Importance of waste management and processing: environmental, economic and social perspectives

India was facing the lacking of resources or the technical expertise necessary to deal with the disposal of municipal solid waste (Kaushal *et al*. 2012). Only 6%–7% of the MSW was converted into compost in India (Annepu 2012). It has been noted that the production of municipal solid waste will rise significantly as India attempts to become an industrialized nation in 2020 (Gupta and Arora 2016), from 42 million tons annually in 2009 to 260 million tons in 2047 (Saxena *et al.* 2021). It was mentioned in the handbook on solid waste management that, according to TERI (The Energy & Resources Institute) the land required for MSW disposal will increase from 200 sq. km in 2011 to 1,400 sq. km in 2047. The opportunity cost of using land for MSW disposal is exceptionally high in urban areas, which have the highest MSW concentrations and are also the most land-scarce (Praja Foundation and Mumbai Vikas Samiti 2018). According to Akolkar (2005), the most Asian cities facing problem of open dumping. The waste collection efficiency in the major cities of India was ranges from 50% to 90% of the solid waste generated. The urban waste management problem has further intensified the already-existing problem of poorly planned cities. Large areas of land are needed to dispose of the bulk of municipal solid garbage. Particularly in developing countries, large amounts of garbage are produced, leading to further issues such as water and soil pollution and the spread of disease-causing vectors. Disposing of large volumes of MSW in landfills without treatment was not a wise decision (Verma 2006).

In India, open dumping is the common way to dispose of waste. Leachate can contaminate groundwater and negatively impact surrounding areas when inadequate barriers allow it to seep into the soil. Methane, a potent greenhouse gas that accounts for 50–60% of landfill emissions and contributes to global warming and unpleasant odours, was produced by decomposing waste (IPCC 2014 a, b). As of 2015, 18 EU (European Union) nations banned landfilling of all recyclable waste by 2025, and many countries (e.g., the United Kingdom, Poland and France) imposed taxes on landfilling to make it a less attractive option for waste disposal (World Energy Council 2016a, b). Incinerating 1 tonnes of municipal solid waste instead of landfilling it, for the same electricity generation as fossil-fuel power plants, resulted in avoiding carbon dioxide emissions equivalent to 1.3 tons (Kumar and Samadder 2017 ; ASME 2008). Furthermore, processing 1 million tonnes of trash annually in a waste-to-energy facility with an average operational lifespan of 30 years requires a land area of less than 1,00,000 m^2. In contrast, landfilling 30 million tonnes

Table 1. Type of litter we generate and approximate time it takes to degenerate.

Type of litter	Approximate time to degenerate
Organic waste (Vegetable & fruit peels, foodstuff)	A week or two
Paper	10-30 days
Cotton cloth	2-5 months
Wood	10-15 years
Woolen items	100-500 years
Tin, aluminum, and other	100-500 years
Metal items such as cans	One million years ?
Plastic bags	Undetermined
Glass bottles	Undetermined

Source: Handbook on Solid Waste Management (Praja Foundation PDF).

of waste requires an area exceeding 3, 00,000 m^2 (Kumar and Samadder 2017).

Table 1 Shows that the time required for waste degradation depends on type of waste. Organic waste like food and vegetable peels breaks down quickly, within weeks, and paper also decomposes in a short time. Cotton cloth and wood take more time for degradation; it takes months to years. In contrast, materials like wool, metals, and cans take hundreds of years to break down. Plastic bags and glass bottles are the most persistent, as they may not decompose for a very long time.

Table 2 Show a clear relationship between population growth, waste generation, land use and methane emissions in India. As the urban population increased from 56.9 million in 1947 to 247 million in 1997, both total waste and per capita waste also increased. This caused total municipal solid waste to rise from 6 million tonnes to 48 million tonnes per year. More waste was produced, more land was needed for dumping, and the land for dumping increased from 0.12 thousand hectares in 1947 to 20.2 thousand hectares in 1997. Meanwhile, methane released by landfills also, rising from 0.87 to 7.1 million tonnes. The projections for 2047 will be higher per capita waste (925 g/day), higher total waste (300 million tonnes), higher landfill area needs (140 thousand hectares) and higher methane emissions (39 million tonnes). Overall, the study indicated that population growth and consumption growth is directly correlated with waste generation, leads to increase in land use and greenhouse gas emissions.

Table 3. Area of land required for unsanitary disposal of municipal solid waste generated in India.

Year	Area of land occupied/ required for MSW disposal (km^2)	City equivalents (area wise)
1947-2001	240	50% of Mumbai
1947-2011	380	90% of Chennai
1947-2021	590	Hyderabad
1947-2047	1400	Hyderabad + Mumbai + Chennai

Source: Data from (Annepu 2012, Kalyani and Pandey 2014).

According to the Table 3, if the municipal solid waste was not properly managed, the land needed for dumping would be increased. It was estimated that about 240 km² would be required by 2001 (about half of Mumbai), 380 km² by 2011 (almost equal to Chennai), and 590 km² by 2021 (about the size of Hyderabad). By 2047, the requirement could reach around 1,400 km², which is roughly equal to the combined area of Mumbai, Chennai and Hyderabad.

In the perspective of sustainability and environmental protection, various waste management

Table 2. Increase in Municipal Solid Waste in India. (Singhal and Pandey 2001).

Year	Urban Population (Millions)	Daily Per Capita waste Generation (Grams)	Total waste Generated (Million tonnes)	Area under Landfills (Thousands of ha)	Annual Methane Emission (Million Tonnes)
1947	56.9	295	6	0.12	0.87
1997	247	490	48	20.2	7.1
2047 (Projected)	–	925	300	140	39

techniques have been developed and improved, including microbial processes such as composting and anaerobic digestion (AD). These methods produce useful products like nutrient-rich compost and biogas, whereas thermochemical processes such as gasification and pyrolysis produce outputs like syngas and bio-oil. (Cucchiella *et al.* 2017; Lu *et al.* 2020; Nanda and Berruti, 2021; Roy *et al.* 2022). Likewise, bio methanation (anaerobic digestion) is a promising technology for the production of biogas and digestate from organic waste, which contributing to renewable energy generation and nutrient recovery (Nanda and Berruti 2021).

New developments in waste-to-energy systems have also demonstrated that the use of Refuse Derived Fuel (RDF), which is produced by converting non-recyclable combustible wastes, especially in cement industries, is gaining momentum in the field of fossil fuel substitution and energy recovery (Kumar *et al.* 2024 ; Sarangi *et al.* 2023). The use of thermal treatment technologies, particularly incineration which was substantially reduced waste volume by up to 80–90% and mass up to 70–85%. (Farooq *et al.* 2021 ; Nanda and Berruti 2021). In addition, several studies have been conducted to determine the benefits of composting, waste -to-energy (WTE) and anerobic digestion to manage waste and recover valuable resources.

MATERIALS AND METHODS

Aurangabad, the "City of Gates", presently known as Chhatrapati Sambhaji Nagar located at 190 53'50''N and 750 22'46''E, Marathwada region, Maharashtra, India. The city is situated on the banks of Kham River, a tributary of the Godavari River, having population of 1,175,116. It is divided into 10 zones, each with 9 to 13 wards. In 2022, the town produced about 455-500 metric tonne (MT) of municipal solid waste. The city's residential areas (roughly 2.5-3 lakh housing units), businesses, vegetable markets, guest houses, restaurants, hospitals, health centers, and Mangalkaryalaya (marriage halls) are the primary sources of municipal solid waste in the Chh Sambhajinagar. Hence, the study is conducted to determine the performance of the existing solid waste processing unit.

Table 4. Processing and recycling unit.

Dumping Yard	Waste processing on average in Tonnes/day
Chikalthana	150 MT
Padegaon	150 MT
Harsool	150 MT
Kanchanwadi (Bio methanation)	30 MT

In Chh. Sambhajinagar, the Municipal Corporation has established four municipal solid waste treatment facilities in Padegaon, Chikalthana, Harsool, and Kanchanwadi, employing an integrated waste management system focused on recycling, reuse, and waste reduction. The Kanchanwadi facility processes 30 metric tonnes per day, while Padegaon, Chikalthana, and Harsool each handle 150 TPD (Table 4).

The collected waste was transported to a covered pre-sorting shed, the waste from the transfer station is emptied onto a tipper platform. After that, it goes into a feeding hopper by use of mechanical devices like tractors or grapple loaders. Later the waste has gone through a 100 mm pre-sorting trommel, the remaining non-biodegradable and inert elements are manually removed, and the rest of the biodegradable fraction is collected. The remaining fraction, which consists of bigger materials, was directed to the RDF processing for selection of additional use, while the separated organic waste is moved to a concrete composting pad for decomposition. The windrows of about 4 m × 2.5 m size are made, and on the composting pad, the waste is spread out with microbial culture, and then the material was left to undergo aerobic decomposition for a first period of 7 days. Ensuring the maintenance of critical conditions such as moisture, temperature, and aeration to promote optimal microbial activity. The windrows are subsequently turned, loosened and aerated at the end of each 7th day to provide an adequate supply of oxygen to the windrows and to ensure a uniform decomposition.

The material from 35 mm screen is passed to 14 mm screen and reject from 35 mm and 14 mm screens are passed to the reject heap. Partly used the non-degradable materials for Refuse Derived Fuel (RDF) and the rest as landfill cover material. The

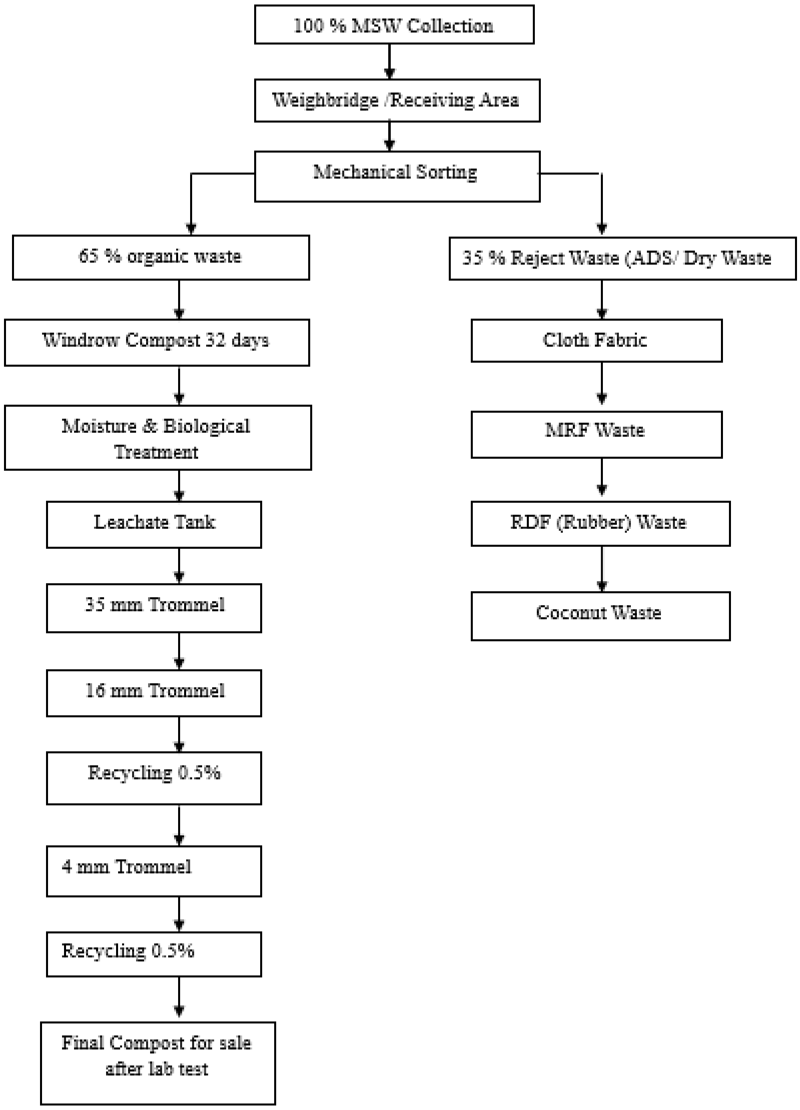

Fig. 1. Flow diagram of MSW processing and compost production.

material from the 14 mm screen is fed through the magnetic separator to remove ferrous materials, and then it was passed through the final screen (6 mm) to get fine compost. It is then preserved for 10-15 days in a curing shed to stabilize and mature the material. The plant not have the crushing or grinding facilities, which reduces the glass or sharp inert materials. There is a gravity de-stoning system to separate sand and silica. The 6 mm rejects are used to make pit-fill manure or land fill cover. The final compost sample is sent to the laboratory for testing and then it is packed and ready for use (Fig. 1). It was estimated that approximately 1200 lakh MT of old waste was dumped at Naregaon, which is now being transferred for biomining.

Bio-mining of legacy waste

It refers to the excavation of old dumped waste and the creation of a windrow of legacy waste. Thereafter, stabilization of the waste through bio-remediation i.e. exposure of all the waste to air along with use of composting bio-cultures. Screening of the stabilized waste to recover all 11 valuable resources (like organic fines, bricks, stones, plastics, metals, clothes, rags, etc.), followed by its sustainable management through recycling, co-processing, road making, etc. However, there are also some drawbacks linked to bio-mining like the presence of contaminants, presence of heterogeneity in wastes, operational inefficiencies and the need for appropriate processing facilities for the safe utilization of recovered fractions (CPCB 2019).

Despite these limitations, bio-mining is known to be key among the interventions under sustainable urban waste management policies like the Indian government's Swachh Bharat Mission–Urban, which aims at scientific remediation of legacy waste in cities in India (Swachh Bharat Mission–Urban 2024). In general, it can be said that bio-mining is a promising method to convert the legacy waste into valuable resources, which can sustain the principles of circular economy and enhance environmental quality in the fast-growing urbanized areas (World Bank 2022 Kumar and Samadder 2017).

Bio-Methanation Plant which is located in Kanchanwadi having capacity Around 30 MTPD. This waste was collected and transferred to the Chh. Sambhajinagar Municipal Corporation (CSMC) waste processing and disposal site. Anaerobic digestion is a biochemical process in which complex organic materials are converted, through the biological process, to biogas without the presence of oxygen, which involves several reactions. The first step in the process is hydrolysis, where complex polymers, like carbohydrates, lipids and proteins found in the organic waste, are enzymatically converted to simpler soluble compounds, such as sugars, amino acids and long chain fatty acids. This is followed by acidogenesis in which these hydrolysis products are utilised by acidogenic microorganisms, creating a variety of intermediary products including volatile fatty acids, keto acids, carboxylic acids, alcohols, ketones and other organic by-products.

These intermediate products are then used by sub-sequent acetogenesis to form simpler compounds, mainly acetic acid and others like hydrogen, carbon dioxide, formic acid and short-chain fatty acids. A methanogenic archaeon is an anaerobic organism that converts mixtures of acetate and hydrogen-carbon dioxide to methane and carbon dioxide, and forms the last step of methanogenesis. Methane and carbon dioxide are the last products of the anaerobic digestion and form biogas.

RESULTS AND DISCUSSION

In the existing solid waste management treatment facility, mixed and contaminated nature of incoming waste leads to operational inefficiencies, increased equipment wears and tear and required high maintenance. So, it reduces overall performance and capacity utilization of the plants. The results indicated the need for efficient waste processing for environmental protection and sustainable urban development. The treatment technologies like waste to energy system helps to minimize the emission of Green House Gases (GHG) and enable energy recovery, and bio mining helps reclaim the landfill sites and minimize the long-term environmental risk. Therefore, better segregation practices and upgrading processing equipment was necessary to make the system of managing MSW more efficient and sustainable.

The comparative operational performance of the Chh. Sambhajinagar and Indore MSWM system is shown in Table 5.

The Table 5. shows the differences about system utilization and operational efficiencies of Chhatrapati Sambhajinagar and Indore. Chhatrapati Sambhajinagar was highly dependent on landfilling, municipality has a medium level of processing efficiency, and has a moderate level of open dumping. In Indore, landfilling activity was very low and has a high processing efficiency with minimal open dumping. The corresponding study was limited in its ability to optimize its processing efficiency due to moderate source segregation, high landfill dependency and low community involvement. Waste segregation at source was moderate with inconsistent practices in various wards. This led to increased landfill reliance and was reflected in relatively moderate levels of

Table 5. Shows Performance Comparison of MSWM Systems: Chhatrapati Sambhajinagar vs Indore (2023 & 2025).

Indicator (2023–2025)	Chh. Sambhajinagar	Indore
Landfilling / Dumping	High	Very low
Composting (Organic waste)	Medium	Included in processing
Recycling (Dry waste)	Medium-low	Included in processing
Other treatment (WtE / RDF/ Bio-CNG)	Low	Included in processing
Total Processing/ Treatment efficiency	Low-medium	Very high
Open dumping	Moderate presence	Negligible
Segregation at source	Moderate	~100%
Processing capacity	Limited	High-scale integrated
Landfill dependency	High	Very low
Mechanization level	Medium-low	High
Citizen participation	Moderate	Very high
System maturity	Transitional	Fully integrated model

Source : (CPCB 2023; Indore Municipal Corporation 2023; Kaushal *et al.* 2012; Samuel *et al.* 2024; Swachh Bharat Mission–Urban 2024 ; World Bank 2022).

mechanization of waste operations. Also, the citizen participation was low meaning that citizen participation programs were implemented, but not yet fully and consistently integrated. As a result, the performance of waste management was moderate.

On the other hand, Indore has a very efficient and integrated solid waste management system with close to 100% source segregation and citizen participation. It has well-equipped processing facilities with high mechanization, low landfill waste, and implementation of circular economy. Finally, the case study suggested that even though Chh. Sambhajinagar was moving towards an integrated MSWM system. However, the framework was in the process of development with continuous upgradation for achieving greater efficiency and sustainability. While Indore has a well-functioning and efficient urban solid waste management system.

The findings of Gautam *et al.* (2010) supported the use of composting as an effective municipal solid waste management method. The study showed that the high organic content of municipal waste can be converted into nutrient-rich compost through the windrow composting method. This process not only decreases the amount of waste in landfills, but also generates benefits for the soil fertility, sustainable and cost-effective solution in urban waste management. The study done by Kumar and Samadder (2017) discussed about various waste to energy technologies and concluded that these technologies have a great potential in managing the municipal solid waste. The study noted that these technologies can help to shrink waste volume and recover energy. But their effectiveness relies on effective source segregation, choice of technology and implementation strategies. Axelsson and Kvarnstrom 2010 stated that waste to energy plant on BOOM ((Build, Own, Operate and Maintenance) based was established by Asia Bio-energy LTD., Chennai for Lucknow city in the year 2003 utilizing 500—600 tonnes of waste, the plant has produced a power generation capacity of 5 MW. Ramachandra and Bachamanda (2007), found that the municipal solid waste management system of Bangalore was plagued by sub-optimal source separation and collection making treatment technologies less effective. The analysis shows that mix and contaminated waste stream was a major issue in the operation of composting plants facility that hinders the plants to function at their best level. It has determined that the operational and infrastructural limitations are one of the main challenges to achieve sustainable waste management in the urban area.

Gupta *et al.* (2015) indicated that in India, municipal solid waste management was mostly dominated by inefficient collection and disposal methods, with little use of modern technologies. Study identified that the lack of bio-methanation and recycling facilities was due to low segregation and suitable infrastructure. Study also pointed out the necessity of integrated and technology-based waste management strategies. About 500 TPD municipal solid waste and 6 MW of power generation capacity waste-to-energy plant was set up by Shriram Energy Systems Ltd. at Vijayawada, Kumar said. Since December 2003, the plant has been in successful operation and is proving the feasibility of electricity production from urban waste (Kumar *et al.* 2009).

CONCLUSION

In summary, bio-methanation and composting are sustainable and resource-efficient technologies to manage municipal solid waste in India with additional advantages of generating renewable energy and mitigating environmental impacts. Although effective decentralized and large-scale projects have been implemented in some cities, issues such as lack of segregation and feedstock availability remain. Earlier research stated that larger and properly managed facilities could boost efficiency and feasibility of MSW. So, improvements in waste management and technology deployment are needed to better realise the potential of MSWM.

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