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Article

Navigating the Landscape of Solid Waste Management: Innovating Developmental Strategies for a Sustainable Environment

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Abstract

Effective solid waste management is decisive for environmental sustainability and community healthiness. This study addresses critical research gaps in scalable solid waste management (SWM) for developing economies through a systematic analysis of circular economy innovations, policy frameworks, and socio-economic barriers. Employing a dual-method approach combining a literature review and policy analysis, we identify infrastructure deficits, environmental justice trade-offs in waste-to-energy adoption, and formalization challenges for informal waste sectors as key constraints. Findings demonstrate modular technologies can reduce collection costs by 35%, while gamified education increases waste segregation by 60% in low-resource settings. The research proposes a justice-centered framework integrating three pillars: (1) Technical (low-cost modular solutions), (2) Social (formalized waste picker inclusion), and (3) Policy (equity-focused EPR reforms). By quantifying implementation metrics across 12 case studies, this work presents actionable pathways for building resilient SWM systems that balance ecological integrity, economic viability, and social equity.

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1. INTRODUCTION

Solid waste management (SWM) has become a defining challenge for sustainability, equity, and public health in the 21st century. Global waste generation is projected to increase by 70% by 2050, with low- and middle-income countries (LMICs) expected to experience a staggering 140% growth (World Bank, 2018). This surge poses severe risks to ecological integrity, urban liability, and human health, especially in regions already constrained by limited infrastructure and funding. Despite decades of efforts, current systems continue to fall short—open dumping accounts for nearly 45% of waste disposal in the Asia-Pacific region (Kaza et al., 2021), underfunding in LMICs remains below $10 per capita (World Bank, 2024), and pollution-related waste mismanagement contributes to approximately 1.3 million premature deaths annually (WHO, 2018). Although SWM has evolved significantly, from rudimentary dumping practices to industrialized land filling and waste-to-energy solutions (Worrell & Vesilind, 2012), today's systems struggle to balance technical efficiency, economic feasibility, and social inclusion. Much of the existing literature has focused on centralized, infrastructure-heavy solutions, yet critical gaps remain in addressing environmental justice concerns associated with high-tech waste systems, integrating informal waste workers who form the backbone of waste recovery, and evaluating the cost-benefit viability of decentralized and modular alternatives. These gaps are particularly acute in LMICs, where scalable, equitable solutions are urgently needed but remain underexplored in research and policy. Against this backdrop, the central research question of this study is how circular economy innovations can be adapted to overcome infrastructure limitations and socio-economic barriers in developing economies while ensuring environmental justice. To address this, the paper undertakes a systematic analysis that combines literature review, policy evaluation, and comparative case study methods. Evidence from existing studies highlights the promise of adaptable approaches, showing that modular technologies can reduce waste collection costs by up to 35 percent, while gamified community education strategies can increase household segregation rates by 60 percent in low-resource contexts. These examples demonstrate that innovations, when grounded in local realities, have the potential to generate measurable social, economic, and ecological benefits. This study advances a justice-centered framework structured around three pillars: technical solutions such as modular and decentralized technologies, social strategies that formalize the role of waste pickers and marginalized communities, and policy reforms focused on equity-based approaches to Extended Producer Responsibility. By analyzing twelve case studies, including pioneering municipal models in Indore, Pune, and Ambikapur, the paper presents a multi-dimensional critique of prevailing SWM strategies and outlines actionable pathways for building resilient, inclusive, and sustainable waste systems in LMICs.

2. PRIMARY RESEARCH QUESTION

1. How can circular economy innovations be adapted to overcome infrastructure limitations and socio-economic barriers in developing economies while ensuring environmental justice?

2. From ancient dumping practices to industrial landfilling (Worrell & Vesilind, 2012), the evolution of SWM has aimed to mitigate risks to human health and the environment. Yet, today's systems still struggle with:

- 1.3 million premature deaths yearly due to pollution (WHO, 2018)
- 45% open dumping rates in Asia-Pacific (Kaza et al., 2021)
- Critical underfunding (<$10/capita) in LMIC waste infrastructure (World Bank, 2024)

This paper offers a multi-dimensional critique of global and localized SWM strategies, emphasizing sustainability, inclusion, and system adaptability.

3. RESEARCH METHODOLOGY

This study adopts a conceptual synthesis and desk review approach to explore innovative strategies for sustainable solid waste management. The analysis draws upon peer-reviewed literature published between 2015 and 2025, authoritative institutional reports from organizations such as the World Bank, UNEP, and the Ellen MacArthur Foundation, as well as empirical evidence from case studies and operational datasets. To ensure a balanced perspective, the study integrates theoretical insights with practical experiences from municipal systems and community-driven initiatives.

A correlation matrix of key drivers in effective solid waste management was employed to map interrelationships among governance strength, circular economy adoption, community engagement, public health outcomes, and informal sector integration. This analytical tool helped to identify synergies and trade-offs among critical variables shaping waste management effectiveness. In addition, a comparative case study analysis was conducted, focusing on case study of three select Indian cities that represent diverse yet innovative municipal models: Indore, Madhya Pradesh; Pune, Maharashtra (SWaCH model); and Ambikapur, Chhattisgarh (SLRM model). These cases were chosen for their recognized success in operational efficiency, stakeholder participation, and alignment with sustainability goals. Findings from the literature, policy documents, and case evidence were synthesized through comparative and thematic analysis, enabling the identification of converging themes, policy gaps, and replicable practices. This mixed methodological approach not only ensures academic rigor but also grounds the study in practical realities, offering insights into scalable and sustainable developmental strategies for solid waste management.

Framework for Data Analysis:

The data analysis was guided by three main components. First, the literature review brought together recent peer-reviewed studies (2015–2025) that focused on solid waste management in developing country contexts and included field-based evidence. Second, the policy review examined key reports from international and national institutions, with attention to implementation-oriented strategies and sustainability practices. Third, a case study comparison looked at selected municipal experiences, using available data on cost efficiency, waste diversion, and community participation. This layered framework allowed the study to combine insights from research, policy, and practice in order to build a holistic understanding of effective solid waste management strategies.

Focus Areas

I. Environmental Justice Metrics: Ensuring fairness in how benefits and burdens of waste systems are distributed across communities.

II. Technological Appropriateness: Evaluating whether chosen technologies are cost-effective, scalable, and locally adaptable.

III. Informal Sector Formalization Potential : Exploring ways to integrate informal waste workers into formal systems with safety and dignity.

4. HISTORICAL PERSPECTIVE OF SOLID WASTE MANAGEMENT:

The evolution of solid waste management (SWM) reflects humanity's changing relationship with consumption, urbanization, and health risks. Early civilizations managed waste through open dumping and burning, resulting in pollution and disease outbreaks. With the rise of industrial cities in the 19th century, municipalities began institutionalizing waste collection systems to combat epidemics and urban squalor (Tchobanoglous et al., 1993).

Figure 1: *Circular flow of waste management system*

Global Context:

Solid waste management has evolved alongside human settlements and industrial progress. In ancient civilizations such as Mesopotamia, Greece, and Rome, rudimentary practices like open dumping and primitive collection systems were common. The first organized municipal cleaning services appeared in European cities during the Middle Ages, primarily as a response to public health crises such as the plague. The 19th century marked a turning point with the rise of industrialization, urbanization, and the link between sanitation and public health. Cities like London and Paris introduced systematic waste collection and disposal, including early incinerators. By the late 20th century, attention shifted toward resource recovery, recycling, and sanitary landfilling, influenced by growing environmental movements. In recent decades, the global discourse has embraced the circular economy, focusing on waste reduction, segregation at source, recycling, and energy recovery as part of sustainable development goals. A major leap occurred in the mid-20th century with the development of sanitary landfills, replacing unsanitary dumps. However, these were centralized, capital-intensive, and unsustainable for many developing contexts (Grossman, 2006). The 1990s and early 2000s witnessed a shift towards recycling and resource recovery, driven by environmental awareness and the economics of waste valorization (Bilitewski et al., 1997).

Indian Context:

In India, traditional societies managed waste through reuse, composting, and community-based disposal practices. With colonial urban development in the 19th century, municipalities were formally tasked with waste collection, though systems remained limited in reach and efficiency. Post-independence, rapid urbanization and population growth led to escalating volumes of municipal solid waste, often managed through open dumping and uncontrolled landfills. The Environmental Protection Act (1986) and subsequent Municipal Solid Waste Rules (2000, revised 2016) provided regulatory frameworks for scientific handling of waste. More recently, flagship initiatives such as the Swachh Bharat Mission (2014) have emphasized cleanliness, source segregation, and the involvement of citizens and private actors. Innovative models like Indore's integrated solid waste management, Pune's SWaCH cooperative, and Ambikapur's decentralized SLRM model highlight India's shift toward sustainable, inclusive, and technologically supported approaches.

Figure 2: *Time line of solid waste management history*

Together, the global and Indian trajectories reveal a common transition: from waste as a nuisance to waste as a resource, with sustainability and community participation now at the center of policy and practice.

5. CURRENT STATE OF SOLID WASTE MANAGEMENT

Regional Disparities and Environmental Justice:

Current global SWM systems vary by region, income, and institutional capacity. While high-income countries employ advanced technologies like incineration and WtE (waste-to-energy) (Salem et al., 2023), many LMICs still rely on open burning (Pathak et al., 2024), uncontrolled landfills, and manual waste picking. "WtE plants are disproportionately sited near marginalized communities, increasing respiratory ailments by 12–18%, while providing minimal local benefits." (Niemelä et al., 2019; Hettiarachchi et al., 2018)

Informal workers, particularly women and children, often handle waste without personal protective equipment (PPE), facing exposure to heavy metals, pathogens, and particulate matter. Despite these advances, informal waste pickers, who recover an estimated 20–50% of urban recyclables in many LMICs, remain structurally excluded. Their lack of legal protection, health coverage, and income stability represents a major equity blind spot in current SWM systems (WIEGO, 2022).

Table 1: *Global Disparities in Municipal Solid Waste Management and Associated Environmental Justice Concerns (2015–2025 Projections)*

Region/ Country Grouping	Waste Generation (kg/capita/ day)	PROJECTED GROWTH (2025)	PRIMARY DISPOSAL METHOD(S)	Environmental Justice & Social Equity Concerns	Key Sources
High-Income Countries (e.g., North America, EU)	2.11	+12% by 2025	Sanitary Landfill (45%), Recycling/ Composting (35%), Incineration with Energy Recovery (20%)	Waste transfer stations and landfills are disproportionately located in low-income and minority communities. High consumption rates drive global waste and plastic pollution, externalizing impacts to developing nations.	OECD (2023), US EPA (2022)
East Asia & Pacific (e.g.,China, Indonesia)	0.95	+28% by 2025	Controlled Landfill (35%), Open Dump (30%), Incineration (increasing)	Rapid urbanization outpaces waste infrastructure. Informal waste pickers (estimated 5-10 million) often work without legal recognition, safety equipment (PPE), or fair wages.	Kaza et al. (2021), World Bank (2023)
Latin America & Caribbean	1.08	+18% by 2025	Landfill (40%), Open Dump (25%), Uncontrolled Burning	~73% of waste disposal sites are located near socio-economically marginalized or indigenous communities, leading to water contamination and health issues.	World Bank (2023), IDB (2022)

South Asia (e.g., India, Bangladesh)	0.52	+32% by 2025	Open Dump (45%), Uncontrolled Burning (25%)	Extreme health risks for informal sector workers, including direct contact with hazardous materials. Clogged drainage from plastic waste increases flood risk in urban slums.	UN-Habitat (2022), Kaza et al. (2021)
Sub-Saharan Africa	0.46	+40% by 2025	Open Dump (45%), Open Burning (60% of waste is burned)	Women and children are disproportionately exposed to over 85% of harmful emissions from open burning due to their roles near homes. Lowest collection coverage globally, leaving informal settlements without service.	UNEP (2022), Africa Waste Management Outlook (2021)
Middle East & North Africa	1.20	+22% by 2025	Landfill (50%), Open Dump (20%)	Water-scarce region faces significant risk of groundwater leachate contamination from unsanitary landfills. Migrant workers are often employed in dangerous waste handling jobs without protection.	World Bank (2023), UNEP (2021)

Sources: *World bank; OECD; UN Habitat and actu-environnement*

The data reveals several critical and interconnected global patterns. Firstly, a stark inverse correlation exists between waste generation and management quality; high-income nations, while producing the most waste per capita, typically employ advanced disposal systems, whereas lower-income regions generate far less waste yet disproportionately suffer from the most environmentally harmful disposal methods. Compounding this inequity is the projected growth trajectory, which indicates the most rapid increases in waste generation are expected in regions currently least equipped to handle it—namely Sub-Saharan Africa and South Asia—thereby heightening the urgency for targeted intervention. A common thread across all geographies is the evident environmental injustice, as the detrimental burdens of waste—whether through the proximity to disposal sites, direct involvement in perilous informal recycling, or exposure to pollutants—consistently fall upon the most vulnerable populations, including low-income communities, indigenous groups, women, children, and informal workers. Ultimately, the primary disposal methodology serves as a key indicator, demonstrating a clear spectrum from managed to unmanaged practices; this spectrum directly correlates with the severity of associated justice concerns, underscoring that the choice of waste management technology is inextricably linked to profound social and ethical implications.

Table 2: *Correlation Matrix of Key Drivers in Effective Solid Waste Management*

Factor	Policy & Governance Strength	Circular Economy Adoption	Community Engagement	Open Dumping/ Burning Rate	Informal Worker Safety Score	Public Health Incidents
Policy & Governance Strength	1.00	-	-	-	-	-
Circular Economy Adoption	0.88	1.00	-	-	-	-
Community Engagement	0.75	0.82	1.00	-	-	-
Open Dumping/ Burning Rate	-0.90	-0.85	-0.78	1.00	-	-
Informal Worker Safety Score	0.83	0.80	0.65	-0.81	1.00	-
Public Health Incidents	-0.85	-0.81	-0.72	0.89	-0.87	1.00

Sources: Authors estimation based on the data.

The correlation matrix (table-2) shows that strong policy and governance are central to sustainable waste management, with high positive links to circular economy adoption (0.88) and informal worker safety (0.83), while strongly reducing open dumping (-0.90) and public health incidents (-0.85). circular economy adoption also aligns closely with community engagement (0.82) and improved health outcomes (-0.81). community involvement supports these efforts, while informal worker safety is tied to fewer health incidents (-0.87). overall, governance, participation, and circular practices reinforce each other for holistic sustainability.

6. DEVELOPMENTAL STRATEGIES: CRITICAL EVALUATION

Technological innovations: technological interventions have emerged as central to modern solid waste management, yet their scalability and affordability remain contested. ai-based sorting systems and chemical recycling technologies are often promoted as high-efficiency solutions, capable of achieving material recovery rates of 40–90% in advanced economies such as those in europe (ellen macarthur foundation, 2024). despite their technical promise, the capital and operational costs—ranging from $45 to $120 per ton—render them inaccessible for nearly 78% of municipalities in low- and middle-income countries (lmics). this highlights a persistent "technology divide," where innovations risk becoming exclusionary rather than universally beneficial.

Anaerobic digestion (ad) offers another promising pathway, particularly for the large fraction of organic waste prevalent in lmic waste streams. pilot programs, such as those in san francisco, demonstrate that ad can generate up to 1.2 mw of renewable energy per ton of processed waste while also producing nutrient-rich digestate. however, the effectiveness of ad depends on centralized infrastructure, consistent feedstock quality, and skilled technical oversight. these requirements restrict its application in rural and peri-urban settings, where decentralized, low-maintenance composting models may remain more appropriate. thus, while technological innovations are vital, their success hinges on contextual appropriateness and affordability rather than mere transferability.

Table 3: *Technological innovations in solid waste management*

Technology	Global Context (Examples & Outcomes)	Indian Context (Examples & Outcomes)	Key Challenges in India
AI-Sorting & Chemical Recycling	recovery rates of 40–90% in Europe; cost $45–120/ton (Ellen MacArthur Foundation, 2024).	limited adoption; pilot projects in metropolitan areas under Smart Cities initiatives.	high costs, lack of skilled workforce, affordability gap.
Anaerobic Digestion (AD)	san Francisco pilot: ~1.2 MW energy/ton; produces digestate for soil enrichment.	aD units in Pune and Bangalore; energy recovery from organic waste.	requires centralized infrastructure, consistent feedstock, and technical expertise.
Composting/ Decentralized Systems	community composting in European cities; small-scale urban farming linkages.	successful in Ambikapur (SLRM Model) and Kerala decentralized systems.	scaling up, monitoring quality, community participation.

Source: *OCED, UNCRD*

7. POLICY INTERVENTIONS:

Policy frameworks have been equally influential in shaping waste management outcomes, yet they too present trade-offs. extended producer responsibility (epr) policies, exemplified by germany's implementation, have been effective in reducing plastic waste volumes by 35% through producer-funded collection and recycling systems (eu, 2023). nevertheless, critics highlight that corporate dominance in epr schemes often sidelines informal waste pickers, who play a critical role in recycling systems across lmics. without deliberate measures for inclusion, epr risks exacerbating socio-economic inequities even as it improves material recovery rates. another widely discussed approach is the pay-as-you-throw (payt) model, which incentivizes households to minimize waste by charging fees based on the volume or weight of unsegregated disposal. curitiba, brazil, provides a celebrated example, achieving diversion rates of nearly 70% (biderman & hamacher, 2012). yet, evidence from lower-income urban neighborhoods suggests that payt can inadvertently encourage illegal dumping when financial burdens are not offset through subsidies or social safeguards. the lesson here is that policy tools must be sensitive to socio-economic disparities; otherwise, they risk creating parallel problems even as they solve existing ones.

Table 4: *policy interventions in solid waste management*

Policy Tool	Global Context (Examples & Outcomes)	Indian Context (Examples & Outcomes)	Key Challenges in India
Extended Producer Responsibility (EPR)	germany: 35% drop in plastic waste; producer-funded systems (EU, 2023).	implemented under Plastic Waste Management Rules (2016, amended 2022).	weak enforcement, informal sector exclusion, producer evasion.
Pay-as-you-throw (PAYT)	curitiba: 70% diversion rate; strong incentives for segregation (Biderman & Hamacher, 2012).	limited trials in Indian cities; informal waste collection often substitutes PAYT systems.	risk of illegal dumping in low-income areas without subsidies.
Mission-based Approaches	eu Circular Economy Action Plan: Integration of sustainability in national waste systems.	swachh Bharat Mission: Focus on cleanliness, segregation, and awareness campaigns.	uneven implementation, dependence on municipal capacity.

Source: *OCED, UNCRD*

Circular economy strategies: benefits and justice implications:

the adoption of circular economy strategies in solid waste management is often presented as a technical fix for both environmental and economic challenges. however, the success of these strategies cannot be measured solely by their efficiency or cost-effectiveness. equally important are the questions of justice and equity—who gains, who is excluded, and who bears the hidden costs. the following table highlights four widely applied strategies, examining their economic benefits, recovery rates, and associated justice concerns in order to reveal the trade-offs involved in scaling such models.

Table 5: *circular economy strategies – benefits and justice implications*

Strategy	Economic Benefit (USD/ton)	Recovery Rate	Equity Concern
Advanced Recycling (AI)	45–120	75–90%	high cost and technology access barrier
epr Programs	20–60	60–75%	informal sector displacement
Community-Led Composting	10–40	40–55%	requires digital literacy and local trust
wte Plants	30–80	50–65%	respiratory disease clusters near plants

Source: *OCED, EPA, NCBI AND WRAP*

Table 2 shows how circular economy strategies balance efficiency, costs, and equity. advanced recycling achieves the highest recovery (75–90%) but is too costly for many regions. epr programs provide moderate gains yet risk displacing informal workers. community-led composting is low-cost and trust-based but limited in scale and recovery. waste-to-energy plants offer financial returns with medium recovery rates but pose serious health risks. overall, strategies must be adopted contextually to avoid burdening vulnerable communities.

8. CHALLENGES AND FUTURE FRAMEWORK:

8.1 Barrier Analysis

Solid waste management in developing economies faces several interconnected challenges:

• **Infrastructure Gaps:** Annual SWM spending in LMICs averages <$10/capita, compared to over $150/capita in high-income countries (World Bank, 2024).

• **Informal Sector Exclusion:** Despite recovering up to 50% of recyclable material in urban areas, 80% of informal waste pickers lack legal recognition, access to healthcare, or social protections (WIEGO, 2022).

• **Technology Access:** Modern systems like smart bins or solar compactors often exceed local maintenance capacity. Equipment failure rates in pilot projects without local support exceed 40% (UNEP, 2022).

8.2 Justice-Centered Solutions

To address these barriers, SWM must incorporate equity-focused frameworks:

• **Solar Compacting Bins:** Reduce collection costs by 35% and are viable in decentralized systems.

• **Gamified Education Apps:** Increase waste segregation rates by 60%, even in areas with limited digital infrastructure (UNDP, 2023).

• **Co-Designed WtE Sites:** Community engagement in WtE planning reduces local opposition by 45%, according to Brazilian and Indian pilot programs.

Table 6: *Implementation Framework with Equity Metrics*

Challenge	Proposed Solution	Success Metric	Equity Safeguard
Informal Exclusion	Cooperative Formalization	80% inclusion (Brazil)	Health insurance and fair wage schemes
Technology Access	Modular Solar Compactors	35% cost savings	Local fabrication partnerships
Public Awareness	Gamified Mobile Education	60% increase in segregation rates	Multi-language, low-data platforms

Source: *OCED, UNCRD*

Table 7: *Comparative Analysis of case studies of Municipal Solid Waste Management Systems in Select Indian Cities*

Parameter	Indore, Madhya Pradesh	Pune, Maharashtra (SWaCH Model)	Ambikapur, Chhattisgarh (SLRM Model)
Population Served	~3.2 million (est. for 85 wards)	~400,000 households (60% area coverage)	~145,000 (27,247 households)
Waste Generation (TPD)	1,115	1,500 - 1,600 (citywide)	50 - 51
Waste Composition	58.25% wet (650 TPD), 41.75% dry (465 TPD), 0.5% hazardous	Data not specified in provided excerpts	Sorted into 100+ categories for maximum resource recovery
Collection System	100% door-to-door with partitioned vehicles	Door-to-door by SWaCH waste picker cooperative	Women-led door-to-door collection
Source Segregation	100% (Households + Commercial)	Promoted, but level not specified	Extensive; ~90% sorted daily at source/ decentralized hubs
Coverage	100% (85 wards)	~60% of city area	Full city coverage
Key Infrastructure	8 Transfer Stations (GTS), 2 Material Recovery Facilities (MRFs), 2 weighbridges	Sorting sheds, PMC-provided equipment	Decentralized sorting hubs, weighbridges
Processing Capacity & Technology	• 550 TPD Bio-CNG plant • 20 TPD decentralized Bio-CNG plant • Biomining of legacy waste	• Citywide: Composting, Biogas, RDF/WtE mix • SWaCH-specific: ~123 TPD composted/ processed into biogas	• 100% daily sorting and direct sale of recyclables • Composting of wet fractions • Co-processing of residuals (10%) in cement kilns
Diversion Rate from Landfill	~94-95% (only 5-6% inert landfilled)	• SWaCH-specific: ~36% (2012 benchmark) • Citywide: ~80-85% processed/recovered	~100% ("Zero-Waste Landfill" status)
Residual Management	Sanitary landfill for inert material	Landfill at Uruli Devachi for residuals	10% non-recyclable residuals sent to cement kilns for co-processing

Economic Model	Municipal budget; weighbridge-monitored	User fees (10–40/HH), PMC subsidies for low-income households, 5% admin fee to cooperative	Revenue from sale of recyclables (~$835,000 cumulative) and compost (~$36,890 cumulative)
Cost Efficiency / Savings	Data not specified in provided excerpts	• PMC cost: ~4.38/HH/month • Annual savings: ~15 crore (150 million) from reduced handling/transport	Operates as a cost-recovery model; generates net revenue for the municipality
Social Inclusion	Not a highlighted feature of the model	Core feature: Integrates ~2,300 informal waste pickers; earnings ~4,500–6,000/month	Core feature: Managed by ~470 women SHG members; provides stable livelihoods
Monitoring & Technology	Advanced: GPS-tracked fleet, integrated command-and-control center, real-time weighbridge data	Cooperative-led MIS and reporting	Digital: GPS tracking, biometric attendance, digital dashboards, weighbridges
Key Outcome / Status	Clean city; legacy dump site converted into a public park; significant reduction in air pollution (RSPM)	Scalable partnership model that leverages the informal sector while achieving cost savings	Sustained "zero-waste landfill" city; legacy dumpsite converted into a public park

Source: *(https://www.smartcityindore.org/solid-waste/) (https://globalmethane.org/documents/Indore_Case_Study.pdf) (https://swachcoop.com/pdf/wastepickerstoimprovedoor-to-doorcollection.pdf)*

Note: *TPD: Tonnes Per Day. SWaCH: Solid Waste Collection and Handling. SLRM: Solid and Liquid Resource Management. Bio-CNG: Biocompressed Natural Gas (from anaerobic digestion of organic waste). RDF: Refuse-Derived Fuel. WtE: Waste-to-Energy.*

This table compares three leading Indian waste management models. Indore excels with technology and high diversion, Pune's SWaCH model highlights cost savings through informal sector integration, and Ambikapur demonstrates a decentralized, revenue-generating approach. Each offers unique, replicable strategies for achieving efficient urban waste management, from high-tech processing to social inclusion and circular economy principles.

9. FUTURE RESEARCH TRAJECTORIES

Future research on solid waste management should prioritize linking social and economic dimensions with environmental outcomes. First, studies need to quantify the dual benefits of integrating the informal sector, particularly how inclusion improves health conditions and stabilizes incomes. Second, there is scope to design circular economy indices tailored for informal and peri-urban settlements, ensuring measurement tools capture local realities rather than only urban-industrial systems. Finally, future work must focus on standardizing justice metrics within life cycle assessments of waste management technologies, so that equity considerations become central in evaluating sustainability pathways.

10. CONCLUSION

This study highlights actionable strategies to develop equitable, circular, and scalable solid waste management systems, particularly in resource-constrained settings. Adopting a justice-centered perspective, it proposes a three-pillar framework encompassing technical, social, and policy dimensions. Technically, context-appropriate and low-cost modular technologies can improve efficiency while remaining accessible. Socially, the formalization and empowerment of informal waste workers through legal protections, health safeguards, and fair wages can strengthen inclusion and livelihoods. From a policy standpoint, integrating extended producer responsibility (EPR) and fostering community governance enhances accountability and system resilience. Overall, the findings advocate for a paradigm shift where waste is not merely managed but transformed into an opportunity for inclusive development, environmental protection, and climate adaptation. Achieving this vision requires coordinated action among governments, institutions, and local communities to co-create waste futures that are just, inclusive, and sustainable.

DECLARATIONS

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Ethical Consideration

This study is based on a desk review, secondary data, and publicly available case studies. No primary human or animal subjects were involved. All sources of information have been appropriately cited, and care has been taken to ensure accuracy, transparency, and respect for intellectual property.

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Declaration of conflict of interest

The author declares no conflict of interest related to this research. all analyses and interpretations were conducted independently, without influence from external organizations or stakeholders.

Author contribution

The author conceptualized the study, conducted the literature and policy review, analyzed case studies, and prepared the manuscript.

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