

Life Cycle Assessment and Environmental Impact Assessment Nashik Solid Waste Management Plant

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ABSTRACT

Rapid urbanization and population growth have significantly increased municipal solid waste (MSW) generation in Indian cities, posing serious environmental and public health challenges. Nashik city, Maharashtra, has experienced a nearly threefold population increase over the past three decades, resulting in a corresponding rise in waste generation. This study evaluates the sustainability of the Nashik Municipal Solid Waste Management (MSWM) system using an integrated approach combining Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA). The assessment follows ISO 14040 and ISO 14044 guidelines, considering the complete waste management chain from collection and transportation to processing and final disposal using one tonne of MSW as the functional unit. Population and waste generation data from 1995 to 2025 were analysed, revealing an increase in MSW generation from approximately 441 tonnes per day to 1,176 tonnes per day, with an average per-capita waste generation rate of 0.5 kg/day. Waste composition analysis indicated that 52% of the waste is organic, highlighting significant potential for composting and biogas recovery. Life Cycle Inventory (LCI) data were developed using primary and secondary sources to estimate energy use, fuel consumption, and greenhouse gas emissions. Results indicate that landfilling remains the major contributor to environmental impacts, particularly global warming potential. Scenario analysis suggests that improved source segregation, decentralized composting, biogas utilization, and enhanced landfill gas capture can substantially reduce environmental burdens. The study emphasizes the importance of integrating LCA and EIA into municipal decision-making to support sustainable, resource-efficient, and environmentally sound solid waste management strategies for rapidly growing urban centres.

Keywords:- Life Cycle Assessment (LCA), Environmental Impact Assessment (EIA), municipal solid waste (MSW), Life Cycle Inventory (LCI)

1. INTRODUCTION

Solid waste one of the net results of economic development, adversely influences the environmental resources and this has become a major environmental issue in the era of modern economic development. This necessitates proper SWM systems, which is essential to maintain healthy environment of the globe as green as. It is learned from the scanning of earlier research studies on SWM that the conventional approaches that is prior to 1970s, visualized the problem of SWM as a responsibility of urban and semi-urban government, where the economic activities largely occurred, which in turn produced large quantum of solid waste and affected the quality of environmental resources. After 1970s, the research studies started focusing on other regions (semi urban, urban, rural) and also others economic sectors (households and territory). There are also studies on technological aspects of SWM. But, relatively very few studies have examined the SWM in semi-urban and rural areas of an economy particularly at the levels of town and village panchayats.

Further, there has been a shift in methods and techniques used for managing the solid waste. Expressing concern regarding the negative impacts of the growing volume of solid waste and initiating measures to implement an appropriate Solid Waste Management (SWM) system aimed at mitigating the harmful properties of solid waste generated by various economic sectors.

2. LITERATURE REVIEW

[1] Nilofar Saifi, Bandana Jha (2024) - This study presents an overview of solid waste management practices in Pune, Maharashtra, highlighting the effectiveness of the SWaCH-PMC model. The city has achieved a 95% waste segregation rate through active participation of informal waste pickers, ensuring economic, social, and environmental benefits. Key initiatives include efficient plastic waste management (69% recovery for rigid

plastics), the Red Dot Campaign for sanitary waste segregation (1.5 TPD), and decentralized biogas and composting facilities processing 30% of total waste. Despite generating ~10,000 MT of e-waste annually, formal infrastructure remains limited, with informal sectors leading collection and recycling. The findings emphasize a circular economy approach, integrating decentralized systems and community participation for sustainable urban waste management.

[2] Ana Ramos (2024) - This study reviews the social perspective of sustainability assessment in Waste-to-Energy (WtE) projects. Findings reveal inconsistent reporting practices and limited standardization in Social Life Cycle Assessment (S-LCA). Key social concerns include employment, human health, safety, accessibility, and odor-related issues. Significant knowledge gaps persist, particularly in integrating social aspects with environmental and economic pillars, alongside weak legislation and sector engagement. The UNEP/SETAC framework emerges as the most applied methodology, with multi-criteria and qualitative approaches dominating. The study highlights the urgent need for standardized frameworks and robust sensitivity analysis to ensure sustainable WtE evaluations.

[3] Naveen Suresh Chomal, Anuska Mahalik, Ritu Agrawal, Shweta Suhane, Mohammad Arif Kamal (2024) - Integrated Waste Management (IWM) plan is a feasible and effective solution to South Goa's waste management challenges, which are exacerbated by population growth and tourism. Currently, the district generates approximately 197.87 metric tons of waste daily, with 51% being wet waste and 49% being dry waste. Residential and commercial sources, along with tourist inflow, are the primary contributors.

[4] Dr. Tarun Madan Kanade, Dr. Jonathan Joseph, Dr. Sophia Ansari, Mrs. Ashima Manoj Varghese, Dr. Tushar Savale (2024) - It covers the paper's framework, which is based on the 3R approach and a circular economy, the emphasis on advanced technologies, the importance of community engagement, and the consequences of improper solid waste management on environmental and human health. It also mentions the different types of waste and the historical shift in waste management strategies.

3. METHODOLOGY

This study adopts a mixed-methods, multi-stage research design to evaluate the municipal solid waste (MSW) management system of Nashik Municipal Corporation. The approach is both descriptive, documenting existing practices, and analytical, quantifying system performance, impacts, and improvement opportunities. The study area is stratified by settlement type (high-, medium- and low-density areas) and socioeconomic characteristics. Sampling includes approximately 5% of households in selected wards, along with commercial and institutional waste generators.

Primary data are collected through household and generator surveys, field observations, waste characterization studies, operational and technical audits, key informant interviews, and focus group discussions. Waste characterization involves manual sorting of representative samples to determine generation rates, composition, moisture content, and recycling/composting potential. Operational audits assess collection efficiency, fleet utilization, route productivity, and landfill or processing facility performance. Environmental sampling of air, water, and soil supports Environmental Impact Assessment (EIA).

System performance is evaluated using standard indicators such as collection coverage, segregation rate, diversion rate, and per-capita waste generation, followed by gap analysis against national benchmarks. A Life Cycle Assessment (LCA) quantifies environmental impacts across collection, processing, and disposal stages. Finally, economic, social, and sustainability assessments using life-cycle costing and cost-benefit analysis provide an integrated evaluation to inform evidence-based recommendations for sustainable MSW management.

4. DATA COLLECTION

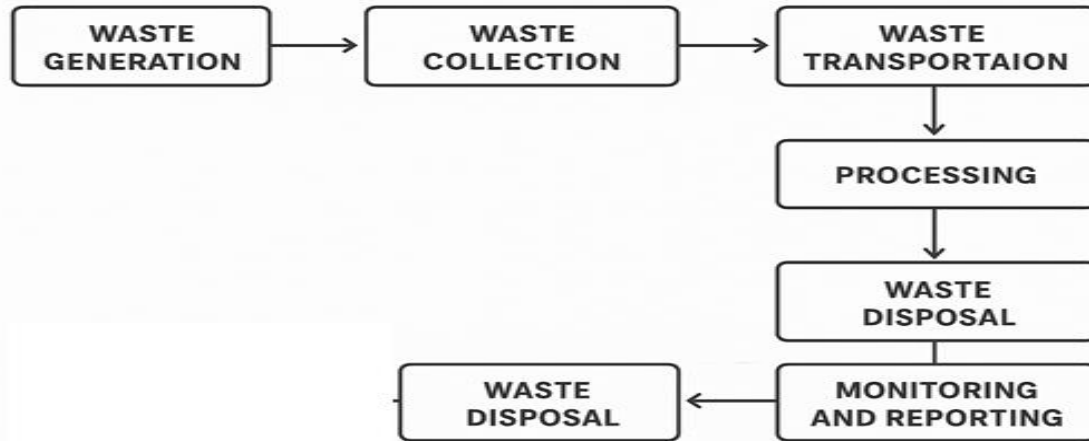
Life Cycle Assessment (LCA) was carried out to evaluate the environmental performance of the Municipal Solid Waste Management (MSWM) system of Nashik Municipal Corporation (NMC) in accordance with ISO 14040 and ISO 14044 standards. The assessment covers the complete waste management chain from waste generation to final disposal and compares the existing baseline system with improved scenarios emphasizing source segregation, composting, and biogas generation.

The functional unit adopted was the management of 1 tonne of municipal solid waste (MSW) generated within NMC limits. System boundaries include waste collection, transportation, processing (composting, biogas, and recycling), and landfill disposal, while excluding upstream production of consumer goods, capital infrastructure, and end-use consumption.

Population and waste generation data for Nashik city from 1995 to 2025 were compiled to support the Life Cycle Inventory (LCI). Population data were obtained from the Census of India (1991, 2001, 2011) and projected to 2025 using exponential interpolation, indicating growth from approximately 0.88 million to 2.35 million. MSW generation was estimated using a per-capita rate of 0.45–0.55 kg/capita/day, resulting in total waste generation increasing from about 400–485 tpd in 1995 to 1,060–1,290 tpd in 2025. Waste composition

was assumed as 52% organic and 48% inorganic, reflecting Nashik's waste profile. These datasets form the basis for evaluating environmental impacts and identifying sustainable MSWM improvement options.

DATA COLLECTION



5. RESULTS

The analysis is based on a per-capita municipal solid waste generation rate of 0.5 kg/capita/day. The waste composition is assumed to consist of 52% wet (organic) waste and 48% dry (non-organic) waste, reflecting the typical waste profile of Nashik city. Population data were compiled from the Census of India (1991, 2001, and 2011) and extended using the 2025 city population estimate. All quantities refer to total waste generated; the effectively collected waste was estimated by applying a collection efficiency of 88% to the generated waste figures.

To improve the sustainability of municipal solid waste management in Nashik, the study recommends strengthening source segregation by increasing segregation levels to about 80%, which would significantly enhance material recovery and reduce contamination of recyclable and organic waste streams. Decentralized composting and biogas (biomethanation) units should be scaled up in residential, commercial, and institutional clusters to efficiently treat wet waste close to the point of generation and reduce transportation and landfill loads. Further, landfill gas capture systems, including methane collection and flaring, should be implemented to mitigate greenhouse gas emissions from disposal sites. The study also emphasizes the importance of public-private partnerships, particularly by formally integrating informal waste pickers into recycling value chains to achieve both environmental benefits and social-economic co-benefits. Finally, it is recommended that Life Cycle Assessment (LCA) be institutionalized within Nashik Municipal Corporation's planning and decision-making framework to ensure that future waste management investments are guided by scientifically informed environmental performance evaluations.

6. CONCLUSIONS

This study demonstrates that rapid urbanization and population growth have placed significant pressure on the municipal solid waste management (MSWM) system of Nashik city, leading to a substantial increase in waste generation over the last three decades. The integrated application of Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA) provided a comprehensive evaluation of environmental performance across the entire waste management chain, from collection and transportation to processing and final disposal.

The results indicate that landfilling remains the dominant contributor to environmental impacts, particularly in terms of greenhouse gas emissions and global warming potential. With nearly 52% of the waste stream being organic, there is considerable untapped potential for source segregation, decentralized composting, and biogas generation, which can significantly reduce the quantity of waste sent to landfills while recovering valuable resources and energy. Scenario analysis confirms that improved segregation efficiency, enhanced processing capacity, and effective landfill gas capture can substantially lower environmental burdens and support climate mitigation goals.

The findings also highlight the importance of institutional strengthening and inclusive governance, including the integration of informal waste pickers through public-private partnerships to achieve social and economic co-benefits alongside environmental improvements. Overall, the study concludes that embedding LCA and EIA as

routine decision-support tools within municipal planning can enable Nashik Municipal Corporation to transition toward a more sustainable, resource-efficient, and environmentally sound MSWM system, offering a replicable framework for other rapidly growing Indian cities.

7. REFERENCES

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