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Assessment of Solid Waste Management Performance in Urban Areas

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Abstract: *The rapid increase in organic waste generation has become a critical environmental challenge, particularly in developing countries where landfill dependency remains high. Composting has been widely recognized as a sustainable and cost-effective method for reducing organic waste while producing value-added soil amendments. This study aims to evaluate and compare various composting methods in terms of their effectiveness in organic waste reduction, process efficiency, environmental performance, and socio-economic feasibility. A systematic literature-based evaluation was conducted using qualitative synthesis and comparative analysis of empirical findings from peer-reviewed international journals. The reviewed composting methods include windrow composting, aerobic composting, anaerobic composting, vermicomposting, in-vessel composting, pit composting, and hybrid systems. The results indicate that aerobic-based composting methods, particularly windrow and in-vessel systems, demonstrate higher waste reduction rates (40–95%), faster stabilization, and better compost quality compared to anaerobic and pit-based systems. Hybrid approaches combining windrow and vermicomposting were found to be effective in accelerating maturation and pathogen reduction. Furthermore, technological enhancements such as microbial inoculants and controlled aeration significantly improve composting efficiency. This study concludes that composting is a viable strategy for sustainable organic waste management, although method selection should consider local conditions, waste characteristics, and socio-economic factors. The findings provide valuable insights for policymakers and practitioners seeking to optimize composting systems for sustainable waste reduction.*

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INTRODUCTION

Rapid urbanization has significantly intensified the challenges of municipal solid waste management in cities worldwide. The continuous growth of urban populations, combined with economic expansion and changing consumption patterns, has led to a steady increase in both the quantity and complexity of municipal solid waste. In many urban areas, particularly in developing countries, waste generation rates have exceeded the capacity of existing collection, treatment, and disposal systems. As a result, municipal solid waste management has emerged as one of the most pressing environmental governance issues in contemporary urban development.

Urban solid waste systems are required to manage increasingly heterogeneous waste streams that include organic waste, plastics, paper, metals, and hazardous residues. However, the development of waste management infrastructure has often lagged behind the pace of urban growth. Empirical studies from Asia and Africa consistently report low collection coverage, inadequate treatment facilities, and widespread reliance on open dumping and uncontrolled disposal practices. These deficiencies contribute to environmental pollution, greenhouse gas emissions, and heightened public

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health risks, particularly in densely populated urban settlements (Iraguha et al., 2022; Ayub et al., 2024).

In many cities, the technical shortcomings of waste management systems are closely linked to institutional and governance constraints. Limited financial resources, weak regulatory enforcement, and fragmented administrative responsibilities undermine the effectiveness of municipal services. Several studies highlight that the absence of coherent planning and clear institutional roles results in inefficient service delivery and poor operational performance (Fanta Sima & Debelo, 2023; Bermudez dos Reis et al., 2016). Consequently, waste management challenges in urban areas cannot be understood solely as technical problems, but rather as complex socio-institutional issues that require integrated assessment and policy responses.

Performance assessment has therefore become a critical instrument for evaluating municipal solid waste management systems and guiding improvement strategies. Performance assessment frameworks enable local governments to measure service effectiveness, identify operational bottlenecks, and monitor progress toward environmental and sustainability objectives. Indicator-based approaches are widely applied to capture multiple dimensions of waste management performance, including waste generation, collection efficiency, treatment and recycling rates, environmental impacts, economic efficiency, and social participation (Elsaid & Aghezzaf, 2018; Guadagnin & Luchese, 2018). By integrating these dimensions, performance indicators provide a systematic basis for evidence-based decision-making.

Despite their importance, performance assessment practices remain uneven across urban contexts. Many cities lack standardized and context-sensitive frameworks that reflect local conditions and institutional capacities. Existing assessment tools are often applied in a fragmented manner, focusing on selected technical indicators while neglecting governance, institutional capacity, and community participation. This partial approach limits the usefulness of performance assessments for comprehensive policy evaluation and long-term planning (Bermudez dos Reis et al., 2016; Elsaid & Aghezzaf, 2018).

Empirical evidence from developing countries indicates that municipal solid waste management performance is generally low to moderate. Studies conducted in Ethiopia and Rwanda demonstrate that limited institutional capacity and low levels of community involvement significantly reduce collection coverage and service efficiency. In these contexts, waste management systems rely heavily on informal practices, and organized recycling and treatment activities remain minimal (Fanta Sima & Debelo, 2023; Iraguha et al., 2022). Similar patterns are observed in rapidly urbanizing cities in Pakistan and India, where municipal authorities struggle to expand services at a pace consistent with urban growth (Ayub et al., 2024; Kaur & Punera, 2023).

In contrast, experiences from European cities suggest that improvements in municipal solid waste management performance are achievable through consistent policy implementation and integrated governance approaches. Several studies report gradual reductions in waste generation and significant increases in recycling rates as a result of regulatory incentives, economic instruments, and public awareness campaigns. For instance, metropolitan areas in Greece have demonstrated improved waste management outcomes linked to economic conditions and policy reforms that promote circular economy principles (Vardopoulos et al., 2021). These contrasting experiences underscore the critical role of governance quality and economic context in shaping waste management performance.

Recent methodological developments have further expanded the scope of performance assessment in municipal solid waste management. Beyond descriptive indicator frameworks, advanced quantitative methods have been applied to evaluate efficiency and sustainability outcomes. Data Envelopment Analysis has been widely used to compare the relative efficiency of waste management systems across municipalities and to identify performance gaps that are not captured by compliance-based assessments (Costa et al., 2024; Molinos-Senante et al., 2024). These studies reveal substantial inefficiencies even among cities that formally comply with regulatory requirements, highlighting the limitations of traditional evaluation approaches.

In addition, large-scale analytical studies employing data-driven techniques emphasize the importance of socioeconomic determinants in influencing waste management performance. Global analyses using machine learning approaches demonstrate that higher levels of socioeconomic development, institutional capacity, and public awareness are consistently associated with better waste management outcomes (Velis et al., 2023). These findings reinforce the understanding of municipal solid waste management as a multidimensional system influenced by technical, economic, social, and institutional factors.

Despite the growing body of literature, research on municipal solid waste management performance remains fragmented and context-specific. Many studies focus on individual cities or countries and apply diverse indicators and assessment methods, which complicates cross-regional comparison and the derivation of generalizable policy lessons. This fragmentation limits the ability of policymakers and urban planners to identify transferable best practices and to design performance improvement strategies that are adaptable to different urban contexts (Alvarenga et al., 2023; Ghardenny Herrera-Uchalin et al., 2023).

The absence of comprehensive syntheses that integrate empirical evidence across regions and methodologies represents a significant research gap. Comparative assessments that systematically examine performance dimensions and influencing factors can provide valuable insights into common challenges and success drivers. Such syntheses are particularly important for rapidly urbanizing cities in developing countries, where resource constraints demand efficient and evidence-based policy interventions.

In response to this gap, this article aims to assess municipal solid waste management performance in urban areas through a systematic synthesis of empirical studies published between 2015 and 2024. The analysis integrates key performance dimensions, including waste generation, collection efficiency, treatment and recycling rates, disposal practices, institutional capacity, and community participation. By examining evidence from Asia, Africa, Europe, and Latin America, this study seeks to identify recurring performance patterns and the main factors influencing municipal solid waste management outcomes.

The contribution of this article lies in its cross-regional synthesis of performance assessment findings and its emphasis on integrated evaluation frameworks. The results provide policy-relevant insights that support the development of standardized performance indicators, performance-based evaluation approaches, and governance strategies tailored to urban contexts. Ultimately, the study aims to inform policymakers, urban planners, and researchers seeking to enhance the sustainability and effectiveness of municipal solid waste management systems in rapidly urbanizing environments.

METHODS

Research Design

This study adopts a qualitative systematic review and comparative assessment design to evaluate municipal solid waste management performance in urban areas. The research focuses on synthesizing empirical evidence from published studies that assess waste management performance using indicators, efficiency analysis, or integrated evaluation frameworks. A qualitative approach was selected to allow an in-depth examination of performance dimensions, assessment methods, and contextual factors across diverse urban settings.

The review emphasizes comparative analysis rather than statistical meta-analysis, as the included studies employ heterogeneous indicators, methodological frameworks, and units of analysis. This design enables the identification of recurring performance patterns and key determinants of municipal solid waste management outcomes across different geographical and socioeconomic contexts.

Data Sources and Literature Selection

The dataset consists of peer-reviewed journal articles, book chapters, preprints, and doctoral dissertations published between 2015 and 2024. The selected studies were sourced from international academic databases and repositories commonly used in environmental and urban studies. The literature selection process focused on studies that explicitly assess municipal solid waste management performance in urban areas.

Inclusion criteria were defined as follows:

1. the study examines municipal or urban solid waste management systems;
2. the study applies performance indicators, efficiency analysis, or structured assessment frameworks;
3. the study reports empirical findings based on real urban cases; and
4. the study provides sufficient methodological detail to support comparative analysis.

Studies that focused exclusively on technical treatment processes without system-level performance evaluation were excluded. Based on these criteria, a total of 30 relevant studies were selected for analysis, covering urban areas in Asia, Africa, Europe, and Latin America.

Data Extraction and Analytical Framework

A structured data extraction protocol was applied to ensure consistency in the review process. For each selected study, information was systematically recorded regarding geographical context, assessment objectives, performance dimensions, indicators used, methodological approach, and key findings. This information was then organized into analytical matrices to facilitate cross-study comparison.

The analysis framework categorizes municipal solid waste management performance into six core dimensions: waste generation, collection efficiency, treatment and recycling performance, disposal practices, institutional capacity, and community participation. These dimensions were selected because they are consistently applied across the reviewed literature and reflect the technical, environmental, and governance aspects of waste management systems (Elsaid & Aghezzaf, 2018; Guadagnin & Luchese, 2018).

Qualitative Content Analysis

Qualitative content analysis was employed to examine how performance is defined, measured, and interpreted across the selected studies. The analysis focused on identifying common indicators, methodological trends, and reported performance levels. Particular attention was given to how studies contextualize performance outcomes in relation to socioeconomic conditions, governance structures, and infrastructure availability.

Through iterative coding and thematic grouping, recurring challenges and success factors influencing municipal solid waste management performance were identified. This process enabled the synthesis of qualitative evidence while preserving the contextual specificity of individual case studies.

Cross-Case Comparative Analysis

To enhance analytical rigor, a cross-case comparative approach was applied to examine similarities and differences in performance outcomes across regions. Studies were grouped by geographical context and income level to identify regional patterns and disparities. Comparative analysis focused on key performance bottlenecks, such as collection coverage, recycling rates, and institutional effectiveness, as well as enabling factors, including integrated planning and community engagement.

Advanced assessment approaches reported in the literature, such as Data Envelopment Analysis and composite performance indices, were examined to understand their contribution to performance evaluation and policy relevance (Costa et al., 2024; Molinos-Senante et al., 2024). Rather than recalculating efficiency scores, the study synthesizes reported findings to assess their implications for performance-based evaluation.

Validity and Reliability Considerations

To enhance the credibility of the synthesis, multiple strategies were applied. First, only studies published in recognized academic outlets or reputable repositories were included. Second, performance dimensions and indicators were cross-validated across multiple sources to ensure consistency. Third, findings were interpreted conservatively, focusing on patterns supported by evidence from multiple studies.

While the qualitative nature of the review limits statistical generalization, the systematic selection and comparative analysis of empirical studies strengthen the analytical validity of the findings. The methodological approach ensures transparency and replicability for future research on municipal solid waste management performance assessment.

RESULTS AND DISCUSSION

Overall Performance Patterns of Municipal Solid Waste Management

The synthesis of reviewed studies indicates that municipal solid waste management performance in urban areas remains uneven across regions and performance dimensions. Most cities exhibit low to moderate performance levels, particularly in waste collection efficiency, treatment capacity, and recycling outcomes. These patterns are consistently reported across developing regions, while higher-income urban contexts demonstrate relatively better but still heterogeneous performance.

Table 1 summarizes the dominant performance characteristics reported in the reviewed empirical studies, grouped by major geographical regions. The table consolidates evidence on

collection coverage, recycling and treatment performance, disposal practices, and institutional conditions without introducing new numerical data.

Table 1. Summary of Municipal Solid Waste Management Performance by Region (2015–2024)

Region	Collection Coverage	Recycling and Treatment	Disposal Practices	Institutional Characteristics	Key References
Africa	Low, often below 40%	Very limited, mostly informal	Open dumping prevalent	Weak enforcement, limited capacity	Iraguha et al. (2022); Fanta Sima & Debelo (2023)
South Asia	Low to moderate	Low composting and recovery	Heavy reliance on dumpsites	Rapid urban growth, funding constraints	Ayub et al. (2024); Kaur & Punera (2023)
Latin America	Moderate with disparities	Low to moderate	Mixed sanitary and open disposal	Fragmented governance	Bermudez dos Reis et al. (2016); Costa et al. (2024)
Europe	High	Moderate to high	Controlled disposal	Strong regulatory frameworks	Vardopoulos et al. (2021)

The table highlights that collection efficiency remains the most critical bottleneck across regions, particularly in African and South Asian cities. Limited recycling and treatment capacity further constrain system performance, reinforcing dependence on environmentally unsound disposal methods.

Waste Collection Efficiency as a Primary Bottleneck

Waste collection efficiency emerges as the most frequently reported performance constraint in urban solid waste management systems. Several studies document collection coverage below 40% in cities such as Greater Lomé and Mettu Town, resulting in widespread illegal dumping and unmanaged waste accumulation (GBEKLEY et al., 2023; Fanta Sima & Debelo, 2023). Similar challenges are reported in Indian and Pakistani cities, where rapid urban expansion outpaces municipal service capacity (Ayub et al., 2024; Kaur & Punera, 2023).

The recurring nature of low collection coverage indicates structural deficiencies rather than isolated operational failures. Inadequate vehicle fleets, insufficient personnel, and poorly defined service areas are commonly cited constraints. These issues are closely linked to limited municipal budgets and weak planning mechanisms, which restrict the scalability of waste collection systems in rapidly growing urban areas.

Recycling and Treatment Performance

Recycling and treatment performance is consistently reported as limited in low- and middle-income urban contexts. Composting and material recovery rates rarely exceed 10%, as documented in studies from Togo, Brazil, and Malaysia (Lee, 2018; Vidigal, 2024). Recycling activities are often driven by informal actors, with limited integration into formal municipal systems.

In contrast, European municipalities demonstrate comparatively higher recycling rates due to regulatory incentives, extended producer responsibility schemes, and active public participation. Evidence from Greece shows that policy alignment with circular economy principles contributes to measurable improvements in recycling outcomes (Vardopoulos et al., 2021). However, even in these

contexts, performance disparities persist among municipalities, indicating that regulatory frameworks alone do not guarantee uniform outcomes.

Institutional Capacity and Governance Influence

Institutional and governance factors are repeatedly identified as decisive determinants of municipal solid waste management performance. Weak policy enforcement, fragmented responsibilities, and insufficient funding undermine operational effectiveness across many urban systems (Van Den Berg & Duong, 2018; Bermudez dos Reis et al., 2016). Cities that lack integrated management plans tend to exhibit lower performance across all dimensions.

Advanced efficiency assessment studies reinforce these findings. Large-scale applications of Data Envelopment Analysis in Brazil reveal that only a small proportion of municipalities operate efficiently, regardless of population size or legal compliance status (Costa et al., 2024). These results underscore the limitations of compliance-based evaluation and highlight the importance of performance-based assessment frameworks.

Role of Community Participation

Community participation emerges as a cross-cutting success factor in multiple regional contexts. Studies from Ethiopia, Rwanda, and Brazil demonstrate that citizen involvement in source separation and recycling initiatives contributes to improved system performance (Fanta Sima & Debelo, 2023; Souza & Parente, 2020). Public awareness and environmental education enhance cooperation between households and municipal service providers, leading to more efficient waste handling practices.

These findings indicate that technical and institutional interventions must be complemented by sustained community engagement to achieve long-term performance improvements.

Synthesis and Policy Implications

Overall, the reviewed evidence confirms that municipal solid waste management performance in urban areas is shaped by the interaction of technical capacity, governance quality, and social participation. Regions that adopt integrated assessment frameworks and performance-based evaluation methods demonstrate clearer pathways for improvement. The results support the argument that standardized yet context-adaptive performance indicators are essential for guiding sustainable urban waste management policies.

CONCLUSION

This study provides a comprehensive assessment of municipal solid waste management performance in urban areas through a systematic synthesis of empirical studies published between 2015 and 2024. The findings demonstrate that overall performance remains uneven and generally insufficient to meet sustainability objectives, particularly in rapidly urbanizing cities. Low waste collection efficiency, limited recycling and treatment capacity, and continued reliance on environmentally unsound disposal practices persist as dominant challenges in many developing urban contexts.

Comparative analysis across regions highlights the critical role of institutional capacity and governance quality in shaping waste management outcomes. Cities characterized by fragmented responsibilities, weak policy enforcement, and constrained financial resources consistently exhibit

lower performance levels. In contrast, urban areas that implement integrated management frameworks, performance-based evaluation tools, and clear institutional arrangements tend to achieve more effective and efficient service delivery.

The results further emphasize the importance of community participation as a cross-cutting determinant of success. Evidence indicates that public involvement in waste separation and recycling initiatives enhances system performance and supports the implementation of sustainable waste management practices. Advanced assessment approaches, including efficiency analysis, provide valuable insights beyond compliance-based evaluations and help identify performance gaps within formally regulated systems.

Overall, the study underscores the need for standardized yet context-sensitive performance assessment frameworks to support evidence-based policymaking. Strengthening institutional capacity, enhancing stakeholder engagement, and adopting integrated evaluation tools are essential steps toward improving municipal solid waste management performance and advancing sustainable urban development.

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