Assessment of Solid Waste Management Practices in Guwahati City

Sanchit Shrivastava[1], Rahul Singh[2]
[1]*PG Research Scholar, M.Tech (Environmental Engineering), Department of Civil Engineering, Mangalayatan University, Uttar Pradesh, India*
[2]*Senior Solid Waste Management Expert, Waste and Sustainable Engineering Department, Meinhardt (Singapore) PTE Ltd, Dubai, UAE*

***Abstract*—Rapid urbanization and rising population densities have intensified municipal solid waste challenges in Guwahati, a key urban hub and gateway to Northeast India. The city's system contends with unscientific disposal, weak source segregation, limited community engagement, and institutional and infrastructural constraints. This paper presents an assessment of Guwahati's SWM practices—covering waste generation patterns, collection efficiency, segregation behavior, institutional performance, and environmental impacts—based on field surveys, stakeholder interviews, and secondary data. A SWOT lens is used to surface operational and governance gaps that perpetuate open dumping and ecological risks near sensitive receptors.**

Primary findings indicate implementation shortfalls despite statutory mandates: financial and administrative limitations, low compliance with segregation, and inadequate processing capacity. At the same time, opportunities exist in decentralized treatment, PPP models, integration of the informal sector, and citizen participation to raise diversion and recovery. The analysis emphasizes a context-specific pathway that aligns circular economy principles with ward-scale interventions, translating policy targets into measurable, local outcomes.

The study concludes that strengthening governance, recognizing the role of waste pickers, and deploying distributed composting/bio methanation with robust monitoring can move Guwahati toward sustainable, resilient SWM. The recommendations aim to guide city managers and policymakers in operationalizing inclusive strategies that reduce landfill dependence and improve environmental health.

Index Terms*—Solid Waste Management; Guwahati City; Municipal Waste; Waste Segregation; Community Participation; Urban Governance; Informal Sector; Environmental Sustainability; Circular Economy; SWM Rules 2016; Public–Private Partnerships.

I. INTRODUCTION

Guwahati—the largest urban centre in Assam—illustrates the mid-tier Indian city predicament: rapid population growth, expanding commercial activity, and an SWM system that struggles to keep pace with rising waste quantities. Ward-wise analysis in the dissertation shows clear variation in per-capita generation linked to land-use intensity and income: central commercial/mixed-use wards record higher rates (e.g., Ward 10: 0.56 kg/cap/day; Ward 12: 0.53 kg/cap/day) compared to peripheral wards (e.g., Ward 30: 0.38 kg/cap/day), with an overall household survey average of 0.47 kg/cap/day.

The household waste stream is dominated by organic matter (~52.4%), followed by plastics (~21.7%), paper (~11.3%), metals and glass (~7.1%), and inert (~7.5%), a composition pattern that simultaneously presents a strong opportunity for decentralized organic treatment and an emerging challenge around plastics management.

At the system level, gaps appear across the chain: source segregation is limited and uneven across wards; collection routes show inconsistencies in coverage and frequency; and transport is frequently undertaken in open vehicles, leading to spillage and nuisance along corridors. The dissertation's thematic organization and field observations emphasize these operational frictions and their cumulative effect on downstream recyclability and treatment.

Public awareness and participation further constrain performance—only **34%** of surveyed households were aware of SWM Rules 2016 provisions, and **18%** reported participation in community-led SWM activities—highlighting the need for consistent behaviour-change efforts tied to visible service improvements.

Institutionally, responsibilities are distributed among GMC and other agencies, but practice is characterized by fragmented capacity, constrained technical staffing, and the absence of a dedicated urban waste management unit—factors that hinder innovations such as data-driven route optimization and real-time performance tracking. Ward offices possess granular knowledge yet limited autonomy, and channels for citizen feedback are weak, affecting accountability and trust.

In parallel, the informal sector recovers an estimated **15–20%** of recyclables (notably plastics, paper, metals), but operates without formal recognition, occupational safeguards, or structured access to materials—an integration gap that limits citywide recovery potential and worker protections.

Environmental sensitivities intensify the stakes for Guwahati. Unregulated dumping persists near wetlands and riverbanks, degrading aquatic ecosystems, clogging drainage, and compounding monsoon-season flood risks; observations in the dissertation flag leachate formation, biodiversity loss, and pollution pressures around Deepor Beel and other peri-urban beels. The ecological sections also describe how waste intrusion reduces wetland storage, undermines groundwater recharge, and heightens public-health vulnerabilities in flood-prone neighborhoods, underscoring the need for an integrated approach that links SWM, stormwater management, and land-use regulation.

Taken together, these conditions motivate a localized, evidence-driven pathway that combines decentralized processing (ward-scale composting/bio methanation and material recovery) with strengthened governance, data systems, and citizen engagement. The dissertation frames this shift not as a wholesale replacement of city-level infrastructure but as a pragmatic re-balancing: reduce inflows to the dumpsite through source segregation and proximity processing; recognize and organize informal recovery; and build ward-level accountability and monitoring to translate statutory intent into measurable diversion outcomes.

II. RESEARCH POBLEM

Guwahati's solid waste management system exhibits a persistent implementation gap between statutory mandates (segregation at source, recovery, and scientific disposal) and on-ground performance. At the household interface, segregation remains low, and mixed waste commonly enters the collection stream, reducing downstream recyclability and treatment efficiency. Collection services are uneven across wards, and mixing at intermediate points further degrades material quality. Open-body transport and inadequate containerization contribute to littering and nuisance along corridors, while limited processing capacity keeps the city reliant on a single disposal site with insufficient environmental safeguards.

Institutionally, responsibilities are fragmented across departments and contractors, with siloed decision-making, constrained technical staffing, and weak ward-level autonomy. This limits adoption of data-led operations (e.g., reliable route and tonnage tracking, KPI-based supervision) and slows delivery of decentralized infrastructure. Citizen feedback channels are thin, so service improvements do not consistently translate into behaviour change at the source.

From a systems and environmental perspective, siting sensitivities heighten risk: disposal in or near ecologically vulnerable areas increases exposure to leachate, vectors, and flooding externalities during monsoon conditions. In parallel, the informal recycling sector recovers a significant share of materials but operates without formal protocols, occupational safeguards, or structured access—leaving a critical recovery pathway under-leveraged and workers unprotected.

Against this backdrop, the research problem is to determine how policy intent can be translated into implementable, ward-scale interventions that measurably raise segregation and recovery while reducing landfill dependence and ecological risk. Specifically, the study seeks to:

1. Generate ward-level evidence on waste generation and composition to size and site decentralized facilities (composting, bio methanation, MRFs) and rationalize collection/transport.
2. Identify institutional bottlenecks—roles, capacities, contracting, and coordination—that impede consistent service delivery; and

3. Design a practical improvement pathway that couples' community participation and informal-sector integration with data-driven governance (clear KPIs, routine monitoring, and feedback loops), enabling a progressive shift from mixed-waste disposal toward segregated collection, proximity processing, and compliant final disposal.

III. OBJECTIVE

The research objectives are to:

1. Characterize spatial and compositional patterns of MSW
   Quantify ward-wise per-capita generation and daily loads; profile household waste composition (biodegradable, plastics, paper, metals/glass, inerts); and relate variations to land-use intensity and income for proximity-based sizing of processing assets.
2. Evaluate service performance across the collection–transport–disposal chain
   Assess route coverage/frequency, containerization, degree of source segregation and mixing at transfer points, vehicle containment, and the operational condition of the disposal site; link observed performance to institutional roles, capacities, contracting, and coordination.
3. Map recovery pathways and constraints of the informal sector
   Document materials recovered by waste-pickers/scrap dealers, access and safety conditions, market interfaces, and opportunities for structured integration to raise recovery while improving occupational safeguards.
4. Design ward-scale, decentralized processing options with governance enablers
   Develop feasible options for composting, bio methanation, and MRFs sized to local loads and siting sensitivities; define supporting governance instruments—segregation enforcement, data-led monitoring (ward KPIs, routine reporting), and community participation mechanisms—to translate statutory intent into measurable diversion outcomes.

IV. METHODOLGY

A mixed-methods design was adopted within Guwahati municipal limits, selecting wards that represent distinct land-use profiles (predominantly residential, commercial corridors, and mixed-use belts). The design combines primary sampling (household and stream characterization) with institutional assessment (roles, processes, and operational practices) to capture both material flows and governance/operational realities at ward level.

Sampling & Data Collection:

a) Household sampling and generation estimates: Within each selected ward, households were sampled to estimate per-capita generation and total ward loads. Sampling followed a stratified approach across typical dwelling types and densities to reflect intra-ward variability.
b) Waste characterization: Composite samples were prepared and reduced by quartering to obtain representative sub-samples. Physical characterization recorded major fractions (biodegradable, plastics, paper, metals/glass, inert), while density and moisture were measured using the same standard procedures and apparatus referenced in the dissertation's methods section.
c) Field observation of service chain: Structured checklists were used at collection points, transfer/aggregation locations, and along transport routes to document coverage and frequency, containerization, spillage, and vehicle containment (open/covered; compartmentalization).
d) Key-informant interviews: Semi-structured interviews with ward officials, operations staff/contractors, and scrap-dealers captured route planning practices, constraints in manpower and equipment, material recovery pathways, and coordination challenges between departments/actors.
e) Disposal-site reconnaissance: The active disposal location was visited to note basic environmental controls (leachate pathways, drainage), on-site practices, interface with informal recovery, and proximity to sensitive receptors.

Indicators & Analysis:

Core indicators included ward-wise per-capita waste generation (kg/cap/day), composition by material category (biodegradable, plastics, paper, metals/glass, inert), collection coverage (% households served and frequency), segregation at source (% two-bin compliance and mixing incidence), transport mode and containment, and a qualitative appraisal of institutional arrangements (roles, contracting, data/reporting flows). Composition results were summarized as percentage shares at ward level and for the pooled sample; generation and coverage indicators were compiled into ward profiles. Interview notes and documentary evidence were thematically coded to synthesize operational and governance findings.

Quality Assurance / Control (QA/QC):

Sampling and characterization steps (weighing, quartering, moisture/density tests) followed consistent field protocols; duplicate measurements were taken for a subset of samples to check repeatability. Observation checklists and interview guides were piloted in one ward and refined for clarity and consistency before full deployment.

Data Processing and Triangulation:

Household survey data, field measurements, and operational observations were compiled into ward-wise matrices. Trends from primary data were triangulated with routine municipal records (where available) and interview insights to validate generation estimates, identify points of mixing, and cross-check reported coverage versus observed service frequency. Maps/figures prepared for the dissertation were referenced to interpret spatial patterns of illegal dumping hotspots and sensitive zones.

Ethical and Practical Considerations:

Participation in household surveys and interviews was voluntary, with respondents informed about study purpose and data use. Field teams used appropriate protective gear during handling/characterization. Site visits and photography respected access protocols at facilities and public spaces.

Limitations (Methodological):

Ward selection, while representative, is not exhaustive; routine municipal tonnage data were incomplete in places, requiring cautious triangulation. Characterization reflects the study period and may vary seasonally; these constraints are acknowledged in interpreting results and framing recommendations

V. RESULTS & DISCUSSIONS

Generation and Composition:

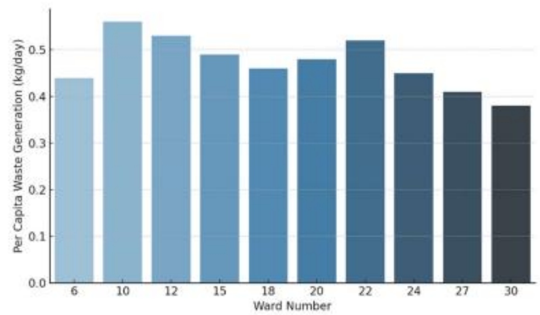

Figure 1 Ward Wise average waste generation

Ward-wise assessment shows per-capita generation ranging 0.38–0.56 kg/cap/day, with higher values concentrated in central, commercially active wards (e.g., Wards 10 and 12) and lower values at the periphery (e.g., Ward 30). The household survey average is ~0.47 kg/cap/day. Composition analysis confirms a dominant biodegradable fraction (~52.4%), followed by plastics (~21.7%), paper (~11.3%), metals & glass (~7.1%), and inert (~7.5%).

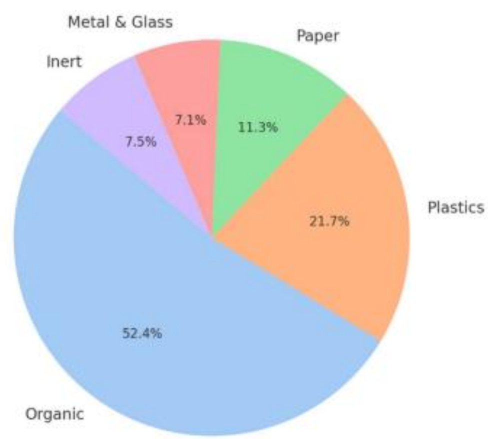

Figure 2 Household Waste Composition

This profile signals immediate technical potential for organic waste processing (composting/bio methanation) and the need for **targeted plastics** reduction and recovery, particularly in high-density commercial wards.

Collection and Transport: While door-to-door collection reaches a majority of surveyed households (~76% overall), coverage and frequency vary substantially by ward: central wards report ~90% daily coverage, whereas peripheral wards fall to ~56% with irregular service, reflecting terrain and road-access constraints. Transport is dominated by older, non-compartmentalized vehicles, leading to mixing during haulage; route planning is pattern-based rather than data-driven, limiting optimization. These conditions degrade recyclable quality and constrain downstream processing efficiency.

Segregation and Community Practices:

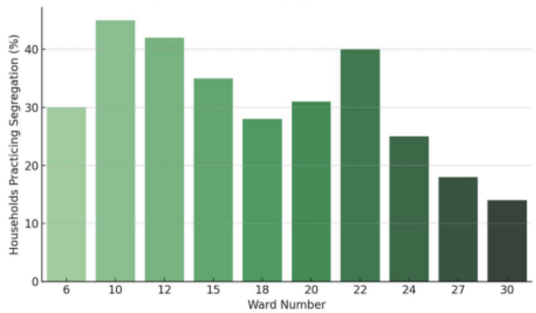

Figure 3 Level of Source Segregation across Wards

Household segregation remains low (about 29% across sampled wards), with significantly higher participation in central/high-income areas (e.g., 45% in Ward 10) and <15% in peripheral wards. Reported barriers include lack of awareness, insufficient storage bins, and the perception that waste is remixed by collection crews—undermining motivation to segregate at source.

Public Awareness & Engagement:

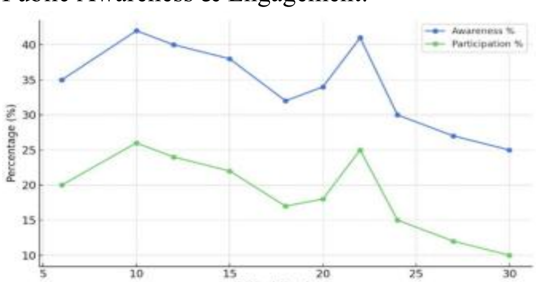

Figure 4 Public Awareness vs Participation Rate

Only 34% of surveyed households were aware of SWM Rules, 2016, and just 18% reported participating in neighborhood SWM activities; participation was highest in wards with active RWAs. The awareness–participation trend is positively related but weak, with participation consistently far lower than awareness. FGDs indicate that sustained behaviour changes hinges on visible, reliable service delivery and consistent communication. Overall, progress is uneven; scaling participation will require targeted public education, segregation infrastructure at source, and trust-building measures linked to service improvements.

Institutional Architecture and Informal Sector. Responsibilities span GMC departments and contractors, but centralized decision-making, limited technical staffing, and the absence of a dedicated urban waste unit slow operational responses and hinder performance monitoring. Ward officials possess granular knowledge yet lack autonomy; citizen feedback loops are weak. The informal sector—waste-pickers and scrap dealers—recovers an estimated 15–20% of recyclables but operates without formal protocols, occupational safeguards, or structured access mechanisms. Formalizing this interface (recognition, PPE, fair access) could raise recovery while improving worker safety.

Environmental Risks and Siting. Field evidence shows unregulated dumping near wetlands and along the Brahmaputra, causing clogged drainage, biodiversity loss, and heightened flood risk. Sensitive receptors—including Deepor Beel and peri-urban beels—exhibit leachate formation and plastic accumulation, underscoring the urgency of reducing inflows to disposal and enforcing scientific disposal standards.

Data and Performance Gaps. Across the service chain, ward-wise tonnage records, vehicle tracking, and monthly recovery reporting remain inconsistent, limiting route optimization and KPI-led supervision. This reinforces uneven service quality and hampers evaluation of segregation and diversion outcomes at ward scale.

Pathway for Improvement. Evidence supports a pragmatic, ward-anchored pathway:

i. **Enforce source segregation** through ward-level monitoring and feedback.
ii. Install distributed composting and biomethanation units sized to ward loads and siting sensitivities.
iii. Develop MRFs for dry fraction sorting with clear inflow protocols;
iv. Formalize informal recovery via registration, access protocols, and basic PPE
v. Upgrade transport to covered/compartmentalized vehicles and rationalize routes; and
vi. Institutionalize routine data capture (ward KPIs, monthly dashboards) to drive route optimization and measure diversion. Together, these steps

reduce landfill dependence, improve environmental outcomes, and align day-to-day practice with statutory mandates.

VI. ABVERATIONS & ACRONYMS

SWM — Solid Waste Management.
MSW — Municipal Solid Waste.
GMC — Guwahati Municipal Corporation.
GMDA — Guwahati Metropolitan Development Authority.
ULBs — Urban Local Bodies.
PPP — Public–Private Partnership.
SDGs — Sustainable Development Goals.
WtE — Waste-to-Energy.
RDF — Refuse-Derived Fuel.
MRF — Material Recovery Facility.
C&D — Construction & Demolition (waste).
CPCB — Central Pollution Control Board.
OFMSW — Organic Fraction of Municipal Solid Waste.
IHR — Indian Himalayan Region.
AMF — Arbuscular Mycorrhizal Fungi.
CI — Confidence Interval.
KII / KIIs — Key Informant Interview(s).
FGD / FGDs — Focus Group Discussion(s).
RWA / RWAs — Resident Welfare Association(s).
GIS — Geographic Information System.
IDW — Inverse Distance Weighting (spatial interpolation).

VII. LIMITATIONS & FUTURE WORK

Limitations of the study

This study's evidence base reflects selected wards within Guwahati that were chosen to represent dominant land-use types; as such, the findings may not capture the full heterogeneity of fringe settlements, high-rise clusters, or specialized activity zones. The assessment is cross-sectional and anchored to the study period, so seasonal dynamics—especially monsoon-related access constraints, moisture shifts in the organic fraction, and festival-driven peaks—were not fully isolated. Routine municipal records (ward-wise tonnages, monthly recovery, GPS traces) were incomplete or inconsistently reported in places, necessitating careful triangulation with primary observations. At the household and stakeholder interface, self-reported responses introduce recall and social-desirability biases, particularly around segregation practice and participation. Operational observation at collection/transfer points and the disposal site focused on visible practices and controls; continuous environmental monitoring (e.g., leachate generation or landfill gas) and detailed sampling were beyond the scope. Mapping of the informal recovery chain documented major pathways but did not quantify full value-chain economics or end-market leakages, and the ward-scale sizing suggestions for decentralized units (composting, biomethanation, MRFs) remain indicative pending site clearances, detailed design, and financial appraisal.

Future Work

Building on these insights, subsequent work should extend measurements across dry, monsoon, and festival seasons to quantify variability in generation, composition, and service reliability, while expanding spatial coverage to additional wards and peri-urban growth corridors. A data-led operational layer—routine GPS/weight logging, ward dashboards for coverage/segregation/recovery, and route-optimization trials—would enable before–after evaluation of performance. Parallel behavioural pilots can test ward-level segregation packages that combine bin provision, feedback loops, and incentive/penalty mixes, with rigorous outcome tracking. Structured models for informal-sector integration—registration, access protocols at MRFs, PPE and safety packages, and transparent revenue interfaces—should be prototyped and evaluated for both recovery gains and livelihood outcomes. Targeted environmental studies at the disposal site and sensitive receptors (tracking leachate pathways, surface-water quality, and flood-risk interactions) can prioritize mitigation investments. Finally, comparative techno-economic appraisals of decentralized options versus business-as-usual—phased by ward typology—and examination of institutional reforms (ward autonomy, contract design, inter-department coordination) will be critical to convert ward-level diagnostics into durable diversion, compliance, and service-reliability gains.

VIII. CONCLUSION

Guwahati's SWM system reflects the characteristic pressures of a rapidly growing mid-tier city: heterogeneous waste streams dominated by organics, uneven collection and segregation, open-body transport with mixing at transfer points, constrained processing capacity, and disposal practices that stress ecologically sensitive receptors. Evidence from ward-level generation and composition, service observations, and stakeholder inputs indicates that performance shortfalls are systemic—rooted as much in operational practices and data gaps as in infrastructure deficits. The analysis points to a practical re-balancing of the system: diverting organics and high-value dry fractions upstream through proximity processing while tightening controls along collection and haulage to protect material quality.

A coherent pathway therefore centres on (i) enforcing source segregation with ward-level monitoring and feedback; (ii) deploying distributed composting and biomethanation sized to local loads; (iii) establishing MRFs with clear inflow protocols and contamination control; (iv) upgrading transport to covered/compartmentalized vehicles and rationalized routes; and (v) integrating the informal recovery network through recognition, access protocols, and basic occupational safeguards. These operational measures must be coupled with governance enablers—defined roles and accountability at ward level, routine KPI dashboards (coverage, segregation, recovery, complaints), and responsive citizen interfaces—so that behavior change at the household level is reinforced by visible, reliable services.

Phased implementation, beginning with wards of high diversion potential and siting feasibility, can yield measurable reductions in landfill inflow while de-risking scale-up. As monitoring and reporting normalize, the city can progressively align daily practice with statutory requirements for segregation, scientific processing, and compliant disposal. In aggregate, this ward-anchored, data-led, and inclusionary approach offers a credible route to lowering environmental risk, improving service reliability, and advancing Guwahati toward a resilient, resource-efficient solid waste management system.

IX. ACKNOWLEDGMENT

The authors gratefully acknowledge the guidance and technical inputs of Rahul Singh, Senior Solid Waste Management Expert, Waste and Sustainable Engineering Department, Meinhardt (Singapore) PTE Ltd, Dubai, UAE, whose expertise substantially strengthened the methodological rigor and practical recommendations of this work. We also thank the Guwahati Municipal Corporation officials, ward representatives, field teams, and participating households for their cooperation during surveys and site observations. Support from the Department of Civil Engineering, Mangalayatan University, Uttar Pradesh, India is sincerely appreciated. Any errors remain the authors' own.

REFERENCES

[1.] Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International Journal of Environmental Research and Public Health, 16(6), 1060.

[2.] Singh, P., & Sharma, V. (2019). Integrated plastic waste management: Environmental and improved health approaches. Procedia Environmental Science, 35, 692–700.

[3.] United Nations. (2022). Transforming Our World: The 2030 Agenda for Sustainable Development (Review Update). UN Publishing.

[4.] Wilson, D. C., Velis, C. A., & Rodic, L. (2019). Integrated sustainable waste management in developing countries. Proceedings of the Institution of Civil Engineers – Waste and Resource Management, 172(1), 25–34.

[5.] Bhattacharya, A., Datta, S., & Chaudhuri, S. (2021). Municipal solid waste management in Indian cities: A review and assessment. Environmental Advances, 4, 100064.

[6.] Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2020). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (Rev. ed.). World Bank Publications.

[7.] Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Anguilano, L., & Colón, J. (2019). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. Energy, 141, 2013–2044.

[8.] Alam, O., & Qiao, X. (2020). An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh. Sustainable Cities and Society, 52, 101775.

[9.] Song, Q., Li, J., & Zeng, X. (2019). Minimizing the increasing solid waste through zero waste strategy. Journal of Cleaner Production, 240, 118198
[10.] Shen, M., & Zhang, Y. (2023). Global initiatives to mitigate plastic pollution: An overview of policy effectiveness. Environmental Science & Policy, 142, 242–253.
[11.] Khandelwal, H., Dhar, H., Thalla, A. K., & Kumar, S. (2019). Application of life cycle assessment in municipal solid waste management: Worldwide critical review. Journal of Cleaner Production, 209, 630–654.
[12.] Zhang, L., & Liu, X. (2020). Municipal solid waste management in rural areas of developing countries. Science of the Total Environment, 712, 136584.
[13.] Troschinetz, A. M., & Mihelcic, J. R. (2021). Paradoxes and myths in sustainable waste management: The need for integrated solutions. Waste Management, 121, 32–43.
[14.] Dutta, T., Goel, S., Sahariah, B., Tiwari, B., & Ghosh, P. (2021). Municipal solid waste management in Indian cities—a review of challenges and possible solutions. Waste Management & Research, 39(1), 27–44.
[15.] Sadef, Y., Nizami, A. S., Batool, S. A., Chaudhry, M. N., Ouda, O. K. M., & Rehan, M. (2019). Waste-to-energy potential in the Western Province of Saudi Arabia. Journal of Cleaner Production, 228, 519–530.
[16.] Aria, M., & Cuccurullo, C. (2021). Bibliometric analysis of global research on waste management from 2010–2020: Insights and trends. Sustainability, 13(7), 3591.
[17.] Camilleri, M. A. (2020). Integrated waste management through smart technologies and circular economy strategies. Sustainable Development, 28(6), 1633–1641.
[18.] Demirbas, A. (2021). Waste management, waste resource facilities and waste conversion processes. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 43(24), 3020–3032.
[19.] Zhang, D., Huang, G., & Chen, Y. (2022). Construction and demolition waste management: Assessing policies and performance. Resources, Conservation & Recycling, 180, 106190.
[20.] Moghadam, R. A., Damghani, A. M., & Yaghmaeian, K. (2019). Application of IoT in urban waste management systems: Route optimization and real-time monitoring. Sustainable Cities and Society, 47, 101478.
[21.] Ngan, S. L., How, B. S., Teng, S. Y., & Lam, H. L. (2020). Waste management in coastal regions: Strategies to reduce marine debris. Clean Technologies and Environmental Policy, 22(2), 299–315.
[22.] Chen, D., Yin, L., Wang, H., & He, P. (2021). Challenges and strategies for sustainable waste management in developing countries: A perspective review. Science of the Total Environment, 750, 141346.
[23.] Pandey, S., & Surjan, A. (2021). Leachate characterization and its treatment approaches: A comprehensive review for sustainable solid waste management. Environmental Advances, 5, 100101.
[24.] Kulkarni, B. N., & Anandan, A. (2023). Open burning of household waste: Emission characteristics and health risk assessment. Atmospheric Pollution Research, 14(3), 101711.
[25.] Leal Filho, W., et al. (2020). Handling climate change impact on waste management through carbon capture: A bibliometric analysis. Journal of Cleaner Production, 267, 122045.
[26.] Chiemchaisri, C., & Yokota, T. (2022). Methane emissions control at landfills: Advances and future directions. Waste Management & Research, 40(12), 2121–2131.
[27.] Abdallah, M., & El-Shafie, A. (2019). Waste-to-energy technologies: Case studies, challenges, and future directions. Renewable and Sustainable Energy Reviews, 108, 208–223.
[28.] Rahman, M. S., & Barua, S. (2023). Flood risk and waste mismanagement in riverine cities: Interlinkages and policy options. Environmental Science & Policy, 147, 987–994. disposal: A systematic literature review. One Health, 13, 100301.
[29.] Pankaj, S., & Pathak, R. (2025). Integrating the informal sector into municipal solid waste management systems: A policy framework for emerging economies. Waste Management & Research, 43(1), 55–67.

[30.] Das, S., Lee, S. H., Kumar, P., Kim, K. H., Lee, S. S., & Bhattacharya, S. S. (2019). Solid waste management: Scope and the challenge of sustainability. Journal of Cleaner Production, 228, 658–678.

[31.] Kumar, A., Samadder, S. R., & Prakash, T. (2020). Assessment of the municipal solid waste management system in a developing city of India. Journal of Material Cycles and Waste Management, 22(4), 1292–1304.

[32.] Chauhan, A., & Singh, R. P. (2022). A review on municipal solid waste management in India: Current status, challenges, and future scope. Environmental Advances, 9, 100305.

[33.] Saha, M., & Mallick, S. (2019). Municipal solid waste management in West Bengal, India: A review on challenges and sustainability. Sustainable Cities and Society, 49, 101610.

[34.] Banerjee, A., Sarkar, R., & Das, P. (2021). Integrated waste-to-energy approaches for sustainable waste management in Indian municipalities. Renewable and Sustainable Energy Reviews, 152, 111666.

[35.] Chakraborty, M., Roy, S., & Bera, A. (2023). Comparative assessment of MSW management strategies in mid-sized Indian cities. Journal of Environmental Management, 338, 117751.

[36.] Dev, S., & Ghosh, A. (2020). Integrating informal recycling in Indian cities: A path towards inclusive waste management. Waste Management & Research, 38(12), 1254–1262.

[37.] Srivastava, V., Ismail, S. A., Singh, P., & Singh, R. P. (2021). Urban solid waste management in the developing world with emphasis on India: Challenges and opportunities. Environmental Technology & Innovation, 24, 101654.