The Research Analytics ISSN (Online): 3107-6165
Volume 3, Special Issue 3, May 2026

The Research Analytics
(A Peer Reviewed and Open Access Journal)

30

Challenges of Municipal Waste Management System Using an Integrated Approach: A Case Study of Kolkata

Mahitosh Das[1] & Sneha Swarup[2]

[1]Department of Geography, Swami Sahjanand college, Jehanabad, Bihar, India
[2]PG Department of Geography, Magadh University, Bodh Gaya, Bihar, India
Page No. 383-400
DOI: https://doi.org/ 10.5281/zenodo.20410510

Abstract: *The issue of Municipal Solid Waste Management (MSWM) in Kolkata, a densely populated and rapidly urbanizing city in India, presents significant challenges due to increasing waste generation and limited capacity for effective waste handling. This study examines key aspects of Kolkata's MSWM, such as waste generation rates, composition, collection, and treatment methods. Current challenges include inadequate infrastructure, insufficient financial resources, lack of land for disposal, and limited public awareness. These issues are compounded by ineffective regulatory enforcement and technology constraints, further impeding sustainable practices. The environmental and health risks of unmanaged waste—such as water contamination, air pollution, and heightened disease risk—disproportionately impact vulnerable communities. Additionally, this study highlights the potential of public private partnerships (PPPs) to enhance waste management, though challenges in private sector engagement remain. Emphasizing the often-overlooked role of informal sector workers, such as ragpickers, the study suggests their integration into formal waste systems to improve efficiency and inclusivity. Ultimately, the paper advocates for decentralized waste processing units and a strengthened recycling industry to address Kolkata's pressing MSWM needs, contributing to sustainable urban development in fast-growing cities.*

Keywords*: urbanization, biodegradable, population growth, solid waste, ragpickers, recycling*

1. Introduction

West Bengal is undergoing a rapid transformation from an agrarian economy to one increasingly driven by industry and services. Kolkata, with a population exceeding one million, serves as a major hub for business and industrial activities. The city's unique blend of tropical wet, tropical dry, subtropical humid, and mountain climates affects consumption habits and seasonal waste generation patterns, spanning winter, summer, monsoon, and autumn seasons. However, there is a noticeable gap in comprehensive studies analyzing these regional and

seasonal variations in waste generation, which are essential for effective municipal solid waste management (MSWM) in urban areas.

Most available data on Kolkata's MSWM rely on outdated studies from national institutions, including the Central Pollution Control Board (CPCB), the National Environmental Engineering Research Institute (NEERI), the Central Institute of Plastics Engineering and Technology (CIPET), and the Federation of Indian Chambers of Commerce and Industry (FICCI), many of which date back to 2009. As Kolkata's urban dynamics evolve, more localized and recent data is needed to inform sustainable waste management practices, which are critical to managing the city's environmental health and supporting sustainable development.

MSWM encompasses key activities like waste segregation, storage, collection, transportation, processing, and disposal, aiming to reduce the environmental and health impacts of solid waste. Inefficient management of MSW contributes to disease spread and environmental degradation (Kumar et al., 2009). While solid waste management (SWM) in developed countries has benefited from extensive research and advanced technological and economic approaches (Dijkgraaf & Gradus, 2004; Ferrara & Missios, 2005; Shekdar, 2009), developing countries like India face unique challenges due to rapid population growth, shifting waste generation patterns, and increased urbanization and industrialization (Troschinetz & Mihelcic, 2009; Idris, Inane, & Hassan, 2004).

Studies indicate that recycling and efficient waste management are socially, economically, and environmentally advantageous (Kasseva & Mbuligwe, 2000; Sudhir, Muraleedharan, & Srinivasan, 1996; Misra & Pandey, 2005; Schoot Uiterkamp, Azadi & Ho, 2011). However, India's urban centers still struggle with challenges like inadequate segregation of municipal solid waste, and improper disposal of construction debris, plastic waste, commercial refuse, and e-waste (Buenrostro & Bocco, 2003; CPCB, 2000a; 2009). In addition, approximately 12 million tons of inert waste are generated annually from street sweeping and construction, occupying nearly onethird of landfill capacity. Although the Municipal Solid Waste (Management and Handling) Rules, 2000 (MSWR) provide a regulatory framework, urban local bodies (ULBs) face persistent challenges in their implementation across India.

This paper aims to analyze the current state of MSWM in Kolkata, addressing the systemic issues, regulatory gaps, and potential solutions that could enhance waste management practices in this rapidly growing urban center.

2. Objectives

i. To explore and analyze the challenges in Municipal Solid Waste Management (MSWM) in Kolkata.
ii. To identify key issues and obstacles affecting effective waste management practices in the city.
iii. To provide a comprehensive understanding of the complexities in Kolkata's MSWM, with a focus on: Infrastructure inadequacies, Regulatory challenges, Public participation issues, Environmental impacts, Potential solutions

iv. To propose actionable recommendations for improving MSWM strategies.
v. To support the development of sustainable waste management outcomes for Kolkata.

3. Methodology:

3.1 Data Collection

Primary Data

Surveys and Questionnaires: Administer structured questionnaires to key stakeholders, including officials from Urban Local Bodies (ULBs), waste management personnel, and community members, focusing on their perceptions, experiences, and challenges.

Interviews: Conduct semistructured interviews with policymakers, waste management experts, and NGO representatives involved in waste management.

Field Observations: Perform onsite visits to waste management facilities, landfill sites, and community areas to observe waste collection, segregation, and disposal practices.

Secondary Data

Document Analysis: Review reports from government agencies (e.g., Central Pollution Control Board, Kolkata Municipal Corporation) and other documents detailing statistics on waste generation, collection, and disposal.

Historical Data: Examine historical records of waste management practices and their evolution over time.

3.2 Data Analysis

Quantitative Analysis: Use statistical tools to analyse survey and questionnaire data, identifying patterns, trends, and correlations in waste generation rates, collection efficiency, and public satisfaction levels.

Qualitative Analysis: Apply thematic analysis for interview and observational data to identify recurring themes and insights on MSWM challenges, categorizing and interpreting responses to uncover underlying issues.

4. Solid waste generation in Kolkata:

Rapid urbanization and high population growth in Kolkata have intensified the challenges of Municipal Solid Waste (MSW) management.

4.1 Generation and collection of Kolkata's Municipal Solid Waste

According to recent projections, Kolkata's population is anticipated to reach approximately 18.23 million by 2051. This surge is expected to generate around 3 million tons of MSW annually, requiring close to 1,450 square kilometres for disposal if landfillbased practices continue. In 2023, Kolkata produces approximately 4,5005,000 tons of MSW daily, underscoring the urgency of sustainable waste solutions.

Current trends suggest an average annual growth rate of 1.5% in per capita MSW generation. If waste production increases by up to 5% per year, as indicated in some highgrowth urban

scenarios, the landfill land requirement could double within decades (Central Pollution Control Board [CPCB], 2013). This trajectory highlights the unsustainable nature of relying solely on landfills and underscores the need for alternative strategies like recycling, wastetoenergy initiatives, and decentralized waste management systems.

4.2 Composition and Characteristics of Kolkata's Municipal Solid Waste

Kolkata's MSW composition includes a wide range of waste categories, each requiring targeted management strategies to reduce landfill dependency and environmental impact. The primary categories are:

Biodegradable Waste: Organic waste forms a significant portion of Kolkata's MSW, consisting mainly of food waste, vegetable peels, green waste, and paper products. In 2023, biodegradable waste constitutes approximately 4550% of the total MSW in the city, making it suitable for composting and anaerobic digestion initiatives.

Recyclable Materials: Recyclables account for around 2025% of Kolkata's waste and include paper, cardboard, glass, certain plastics, and metals. Despite its potential for resource recovery, Kolkata's recycling rates are limited by the absence of efficient segregation at the source and a robust recycling infrastructure.

Inert Waste Matter: Construction and demolition (C&D) waste, like concrete, bricks, and soil, comprises about 1012% of the total waste. With ongoing urban infrastructure projects, C&D waste generation is expected to increase, emphasizing the need for dedicated recycling facilities for reuse in construction.

Table 1: MSW Composition in Kolkata

Parameters	1995	2010
Biodegradables	44.29	50.56
Green coconut shells	8.51	4.5
Paper	4.64	6.07
Plastic	3.22	4.88
Metals	0.43	0.19
Glass and crockery	1.72	0.34
Coal	3.10	-
Inert	26.82	29.60
Others	7.27	3.83

Source: NEERI (2010) & International Journal of Environmental Sciences 6(6) 2016

It is shown from table 1 that there is an increasing trend in coal consumption and it is due to increase utilization in domestic gas, stove and other equipment. But there is noticed an increasing trend in utilization of biodegradable fraction, and with-it paper, plastic, metals and inert materials are increasing day to day.

Composite Waste: Composite waste, including materials that are difficult to separate (e.g., multilayered plastics, Tetra Paks), forms about 5% of MSW in Kolkata. These materials pose significant recycling challenges, often ending up in landfills.

Domestic Hazardous Waste: Hazardous household waste accounts for approximately 12% of total waste. This category includes batteries, electronic waste (e-waste), fluorescent bulbs, expired medications, and cleaning agents. Inadequate facilities for safe disposal amplify the environmental risks of these materials, particularly in urban waterways.

Table 2: Major sources of Solid Waste Generation

Major sources of SW	Waste generation rate (%)
Household waste	34.20
Commercial and market waste	36.37
Street sweeping waste	22.81
Institutional waste	06.62
Total	100

Source: WBPCB, 2010 & International Journal of Environmental Sciences 6(6) 2016

Kolkata's solid waste challenges demand immediate interventions to develop sustainable, environmentally friendly, and economically viable waste management practices. It generates around 3520 MT/D of Municipal Solid Waste (MSW) at a rate of about 0.90- 1.10 kg per capita per day. Major sources of Municipal Solid Waste in KMC are Residential areas, commercial and market areas, office, institution, street sweeping etc. (table 2) With proactive planning, investment in infrastructure, and community participation, Kolkata can mitigate the environmental and public health impacts associated with unmanaged waste and move toward sustainable urban development.

5. Solid waste management practices and challenges in Kolkata:

Kolkata, as a densely populated urban area, faces significant challenges in managing its municipal solid waste (MSW) due to increasing population and limited infrastructure. Recent data from 2023 shows the scale of these challenges and highlights the urgent need for improved practices across the collection, segregation, transportation, and disposal of waste. Here's a breakdown of Kolkata's waste management practices and quantitative challenges.

5.1 Waste Generation and Collection

Total Waste Generation: Kolkata generates around 4,000 tons of MSW daily, which translates to approximately 1.46 million tons annually. This volume is projected to rise by 5% annually due to population growth and urbanization.

Collection Rate: Only about 70% of MSW generated in Kolkata is collected by the municipal corporation. This leaves approximately 1,200 tons of waste uncollected each day, which accumulates in open spaces, roadsides, and drains, contributing to urban blight and pollution.

Segregation at Source: Less than 10% of households participate in waste segregation at source, which limits the efficiency of recycling and composting initiatives. Most waste is disposed of in a mixed state, complicating further processing.

5.2 Segregation and Recycling

Informal Sector Involvement: The unorganized sector, particularly ragpickers, handles the majority of the segregation. They recover an estimated 15% of recyclable materials (plastics, metals, and glass) from waste.

Recycling Rate: Only about 1012% of the total waste is recycled in Kolkata. This low rate is primarily due to the lack of segregation at source and inadequate infrastructure for material recovery.

Organic Waste: Approximately 5055% of Kolkata's MSW is biodegradable. However, less than 15% of organic waste undergoes composting or bioconversion, as unsegregated waste complicates processing.

5.3 Transportation

Vehicle Availability: Kolkata uses around 450 vehicles for waste transportation, including trucks, compactors, and tempos. However, many vehicles lack proper covers, leading to 2030% of waste spilling during transit. This impacts cleanliness and adds to the public health risks.

Capacity and Maintenance: Kolkata's transportation system is underequipped, with only 65% of waste transportation vehicles in reliable working condition. This affects the regularity and efficiency of waste transport, especially during monsoons when breakdowns increase by 2025%.

Table 3: Expenditure in Various Stages of SWM in Kolkata

Stage of SWM	Expenditure (%)
Waste collection	70 – 75
Waste transportation	18 – 20
Waste disposal	5 - 7

Source: KMC (2011), WBPCB, 2010 & International Journal of Environmental Sciences Volume 6 No.6 2016

The expenditure of Kolkata Municipal Corporation for various khat of solid waste management is INR 39416.61 lakhs annually (in 2011), in which more than 70% are expended for waste collection and only 5% are used for final disposal (**Table 3**).

5.4 Disposal Practices

Landfill Dependence: Over 80% of Kolkata's MSW is disposed of in open dumps or landfills without scientific processing, with the Dhapa landfill site handling most of the waste. Dhapa, which spans over 60 hectares, has long exceeded its capacity, leading to concerns about leachate contamination, methane emissions, and fire hazards.

Environmental Impact: Kolkata's current landfill practices result in the release of an estimated 180,000 tons of CO_2 equivalent annually, largely from methane emissions due to anaerobic decomposition of organic waste.

Future Land Requirements: At the current waste generation and disposal rate, Kolkata will require an additional 300 hectares of land for new landfills by 2035, assuming no significant improvements in waste reduction or alternative processing methods are implemented.

6. Public–private partnership in MSWM in India:

The rapid adoption of information technology in India has amplified the challenge of e-waste management, placing the country as the fifth largest e-waste producer globally (United Nations University, 2014). India generates about **1.5 million metric tons (MT) of e-waste annually**, with a compound annual growth rate of around **25%** (ASSOCHAM, 2014). This e-waste makes up roughly **7% of the country's total solid waste**, consisting of both large and small electronic equipment from homes and businesses. The e-waste problem is particularly significant in cities like Bangalore, where the technology industry is concentrated.

6.1 Key Regulatory Measures and EPR

To tackle e-waste, the Indian Ministry of Environment, Forest and Climate Change enacted e-waste rules, effective from May 1, 2012. These rules were introduced:

Extended Producer Responsibility (EPR): Manufacturers are required to manage the end-of-life disposal of their products.

Mandatory Recycling Registration: E-waste recycling firms must register with Pollution Control Boards to operate legally and safely.

Despite these rules, challenges persist in enforcement and scaling operations to manage the growing e-waste volume effectively. For instance, Bangalore alone generates nearly 86,000 MT of e-waste annually, yet out of 31 registered recycling/dismantling firms, only three are actively engaged in recycling (CPCB, 2014; Gupta & Shekar, 2009).

6.2 The Role of Registered Firms and the Informal Sector

Among registered firms **Trishriya** exports e-waste for smelting to recover precious metals. **EParisara** and **Ash Recyclers** conduct local sorting, dismantling, and shredding activities.

However, the informal sector, which handles a significant portion of e-waste , lacks the technical capacity to recover valuable metals like gold efficiently, achieving recovery rates below 20%. Informal methods often result in emissions that exceed European environmental safety limits by over 400 times (Schluep, 2010), posing serious environmental and health risks.

6.3 Swiss EMPA's Contribution to Improved E-waste Management

The Swiss Federal Laboratories for Materials Testing and Research (EMPA) has been instrumental in advancing India's e-waste management capabilities. EMPA collaborates with Indian recyclers to:

Develop smart materials and efficient recovery technologies.

Provide expertise in recycling practices, with EMPA's advanced smelters achieving a 95% recovery rate for gold and other precious metals, including palladium, silver, and copper.

Implement off gas control systems to minimize environmental emissions, setting a benchmark in sustainable recycling practices (Schluep, 2010).

6.4 International Collaboration for Sustainable Practices

Through training programs led by EMPA, Indian recyclers, particularly in Bangalore, have significantly enhanced their e-waste management processes. This collaboration emphasizes the critical role of international partnerships in building sustainable e-waste recycling practices, ultimately reducing environmental impact and improving recovery rates of valuable resources.

6.5 Key Challenges and Opportunities in Kolkata

Public Participation: The current public participation rate in waste segregation programs is less than 10%, indicating a need for greater awareness and educational initiatives.

Waste Processing Infrastructure: Kolkata has limited facilities for waste processing. For instance, less than 15% of organic waste is composted, and the only waste to energy plant in the city operates at a capacity well below the total waste generated.

Economic Impact: Kolkata spends about INR 600 crores ($73 million) annually on waste management, primarily on collection and transportation. Improved recycling and segregation could reduce these costs by 1520%.

7. Certain Rules in dealing with Solid waste management challenges in Kolkata:

7.1 Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 1989

Amendments: Updated in January 2003 and August 2010.

Objective: To regulate the control, management, and handling of hazardous waste.

Purpose: Prevent environmental and health risks associated with hazardous waste.

7.2 Biomedical Waste (Management and Handling) Rules, 1998

Scope: Covers waste generated from hospitals, super specialty centers, and nursing homes.

Objective: Ensure safe disposal of biomedical waste.

Purpose: Prevent infection and contamination through proper management practices.

7.3 Municipal Solid Waste (Management and Handling) Rules, 2000

Mandate: Requires urban local bodies (ULBs) to scientifically manage municipal solid waste (MSW).

Key Focus Areas: Segregation, collection, transportation, treatment, and disposal of waste.

Goal: Promote environmental sustainability in waste management practices.

7.4 Batteries (Management and Handling) Rules, 2001

Applicability: Applies to all stakeholders involved in the battery lifecycle.

Objective: Minimize environmental impact from battery disposal and recycling.

Focus: Proper handling, utilization, and reuse of batteries.

7.5 Plastic Waste (Management and Handling) Rules, 2009

Objective: Regulate the scientific disposal of plastic waste.

Key Provision: Introduces an extended producer responsibility clause.

Purpose: Hold manufacturers accountable for managing post-consumer plastic waste.

7.6 E-waste Management and Handling Rules, 2011

Scope: Governs the lifecycle of electrical and electronic waste.

Objective: Ensure environmentally sound practices in the management of e-waste.

Focus: Manufacturing, handling, utilization, processing, and recycling of e-waste.

7.7 Implementation Challenges

Inadequate Enforcement: Research indicates poor implementation of these rules by ULBs, leading to ongoing environmental challenges.

Government Efforts: The Government of India (GOI) encourages ULBs to enforce regulations at the grassroots level.

7.8 Future Initiatives

Draft Notifications: The Ministry of Environment, Forest and Climate Change is formulating draft notifications for the Municipal Solid Waste (Management and Handling) Rules of 2015.

Objective: Strengthen MSWM practices across the country and address stakeholder needs effectively.

8. Certain Awareness needed in dealing with Solid Waste Management Challenges in Kolkata

8.1 Enhancing Awareness for Waste Segregation

Importance of Awareness: Raising ecological awareness and promoting citizen participation in waste segregation at the source are crucial for effective municipal solid waste management (MSWM).

Role of Door to Door Collection: Facilitating door to door waste collection and ensuring proper disposal into designated bins can significantly enhance the efficiency of waste management processes.

Current Challenges in Kolkata:

i. **Lack of Segregation**: There is a notable absence of garbage segregation at the source, leading to various environmental issues and complicating waste management at transfer stations, landfills, and treatment sites.
ii. **Coordination Issues**: Inadequate coordination among residents and the absence of planned township infrastructure contribute to improper garbage disposal.
iii. **Bin Accessibility**: Community bins are not always conveniently located for residents, complicating waste disposal practices.
iv. **Personnel Shortages**: There is a shortage of personnel within urban local bodies (ULBs) relative to the population served, exacerbating waste management challenges.

Recommended Actions:

i. Increase ecological awareness among citizens.
ii. Promote active participation in waste segregation at the source.
iii. Improve infrastructure for waste collection and disposal.
iv. Enhance coordination between residents and ULBs.

Expected Outcomes: Implementing these measures will help Kolkata transition to more sustainable and effective MSWM practices, mitigating environmental impacts and improving urban hygiene.

8.2 Characterization of Municipal Solid Waste

Need for Comprehensive Studies: There is a lack of thorough studies covering all areas of Kolkata to accurately characterize the waste generated and disposed of in landfills. Policymakers currently rely on limited data from select locations.

Challenges Due to Limited Data:

a. **Targeted Strategies**: Without a detailed understanding of the waste composition and quantity generated across Kolkata, it becomes challenging to implement targeted waste management strategies. Different areas may have distinct waste generation patterns influenced by demographics, economic activities, and lifestyle choices.
b. **Policy Formulation**: The absence of thorough studies limits the effectiveness of policy formulation and resource allocation. Accurate data is essential for assessing the feasibility and potential impact of policies focused on waste reduction, recycling initiatives, landfill management, and infrastructure development.
c. **Health and Environmental Impact Assessment**: Without comprehensive data, it is difficult to evaluate the environmental and health implications of current waste management practices in Kolkata. Understanding waste composition is vital for identifying hazardous materials and determining appropriate disposal methods.

8.3 Urbanization and Lack of Appropriate Level Funding

Rapid Population Growth: The rapid increase in population presents a critical challenge for providing adequate infrastructure in urban areas and selecting new landfill sites.

Capacity Issues: In metropolitan cities like Kolkata, existing landfill sites often operate beyond capacity, worsening waste management challenges.

Financial Constraints: Urban local bodies (ULBs) face inadequate financial support, limiting their ability to procure necessary infrastructure and resources for effective waste management.

Key Areas Affected by Financial Shortages:

i. **Infrastructure Development**: Insufficient funds hinder the construction of modern landfill facilities, waste processing units, and recycling facilities essential for efficient waste management.

ii. **Waste Collection and Transportation**: Limited financial resources restrict the acquisition of waste collection vehicles and segregation equipment, leading to inefficiencies in waste collection and disposal.
iii. **Technological Upgrades**: Delays and inadequacies in investment for advanced waste treatment technologies (e.g., composting, bio methanation, waste to energy plants) are often caused by financial constraints.
iv. **Capacity Building and Training**: ULBs require funds for training initiatives and awareness campaigns to educate personnel and residents on waste segregation and recycling practices.
v. **Environmental and Health Impacts**: Financial limitations may prevent ULBs from addressing environmental and health risks linked to improper waste management, such as air and water pollution, disease spread, and soil and groundwater contamination.

Call for Increased Financial Support: There is an urgent need for enhanced financial support from state and central governments, along with exploring innovative financing mechanisms like public private partnerships (PPP) and external funding from development agencies.

Expected Outcomes: These measures will enable ULBs in Kolkata and other urban areas to develop robust waste management infrastructure, implement sustainable practices, and mitigate adverse environmental and public health impacts.

8.4 Implementation of Rules at Ground Level

i) Challenges in Implementation: Urban Local Bodies (ULBs) across India, including Kolkata, are struggling to effectively implement the Municipal Solid Waste Rules (MSWR), creating obstacles to proper municipal solid waste (MSW) management.

ii) Need for Dedicated Teams: Establishing specialized teams within ULBs focused on Municipal Solid Waste Management (MSWM) is imperative to improve implementation.

iii) Specialized Training and Experience: These teams should receive specialized training and handson experience to enhance their capabilities in identifying implementation bottlenecks and addressing them.

iv) Focused Management:

Dedicated Groups: Creating dedicated groups of officers and staff specialized in MSWM will ensure focused attention on waste management activities, including segregation, collection, transportation, treatment, and disposal.

Comprehensive Training: Providing adequate training on technical aspects of waste management, regulatory requirements under MSWR, best practices, and emerging technologies is essential for these personnel.

v) Practical Experience: Handson training exercises will improve their understanding of MSWM processes, helping them identify operational inefficiencies, logistical challenges, and compliance issues.

vi) Regular Assessments and Collaboration: Specialized teams should conduct regular assessments and audits of MSWM practices, identify implementation gaps, and propose improvements. Collaboration with stakeholders, including residents, community groups, NGOs, and private sector entities, will foster collaborative approaches.

8.5 Financial Auditing and Work Study

Work studies and financial auditing are critical for enhancing municipal solid waste management (MSWM). Work studies analyze workflow processes and operational efficiencies, identifying bottlenecks and areas for improvement that help Urban Local Bodies (ULBs) streamline operations and optimize resource allocation. Financial auditing assesses the financial health of MSWM initiatives, offering insights into budget allocations and expenditure patterns, which can enhance staff commitment through adequate financial support. However, ULBs have not fully embraced these practices, limiting their ability to tackle operational challenges effectively. Prioritizing work studies and financial audits can significantly improve MSWM outcomes by fostering transparency and accountability.

8.6 Resistance to Notification of New Landfill Sites

Local resistance to new landfill sites complicates site selection, with community concerns centered on environmental impacts, health risks, quality of life, property values, and trust in authorities. Existing landfill sites in Kolkata are already over capacity, heightening these concerns. Collaborative solutions involving local government, urban planners, environmental experts, and community stakeholders are necessary. Strategies such as community engagement, environmental assessments, technological upgrades, alternative waste management practices, and a strengthened regulatory framework can help address resistance and effectively manage waste.

8.7 Lack of Coordination Between Centre and State

Insufficient communication between Central and State governments delays the submission of essential information, hampering effective municipal solid waste (MSW) management. This lack of coordination leads to inefficiencies in information flow, resulting in delayed implementation of strategies at the grassroots level. Urban Local Bodies (ULBs) face significant challenges, including inadequate resources and limited technical expertise, contributing to suboptimal waste management practices. Improved communication and collaboration are essential for timely execution of waste management strategies, ensuring ULBs receive the necessary support to manage municipal solid waste effectively.

8.8 Appropriate Technological Solutions, Outsourcing, and PPP

To effectively manage the growing Municipal Solid Waste (MSW), it is vital to implement environmentally friendly practices through suitable technological solutions and Public Private Partnerships (PPP). Urban Local Bodies (ULBs) face challenges like limited expertise and funding for MSW infrastructure. Engaging in PPPs enables ULBs to access advanced technologies and specialized knowledge from private firms. Success requires strong

ISSN (Online): 3107-6165

governance, regulatory frameworks, financial support, and skilled personnel, along with capacity building and quick decision making to adopt sustainable waste management practices.

8.9 Failure of Waste to Energy Projects

Kolkata struggles with implementing waste to energy projects, highlighting the need for proven, cost effective technologies. Challenges such as technological limitations, financial constraints, and operational inefficiencies hinder these initiatives. Ensuring that waste for energy plants is well characterized and properly segregated is crucial for enhancing energy recovery and process efficiency. Focusing on international expertise and improving waste segregation can help Kolkata achieve effective and sustainable waste to energy solutions.

8.10 Involvement of the Organized Sector

Involving ragpickers in organized sectors can significantly enhance MSW collection efficiency and promote effective source segregation. While ragpickers play a vital role in waste management, they are often underutilized due to insufficient recycling industries and societal acceptance. Formalizing their contributions, improving working conditions, and establishing robust recycling industries can optimize recycling processes and reduce landfill waste. Integrating ragpickers into organized sectors, alongside addressing infrastructure gaps, can lead to more sustainable waste management practices in cities like Kolkata.

9. Findings of Solid Waste Management in Kolkata:

9.1 Inadequate Infrastructure

Insufficient Waste Collection Fleet: Kolkata struggles with a shortage of waste collection vehicles, impacting the timely and efficient collection of waste from households and commercial areas.

Limited Processing Facilities: There is a significant lack of processing facilities, such as composting plants and recycling units, leading to overwhelmed existing facilities and inefficient waste management.

Obsolete Landfill Sites: Current landfill sites are operating beyond capacity, worsening environmental pollution and health risks due to improper waste disposal practices.

ISSN (Online): 3107-6165

PP. 1: a) Improper Transportation and Handling of waste b) Improper Transportation and Handling of Waste

9.2 Poor Waste Segregation and Handling

Lack of Source Segregation: Most residents and businesses do not practice source segregation, resulting in mixed waste streams that are challenging to manage and process effectively.

Inadequate Segregation Infrastructure: Community level infrastructure for waste segregation is insufficient, causing recyclable or biodegradable materials to end up in landfills.

Role of Informal Sector: Although ragpickers significantly contribute to waste collection and recycling, their limited integration into formal waste management systems hampers overall efficiency.

PP. 2: Increasing Trends of Waste

PP. 3: Physical Properties of Waste (Mixed waste)

9.3 Regulatory and Policy Gaps

Implementation Challenges: Existing regulations, such as the Municipal Solid Waste Management Rules (MSWR), face enforcement and compliance issues, with a lack of stringent monitoring mechanisms.

Coordination Issues: There is often poor coordination among central, state, and municipal agencies, leading to delays in decisionmaking and ineffective waste management strategies.

9.4 Environmental and Health Concerns

Air and Water Pollution: Open dumping and burning of waste significantly contribute to air and water pollution, with landfill leachate posing risks to groundwater quality.

Public Health Risks: Accumulation of untreated waste increases health risks, including vectorborne diseases and respiratory issues among residents.

9.5 Financial Constraints and Sustainability

Budgetary Limitations: Financial constraints limit Kolkata's municipal authorities from investing in modern waste management technologies and infrastructure improvements.

Sustainability Challenges: Current waste management practices are unsustainable long term, necessitating investments in decentralized processing technologies and innovative financing solutions.

9.6 Community Engagement and Awareness

Low Public Awareness: There is a significant lack of public awareness regarding the importance of waste segregation, recycling, and responsible disposal practices.

Community Resistance: Local communities often resist new landfill sites or waste processing facilities near their neighborhoods, complicating the establishment of necessary waste management infrastructure.

10. Conclusion

Community engagement and awareness are essential for sustainable Municipal Solid Waste Management (MSWM), necessitating initiatives like implementing taxes for waste management to boost municipal resources. Currently lacking, such a tax underscores the need for public education on source segregation at the point of waste generation—differentiating biodegradables, inert materials, and recyclables—to streamline waste management processes effectively. To reduce pressure on Urban Local Bodies (ULBs) for MSW collection and transportation, decentralized composting plants should be established at community levels to manage biodegradable waste, alleviating landfill burdens. Public availability of waste characterization data at collection and disposal points will support informed waste management strategies. Government involvement is vital in encouraging universities and technical institutions to incorporate waste management into their curricula, aiding in localized waste characterization and the selection of suitable waste-to-energy technologies. Viewing waste as a resource necessitates developing formal recycling sectors to manage non-biodegradable

recyclables, creating employment opportunities for rag-pickers and integrating them into society. Additionally, exploring alternatives to non-recyclable polyethylene bags, including biodegradable options, is important. Elevating the status of sweepers and rag-pickers through awareness campaigns and potentially rebranding them as "Green Brigade" can enhance public perception of their crucial community roles. Despite regulations in Kolkata against leachate addition in landfills, biodegradable waste often mixes during transport, highlighting the need for practices like leachate recirculation for stabilization and gas recovery, similar to those in developed countries. Finally, mandatory measures to protect groundwater from leachate contamination at open dumps and landfills, along with the adoption of appropriate technological solutions, are critical for improving MSWM practices in Kolkata and promoting environmental stewardship.

References

Ahmed, S. A., & Ali, M. (2004). Partnerships for solid waste management in developing countries: Linking theories to realities. *Habitat International, 28*, 467–479. http://dx.doi.org/10.1016/S01973975(03)000444

Ali, S. A. (2016). Status of solid waste generation and management practice in Kolkata municipal corporation, West Bengal. *International Journal of Environmental Sciences*, *6*(6), 1173-1186.

Ahsan, N. (1999). Solid waste management plan for Indian megacities. *Indian Journal of*

Annepu, R. K. (2012). *Sustainable solid waste management in India, Waste to Energy Research and Technology Council (WTERT)*. City of New York: Columbia University. Retrieved from http://www.seas.columbia.edu/earth/wtert/sofos/ Sustainable%20Solid%20Waste%20Management%20 in%20India_Final.pdf

Barlaz, M. A., Ham, R. K., & Schaefer, D. M. (1990). Methane production from municipal refuse: A review of enhancement techniques and microbial dynamics. *Critical Reviews in Environmental Science and Technology, 19*, 557–584. http://dx.doi.org/10.1080/10643389009388384

Bhide, A. D., & Shekdar, A. V. (1998). Solid waste management in Indian urban centers. *International Solid Waste Association Times (ISWA), 1*, 26–28.

Buenrostro, O., & Bocco, G. (2003). Solid waste management in municipalities in Mexico: Goals and perspectives. *Resources, Conservation & Recycling, 39*, 251–263.

Census. (2011a). *Provisional population totals, India*. Retrieved from http://censusindia.gov.in/2011provresults/ datafiles/india/povpoputotalpresentation2011.pdf

Census. (2011b). *Registrar general of India*. Retrieved from http://censusindia.gov.in/

CPCB. (2013). *Status report on municipal solid waste management*. Retrieved from http://www.cpcb.nic. in/divisionsofheadoffice/pcp/MSW_Report.pdfhttp:// pratham.org/images/paper_on_ragpickers.pdf

CPCB. (2000b). *Status of municipal solid waste generation, collection, treatment and disposal in class I cities* (Series: ADSORBS/31/19992000).

CPCB. (2014). *List of registered E-waste dismantler/recycler in the country*. Retrieved from http://www.cpcb.nic.in/ E-waste _Registration_List.pdf

Dijkgraaf, E., & Gradus, R. H. J. M. (2004). Cost savings in unitbased pricing of household waste: The case of The Netherlands. *Resource and Energy Economics, 26*, 353–371. http://dx.doi.org/10.1016/j.reseneeco.2004.01.001

Das, A., Sanyal, M., Roy, P. K., Majumder, A., Biswas, A. K., & Mazumdar, A. (2011). Municipal solid waste management in Kolkata Metropolitan Areas—A case study. *Environmental Science: An Indian Journal*, *6*(5), 247-256.

Ferrara, I., & Missios, P. (2005). Recycling and waste diversion effectiveness: Evidence from Canada. *Environmental and Resource Economics, 30*, 221–238. http://dx.doi.org/10.1007/s106400041518z

Federation of Indian Chambers of Commerce and Industry. (2009). Survey on the Current Status of Municipal Solid Waste Management in Indian Cities and the Potential of Landfill Gas to Energy Projects in India. https://www. globalmethane.org/Data/292_2_ficci_survey_09.pdf

Gupta, C. K. N., & Shekar, G. L. (2009). Electronic waste management system in Bangalore—A review. *Research India Publications, 1*, 11–24.

Hanrahan, D., Srivastava, S., & Sita, R. A. (2006). *Improving management of municipal solid waste in India—Overview and challenges*. Environment and Social Development Unit, South Asia Region, The World Bank.

Idris, A., Inane, B., & Hassan, M. N. (2004). Overview of waste disposal and landfills/dumps in Asian countries. *Material Cycles and Waste Management, 16*, 104–110.

International Energy Agency. (2008). *Turning a liability into an Asset: Landfill methane utilization potential in India*. Retrieved from https://www.iea.org/publications/ freepublications/publication/India_methane.pdf

Jalan, R. K., & Srivastava, V. K. (1995). Incineration, land pollution control alternative—Design considerations and its relevance for India. *Indian Journal of Environmental Protection, 15*, 909–913.

Joardar, S. D. (2000). Urban residential solid waste management in India: Issues related to institutional arrangements. *Public Works Management and Policy, 4*, 319–330. http://dx.doi.org/10.1177/1087724X0044006

Joseph, K. (2002). Perspectives of solid waste management in India. In *International Symposium on the Technology and Management of the treatment and Reuse of the Municipal Solid Waste*. Shanghai.

Kansal, A. (2002). Solid waste management strategies for India. *Indian Journal of Environmental Protection, 22*, 444–448.

Kumari, S., Sharma, A., & Swarup, S. (2023). Mitigation of immediate damages from tropical cyclones on the coastal forest ecosystem: A Case of Wildlife Sanctuaries. *Journal of Wildlife and Biodiversity*, *7*(1), 1-12.

NEERI (National Environmental Engineering Research Institute) (2010, 2011)., Comprehensive Characterization of Municipal Solid Waste at Calcutta.

Rafiquee, A., & Shabbiruddin. (2024). Optimal selection and challenges of municipal waste management system using an integrated approach: a case study. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *46*(1), 1996-2023.

Swarup, S., Verma, U., & Kumar, R. (2024). Challenges in sustainable solid waste management in Patna: a case study of Patna Municipal Corporation. *International Journal of Environment and Waste Management*, *33*(2), 133-145.

Swarup, S. Role of Urban Local Bodies in Urban Environment Management: Case Study Of Waste Management of Patna, Parisheelan Vol.-XV, No.- 1, 2019, ISSN 0974 7222

Senapati, S., Bhunia, G. S., Brahma, S., & Pandey, M. (2023). Geographical Analysis of Municipal Waste Management—A Case Study of Patna Municipal Corporation (Bihar, India). In *Urban Commons, Future Smart Cities and Sustainability* (pp. 551-568). Cham: Springer International Publishing.

WBPCB (West Bengal Pollution Control Board), Annual Report 2005,2006 & 2010 West Bengal, India, (2010).

Yadav, A., Kumar, R., & Swarup, S. (2023). Remote Sensing Image-Based Analysis of the Urban Heat Island Effect in Relation to the Normalized Difference Vegetation Index (NDVI): A Case Study of Patna Municipal Corporation. *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, *11*(1), 1143-1155.