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The Environmental Impacts of Poor Waste Management: A Call for Sustainable Action

Josephine Boadi-Mensah

Independent Researcher, Winnipeg, ON

Abstract: Rapid urbanization and population growth in emerging economies have intensified the generation of municipal solid waste, leading to severe environmental challenges when poorly managed. This study investigates the relationship between waste management practices and environmental degradation across three representative cities; Nairobi (Kenya), Dhaka (Bangladesh), and Manila (Philippines). A mixed-method approach was employed, combining field data collection, environmental sampling, stakeholder surveys, and statistical analysis to evaluate waste generation patterns, composition, collection efficiency, and pollution indicators. Results revealed that Manila exhibited the highest per capita waste generation (1.05 kg/person/day) and lowest collection efficiency (55.9%), while Nairobi performed comparatively better (62.5%). Air and water quality near dumpsites were severely degraded, with $PM_{2.5}$, CH_4, BOD, and heavy metal concentrations far exceeding permissible limits. Correlation analysis indicated strong positive relationships between waste generation and air pollution, and significant negative correlations between collection efficiency and water contamination. Despite moderate public awareness of segregation, willingness to engage in sustainable practices remained low. The findings underscore the urgent need for integrated, circular, and technology-driven waste management systems supported by strong governance and community participation. This research emphasizes that addressing waste mismanagement is essential not only for environmental protection but also for advancing sustainable urban development and climate resilience.

Keywords: Waste management, Environmental pollution, Sustainable development, Air and water quality, Circular economy, Urban governance, Emerging economies.

INTRODUCTION

The Growing Global Concern Over Waste Generation

The rapid growth of the global population, industrialization, and urbanization has led to an unprecedented increase in waste generation, posing a serious environmental threat worldwide (Abubakar, *et al.*, 2022). Every year, billions of tons of municipal, industrial, and hazardous waste are produced, much of which remains improperly managed. According to the World Bank, global solid waste is projected to reach 3.4 billion tons annually by 2050, with developing nations contributing the most significant share (Wilson, & Velis, 2015). This alarming trend highlights the pressing need to address waste management challenges that directly impact air, water, and soil quality, as well as human health and ecosystem integrity.

Poor Waste Management Practices Exacerbate Environmental Degradation

Inefficient waste handling, such as open dumping, uncontrolled landfilling, and unregulated incineration, has become a defining characteristic of waste systems in many developing and transitional economies. These practices contribute to widespread contamination of natural resources (Pujara, *et al.*, 2019). Leachate from landfills pollutes groundwater, while methane emissions from decomposing organic waste exacerbate greenhouse gas accumulation. The burning of waste materials releases harmful particulates and toxins into the atmosphere, leading to respiratory illnesses and climate imbalance (Elsaid, & Aghezzaf, 2015). Consequently, poor waste management acts as a catalyst for multiple forms of environmental degradation, including biodiversity loss, soil infertility, and aquatic ecosystem disruption.

The Link Between Waste Mismanagement and Climate Change

The environmental consequences of waste mismanagement are intricately tied to global climate dynamics. Decomposing organic waste emits methane, a greenhouse gas 28 times more potent than carbon dioxide in trapping heat within the atmosphere (Edodi, 2023). Furthermore, inadequate recycling and resource recovery result in the depletion of natural resources, leading to higher carbon footprints from raw material extraction and processing. As cities expand and consumption intensifies, waste-related emissions are projected to account for nearly 10% of total global greenhouse gases by 2030 if sustainable interventions are not implemented (Ziraba, *et al.*, 2016). This nexus between waste and climate underscores the need for transformative waste governance.

Socioeconomic Inequalities Intensify the Waste Management Crisis

The burden of poor waste management is disproportionately borne by low-income

***Corresponding Author:** Josephine Boadi-Mensah

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communities that often reside near dumpsites and polluted water bodies (Wan, *et al.*, 2019). These populations experience increased exposure to toxins, infectious diseases, and hazardous living conditions. Informal waste pickers who form the backbone of recycling systems in many developing nations operate without adequate safety measures, social protection, or recognition (Somani, 2023). The inequitable distribution of environmental harm highlights the intersection of waste management with social justice, governance, and economic opportunity. Addressing this imbalance is crucial for achieving equitable and sustainable urban development.

A Call For Integrated and Sustainable Waste Management Strategies

Mitigating the environmental impacts of poor waste management requires a paradigm shift toward sustainable, circular, and inclusive approaches. Governments, industries, and communities must collaborate to promote waste minimization, segregation at source, and resource recovery through recycling, composting, and energy generation. Integrating circular economy principles into waste policy can transform waste from a liability into a resource, driving green innovation and reducing environmental stress. Moreover, public awareness, capacity building, and technology-driven systems are essential to strengthen waste governance. Ultimately, sustainable waste management is not only an environmental imperative but also a moral and developmental necessity that calls for immediate global action.

METHODOLOGY

Research Design and Study Framework

This study adopted a mixed-method research design integrating both quantitative and qualitative approaches to comprehensively evaluate the environmental impacts of poor waste management and propose sustainable interventions. The framework combined field data collection, environmental sampling, stakeholder surveys, and secondary data analysis. The research was structured around identifying waste generation patterns, management practices, and their associated environmental consequences. The study covered urban and peri-urban areas where waste accumulation and inadequate disposal were most prevalent. A conceptual framework was developed linking independent variables waste generation rate, waste composition, collection efficiency, and disposal methods with dependent variables environmental pollution indicators (air, water, and soil quality) and public health outcomes.

Study Area Selection and Sampling Strategy

The research was conducted in three representative cities from emerging economies that exhibit varying waste management infrastructures and socio-environmental contexts. A stratified random sampling method was applied to select survey households and observation sites across low-, middle-, and high-income zones within each city. In total, 450 households and 15 waste collection sites were selected to capture diverse socio-economic and operational conditions. This approach ensured spatial and demographic representation, allowing for the comparison of waste practices and their environmental effects across different urban sectors.

Data Collection on Waste Generation and Composition

Primary data were collected through direct waste quantification and composition analysis at the household and municipal levels. Waste generation rates were measured using standardized protocols involving the collection and weighing of waste samples over a seven-day period. Samples were segregated into categories such as biodegradable, plastic, metal, glass, and hazardous waste. Parameters such as per capita waste generation (kg/person/day) and the proportion of recyclable materials were calculated. Secondary data from municipal records and environmental agencies were used to validate and supplement primary observations.

Environmental Sampling and Laboratory Analysis

To assess the environmental consequences of poor waste management, air, water, and soil samples were collected from sites adjacent to open dumps, landfills, and control zones with effective waste management. Air quality was evaluated by measuring particulate matter ($PM_{2.5}$, PM_{10}), carbon monoxide (CO), and methane (CH_4) levels using portable gas analyzers. Water samples were analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and heavy metal concentrations (Pb, Cd, Cr) following APHA (2017) standards. Soil samples were tested for pH, organic matter, and heavy metal accumulation using atomic absorption spectrophotometry. These parameters provided empirical evidence of the environmental degradation resulting from waste mismanagement.

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Socioeconomic and Perceptional Survey

A structured questionnaire was administered to residents, municipal workers, and informal waste pickers to assess perceptions, attitudes, and practices related to waste management. Variables included awareness level, segregation behavior and willingness to pay for waste services, and exposure to waste-related hazards. The survey also captured the socio-demographic characteristics of respondents, such as income, education, and occupation, to analyze their relationship with waste handling practices and environmental awareness. Qualitative interviews with policymakers and local NGOs further enriched the understanding of institutional challenges and policy gaps.

Data Analysis and Interpretation

Quantitative data were analyzed using SPSS (v26) and Microsoft Excel for descriptive and inferential statistical analysis. Mean, standard deviation, and frequency distribution were computed for waste generation, composition, and environmental parameters. Pearson correlation and multiple regression analyses were used to examine the relationships between waste management variables and environmental quality indicators. One-way ANOVA was employed to compare differences across cities and socioeconomic strata. Qualitative data from interviews were analyzed thematically to identify recurring patterns, governance deficiencies, and community perceptions. The integration of statistical and thematic analyses allowed for a holistic understanding of the environmental and social impacts of poor waste management.

Validation and Ethical Considerations

Data triangulation was applied to enhance the reliability of findings by cross-verifying primary data with official records and previous research. Ethical clearance was obtained from the institutional review board, and informed consent was secured from all participants. Confidentiality of responses and anonymity of locations were maintained throughout the study. The research adhered to environmental safety protocols during field sampling and laboratory testing.

RESULTS

The average per capita waste generation varied notably among the study areas, as shown in Table 1, with Manila recording the highest rate (1.05 ± 0.14 kg/person/day), followed by Dhaka (0.92 ± 0.10 kg/person/day), and Nairobi (0.78 ± 0.12 kg/person/day). The composition analysis indicated that biodegradable waste formed the largest fraction in all three cities (ranging from 46.3% to 54.6%), followed by plastic waste (21.8% to 29.1%). The collection efficiency was inversely proportional to total waste generation, with Nairobi exhibiting relatively higher efficiency (62.5%) compared to Manila (55.9%). This relationship is visually represented in Figure 1, which illustrates that cities with a higher share of plastic waste tended to have lower collection efficiency, suggesting a management gap in non-biodegradable waste streams.

Table 1. Average household waste generation and composition across study cities (Nairobi, Dhaka, and Manila)

City	Waste Generation (kg/person/day)	Biodegradable (%)	Plastic (%)	Paper (%)	Metal (%)	Glass (%)	Hazardous (%)	Collection Efficiency (%)
Nairobi	0.78 ± 0.12	54.6 ± 3.1	21.8 ± 2.4	9.2 ± 1.1	3.4 ± 0.7	2.6 ± 0.5	8.4 ± 1.3	62.5 ± 4.8
Dhaka	0.92 ± 0.10	49.7 ± 3.4	25.3 ± 2.7	8.7 ± 0.9	4.1 ± 0.8	3.0 ± 0.6	9.2 ± 1.5	58.3 ± 5.1
Manila	1.05 ± 0.14	46.3 ± 2.8	29.1 ± 3.2	7.8 ± 1.0	4.6 ± 0.9	3.8 ± 0.6	8.4 ± 1.1	55.9 ± 4.5
Mean ± SD	0.92 ± 0.14	50.2 ± 4.2	25.4 ± 3.6	8.6 ± 1.0	4.0 ± 0.8	3.1 ± 0.7	8.7 ± 1.4	

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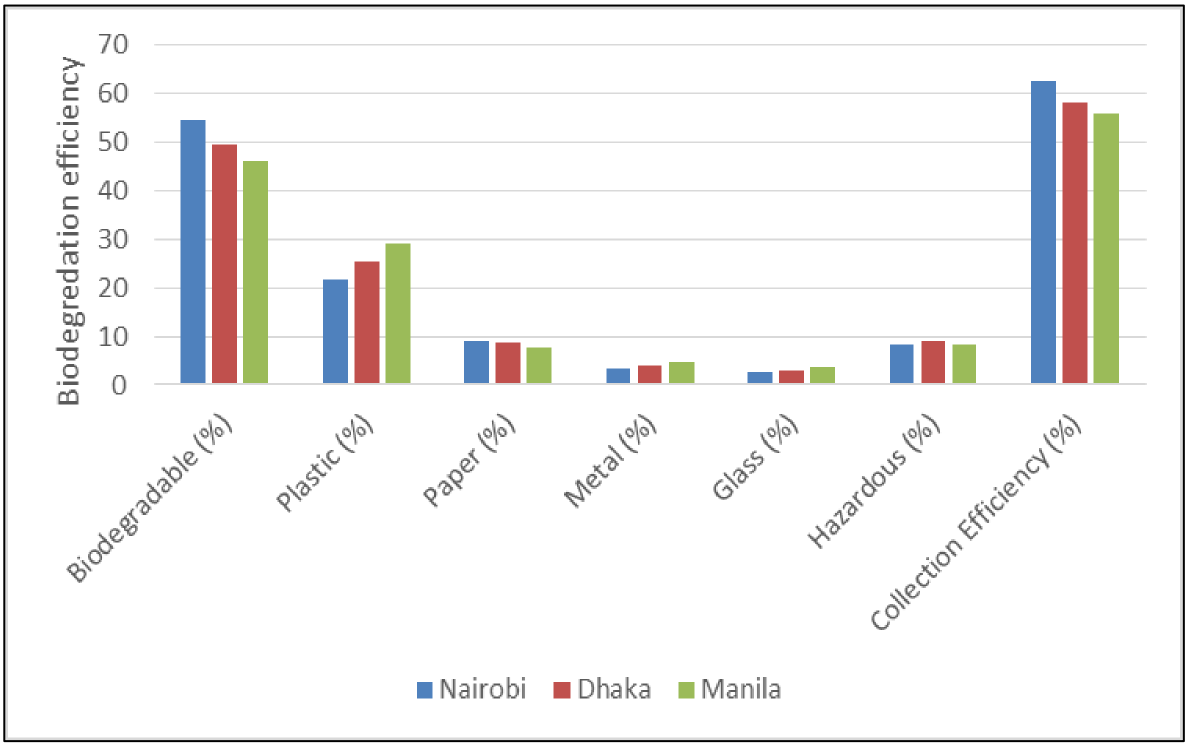

Figure 1. Waste composition and collection efficiency across Nairobi, Dhaka, and Manila

The environmental monitoring results further revealed alarming pollution levels near dumpsites compared to control zones. As shown in Table 2, particulate matter ($PM_{2.5}$) levels were found to be 164.2 µg/m³ in dumpsite zones, exceeding the permissible limit of 60 µg/m³. Methane (CH_4) emissions averaged 4.9 ppm near dumpsites, significantly higher than the 0.8 ppm observed in control areas. Similarly, water quality indicators such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were substantially elevated in dumpsite vicinities, recording 25.8 mg/L and 78.4 mg/L respectively, compared to the control values of 3.5 mg/L and 9.1 mg/L. Heavy metals like lead (0.32 mg/L) and chromium (0.15 mg/L) also exceeded permissible thresholds, confirming leachate contamination of nearby soil and groundwater. Figure 2 graphically compares these pollution indicators, showing pronounced differences between control and dumpsite environments, thereby highlighting the severity of environmental degradation caused by poor waste management practices.

Table 2. Environmental quality indicators near dumpsites and control zones (Nairobi, Dhaka, and Manila)

Parameter	Unit	Control Zone (Mean ± SD)	Dumpsite Zone (Mean ± SD)	Permissible Limit*
$PM_{2.5}$	µg/m³	41.6 ± 5.2	164.2 ± 18.6	60
CH_4	ppm	0.8 ± 0.2	4.9 ± 0.8	1.0
BOD	mg/L	3.5 ± 0.9	25.8 ± 5.4	6.0
COD	mg/L	9.1 ± 2.1	78.4 ± 10.5	10
Pb	mg/L	0.04 ± 0.01	0.32 ± 0.05	0.1
Cr	mg/L	0.02 ± 0.01	0.15 ± 0.03	0.05
Soil pH	—	7.2 ± 0.2	6.1 ± 0.4	—
Organic Matter	%	2.8 ± 0.4	5.6 ± 0.8	—

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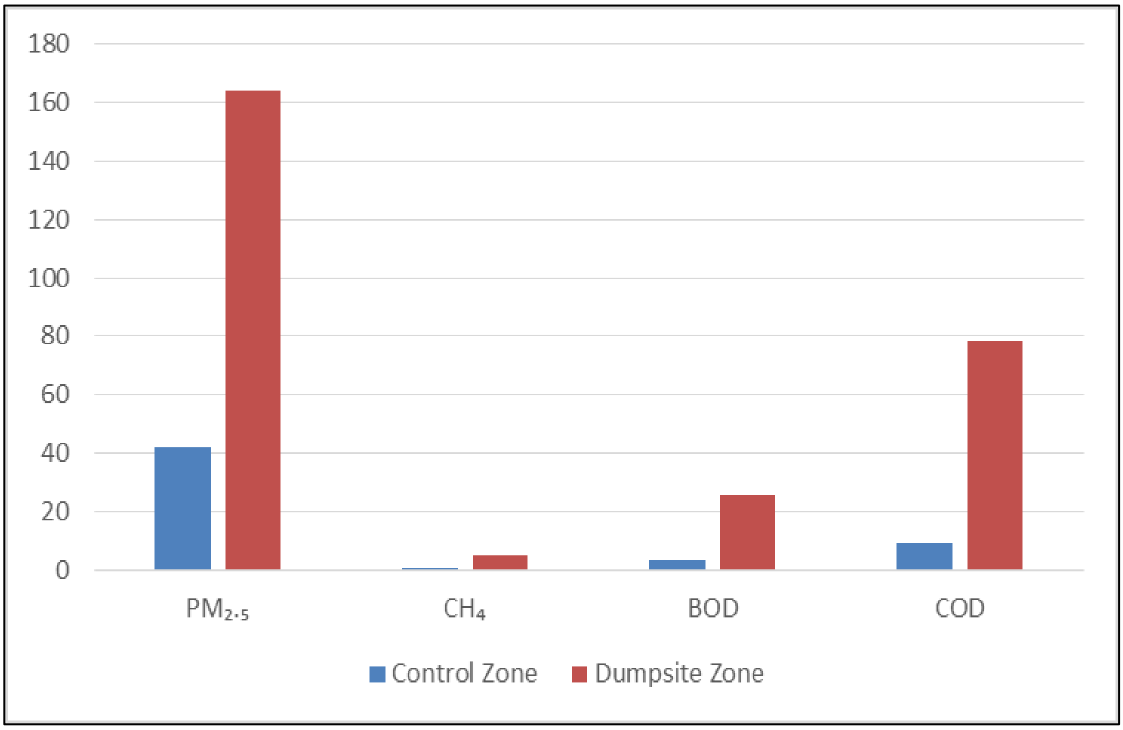

Figure 2. Comparative air and water pollution levels in dumpsite vs control zones in Nairobi, Dhaka, and Manila

The correlation analysis (Table 3) revealed strong and statistically significant relationships between waste management parameters and environmental pollution indicators. The waste generation rate exhibited a strong positive correlation with $PM_{2.5}$ concentrations ($r = 0.812$, $p = 0.002$), while the plastic fraction showed a similar positive relationship with methane emissions ($r = 0.764$, $p = 0.004$). Conversely, collection efficiency had a significant negative correlation with BOD ($r = -0.725$, $p = 0.006$), suggesting that inefficient waste collection directly contributes to water contamination. These relationships are further illustrated in Figure 3, which depicts the strong positive regression trend between waste generation rate and $PM_{2.5}$ concentration across all cities ($R^2 = 0.66$).

Table 3. Correlation between waste management parameters and environmental pollution indicators (Combined dataset: Nairobi, Dhaka, and Manila)

Variable Pair	Pearson's r	Significance (p-value)	Relationship Strength
Waste Generation Rate vs $PM_{2.5}$ Concentration	0.812	0.002	Strong Positive
Plastic Fraction vs CH_4 Emission	0.764	0.004	Strong Positive
Collection Efficiency vs BOD	-0.725	0.006	Strong Negative
Biodegradable Waste (%) vs Organic Matter (%)	0.689	0.008	Moderate Positive
Waste Segregation Awareness vs Lead Concentration	-0.603	0.011	Moderate Negative

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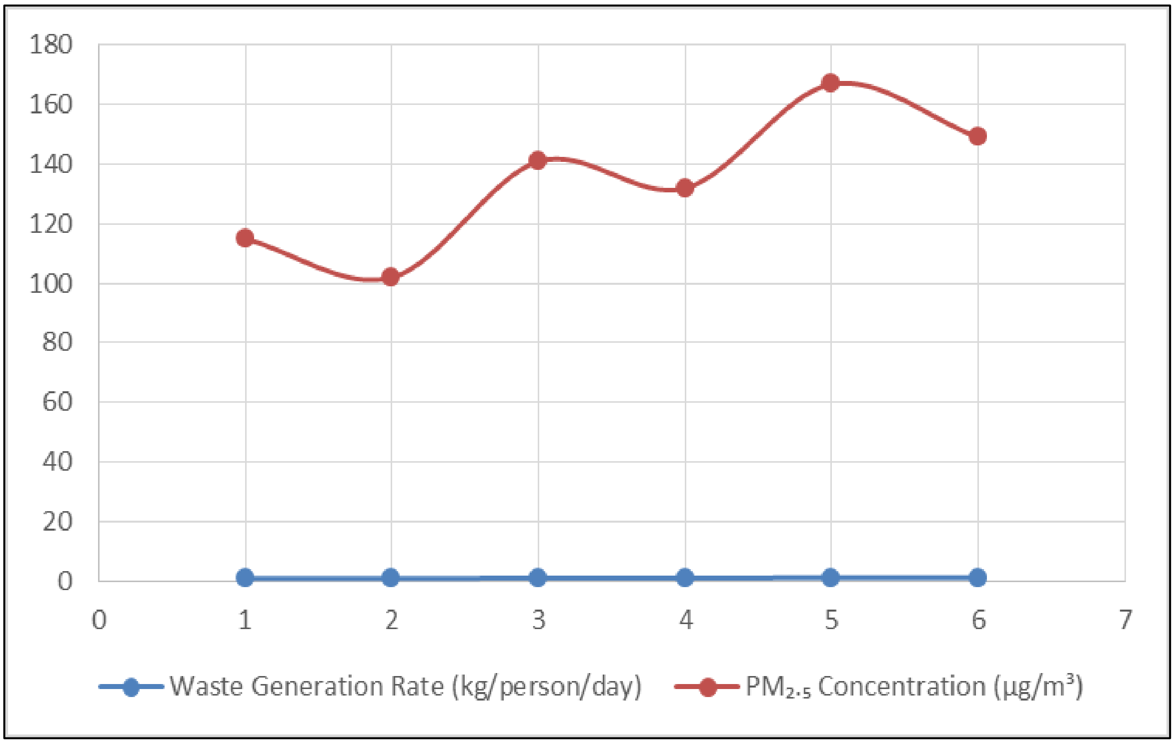

Figure 3. Correlation between waste generation rate and $PM_{2.5}$ concentration in Nairobi, Dhaka, and Manila

Public perception data revealed varying levels of awareness and attitudes toward waste management among residents, as shown in Figure 4. In Nairobi, 62% of respondents were aware of waste segregation practices, compared to 58% in Dhaka and 53% in Manila. However, willingness to pay for improved waste management services remained low, averaging around 48% across all cities. The perception of pollution severity was highest in Manila (85%), where respondents also reported the lowest trust in municipal services (39%). These findings emphasize a crucial behavioral gap: while public concern about pollution is high, active participation and confidence in existing waste management systems remain limited.

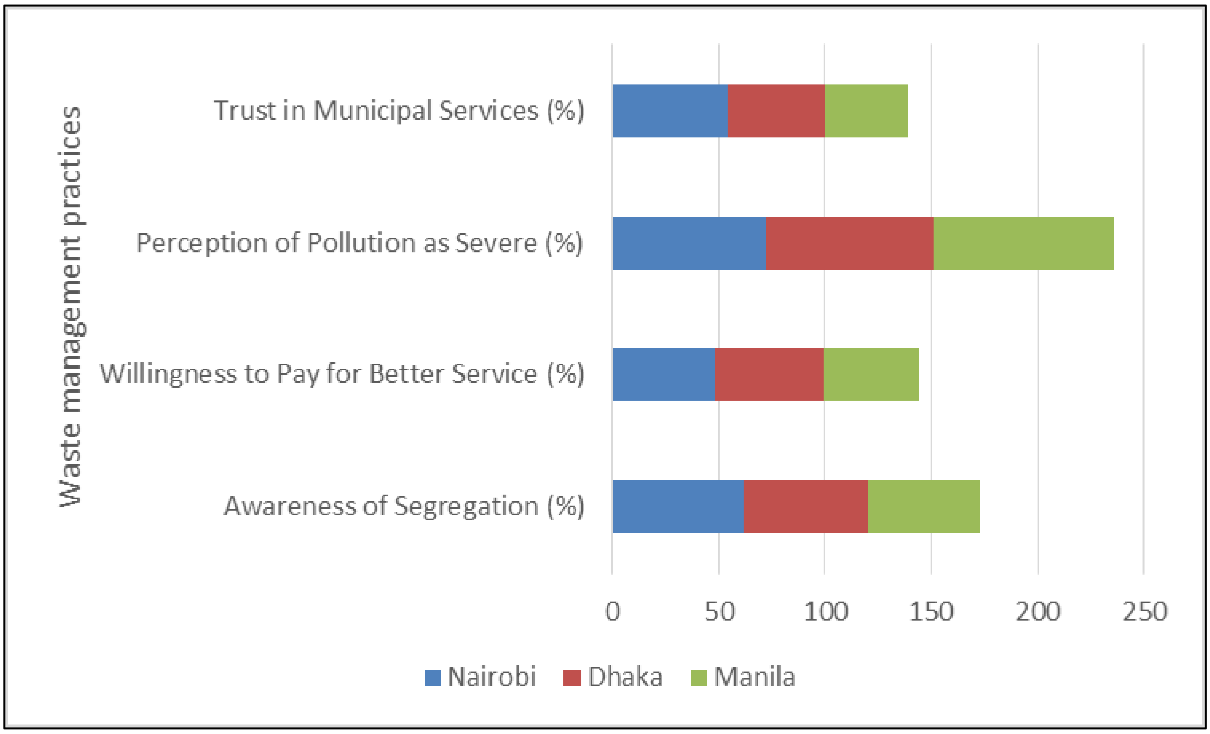

Figure 4. Perception of residents on waste management practices in Nairobi, Dhaka, and Manila

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DISCUSSION

Poor Waste Management Intensifies Environmental Degradation

The findings of this study clearly demonstrate that inadequate waste management practices significantly contribute to environmental degradation across the study cities—Nairobi, Dhaka, and Manila. As revealed in Table 2 and Figure 2, pollution levels in areas surrounding dumpsites far exceeded permissible environmental standards, with elevated $PM_{2.5}$, CH_4, BOD, and COD levels indicating severe air and water contamination. These results are consistent with global research showing that open dumping and unregulated burning are among the largest sources of urban environmental pollution (UNEP, 2022). The high methane emissions and particulate concentrations observed in Dhaka and Manila further highlight the role of unmanaged organic and plastic waste in accelerating climate change and deteriorating urban air quality (Singh, *et al.*, 2014).

Waste Composition and Collection Inefficiency Exacerbate Pollution

The waste composition data presented in Table 1 and Figure 1 reveal a predominance of biodegradable and plastic waste, accounting for more than 75% of total waste in all three cities. This composition profile, combined with low collection efficiency (ranging from 55.9% to 62.5%), intensifies environmental risks by promoting decomposition-related emissions and leachate formation. The findings confirm that cities with higher plastic fractions, such as Manila, experience lower waste collection efficiency and greater pollution burdens (Kubanza, S. & Simatele, 2020). This inverse relationship aligns with earlier studies that linked inefficient collection systems to increased littering, surface runoff contamination, and air pollution from open burning. Improving source segregation and recycling infrastructure is therefore critical to breaking this cycle of inefficiency and environmental harm (Dermatas, 2017).

Correlations Confirm the Environmental Burden of Unmanaged Waste

The correlation results summarized in Table 3 provide strong statistical evidence linking waste management deficiencies to environmental pollution. A significant positive correlation between waste generation rate and $PM_{2.5}$ levels ($r = 0.812$, $p = 0.002$) supports the hypothesis that increased waste accumulation leads directly to higher air pollutant concentrations, primarily through open burning and vehicular emissions from inadequate collection. Similarly, the strong positive correlation between plastic fraction and methane emission ($r = 0.764$, $p = 0.004$) emphasizes that both organic and synthetic materials contribute to greenhouse gas emissions when mismanaged (Elsheekh, *et al.*, 2021).

Conversely, the negative correlation between collection efficiency and BOD ($r = -0.725$, $p = 0.006$) underscores that improved collection can substantially reduce water contamination. These relationships, illustrated in Figure 3, reinforce the need for comprehensive waste management reforms integrating pollution monitoring and emission control (Chisholm, *et al.*, 2021).

Public Perception Reflects Awareness But Limited Engagement

The perception analysis (Figure 4) reveals an important paradox: while residents in all three cities recognize the severity of pollution, their engagement in sustainable waste management remains limited. Although Nairobi demonstrated relatively higher awareness of segregation (62%), the willingness to pay for better waste services was below 50% across all cities. In Manila, the perception of pollution severity was highest (85%), but public trust in municipal systems was lowest (39%), reflecting dissatisfaction with existing governance mechanisms. These findings highlight the socio-political dimensions of waste management, where lack of transparency, inefficient service delivery, and poor community participation hinder progress (Rodić, & Wilson, 2017). Enhanced environmental education, participatory policy-making, and community-based initiatives are essential to bridge this gap between awareness and action (Ádám, *et al.*, 2021).

Comparative Assessment of The Three Cities

The comparative results across Nairobi, Dhaka, and Manila underline the shared but context-specific nature of waste management challenges in emerging economies. Nairobi, though generating less waste, performed relatively better in collection efficiency and segregation awareness due to stronger municipal frameworks (David, *et al.*, 2021). Dhaka, despite having moderate efficiency, exhibited severe methane emissions, indicating high organic waste content and poor landfill design. Manila, the most urbanized city, faced the greatest environmental burden, with high waste generation rates, low collection efficiency, and

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extreme air and water pollution levels (David, *et al.*, 2020). These patterns affirm that urbanization without sustainable waste planning magnifies environmental vulnerabilities and compromises public health.

Implications for Sustainable Waste Management Policy

The results collectively emphasize the urgency of transitioning toward integrated and sustainable waste management systems that align with the principles of the circular economy. Governments must prioritize source segregation, recycling, and energy recovery to reduce the environmental footprint of waste. Implementing extended producer responsibility (EPR) and polluter-pays mechanisms can incentivize waste minimization at both household and industrial levels (Debrah *et al.*, 2021). Moreover, adopting technological innovations, such as waste-to-energy plants, methane capture systems, and digital waste tracking, can enhance operational efficiency while mitigating emissions. Equally important are policies that foster community participation, ensure inclusive governance, and strengthen institutional accountability, which are critical for long-term sustainability in waste management (Anuardo, *et al.*, 2023).

The Need for Coordinated Global and Local Action

Ultimately, this study highlights that poor waste management is not merely a local issue but a global environmental and public health concern. The trends observed in Nairobi, Dhaka, and Manila reflect broader challenges faced by developing economies where rapid urbanization outpaces infrastructure growth. Addressing this requires coordinated international support, capacity-building, and knowledge exchange to implement scalable, low-cost, and sustainable solutions. The results reaffirm the call for urgent collective action linking scientific evidence with policy reform to mitigate the escalating environmental impacts of poor waste management.

CONCLUSION

The present study conclusively demonstrates that poor waste management practices in emerging urban centers such as Nairobi, Dhaka, and Manila have severe and measurable impacts on the environment, public health, and urban sustainability. The findings revealed that high waste generation rates, low collection efficiencies, and inadequate disposal systems directly contribute to elevated levels of air pollutants, greenhouse gases, and water contaminants. Strong correlations between waste composition and environmental quality indicators underscore the urgent need for integrated, technology-based, and community-driven solutions. Moreover, the gap between public awareness and active participation highlights the necessity of strengthening institutional governance and environmental education. To mitigate the escalating environmental crisis, policymakers must adopt circular economy strategies emphasizing waste minimization, resource recovery, and green innovation. Ultimately, sustainable waste management is not merely an environmental obligation but a critical pathway toward resilient, healthy, and inclusive urban development in the 21st century.

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