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Evaluating Municipal SOLID Waste Mismanagement and Surface Water Degradation in Secondary Cities: An Empirical Study of Dinajpur, Bangladesh

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EVALUATING MUNICIPAL SOLID WASTE MISMANAGEMENT AND SURFACE WATER DEGRADATION IN SECONDARY CITIES: AN EMPIRICAL STUDY OF DINAJPUR, BANGLADESH

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Abstract

Rapid urbanization in secondary cities like Dinajpur, Bangladesh, presents severe challenges for municipal solid waste management (SWM). This study evaluates Dinajpur's current SWM system through stratified field surveys, municipal record reviews, and physicochemical laboratory testing of nearby surface water bodies. Findings reveal that 9-11 tons of unsegregated solid waste are generated daily, serviced by only 150 open collection points and six non-compacting vehicles. Unregulated dumping at major sites (Matasagor and Lalbag) has caused severe environmental degradation. Surface water testing adjacent to disposal sites demonstrated alarming contamination, with near-anoxic Dissolved Oxygen levels (Do averaging 0.17 mg/L) and elevated Chemical Oxygen Demand (COD averaging 280 mg/L), alongside high Nitrate (15.6 mg/L) and Phosphorus (10.9 mg/L) loading. To mitigate public health risks and aquatic ecosystem collapse, a multi-tiered framework is proposed: enforcing source segregation, optimizing collection routes, establishing transfer and sorting facilities, adopting decentralized composting, and constructing an engineered trench-type sanitary landfill. This study provides a vital baseline for municipal authorities and offers a scalable waste management model for rapidly growing urban centers in developing nations.

Keywords: Solid waste management, Surface water degradation, Dissolved Oxygen, Composting, Sanitary landfill, Integrated Solid Waste Management (ISWM)

Statements and Declarations
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Author Contribution
Rukaya Yasmin and Kundan Yadav wrote the main manuscript, while Gaurav Karmacharya collected the required data and information. All authors reviewed the manuscript.

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1 Introduction

1.1 General

Solid waste refers to any discarded material, including garbage, debris, sludge from water treatment plants, air pollution control facilities, and other industrial, agricultural, or community-generated waste. In simple terms, it includes anything that is thrown away or abandoned. Managing solid waste involves collection, processing, and disposal to reduce environmental impacts [1], [2].

Dinajpur City has a solid waste management system in place. However, despite these efforts, solid waste pollution remains a significant issue in many parts of the city. Some common problems include:

1. Waste accumulating in open spaces with high population density.
2. People littering randomly outside their homes.
3. Household waste, especially plastic, being burned openly.
4. Lack of proper waste disposal facilities in highly populated areas.

This study aims to improve the existing solid waste management system in Dinajpur City, considering its effectiveness and areas for enhancement.

1.2 Conceptual Framework

The study is based on the principles of Integrated Solid Waste Management (ISWM), which provides a structured and holistic approach to handling urban waste. ISWM promotes the efficient management of waste by considering environmental, economic, and social factors throughout the entire waste lifecycle from generation to final disposal. It emphasizes the integration of various methods like source reduction, waste segregation, collection, transportation, recycling, composting, and sanitary landfilling.

In the context of Dinajpur, the ISWM framework helps to examine how well the existing system aligns with these components. For example, waste segregation at source is nearly absent, and disposal is mostly unplanned, which goes against ISWM's recommendation for early-stage separation and organized processing. The framework also highlights the importance of community participation and institutional responsibility areas where Dinajpur still faces notable challenges. By applying ISWM, the study aims to assess not just the technical issues but also the behavioural and governance gaps in the current system.

Although this study does not apply the entire ISWM model in a quantitative sense, it uses the model as a reference to analyse different parts of the existing waste management system. The purpose is to suggest practical improvements that can be gradually implemented in a resource-constrained city like Dinajpur, even if full compliance with ISWM is not yet achievable.

1.3 Worldwide Condition of Solid Waste

The world currently produces about 1.3 billion tonnes of Municipal Solid Waste (MSW) annually. This number is expected to reach 2.2 billion tonnes by 2025. The average per capita waste generation is projected to rise from 1.2 kg to 1.42 kg per person per day. However, waste generation rates vary widely by country, region, and city, influenced by factors such as climate, public habits, industrialization, and economic growth [2], [3].

Generally, urbanization and rising income levels contribute to increased waste production. Urban areas tend to generate nearly double the waste compared to rural regions due to higher consumption levels and lifestyle differences.

1.3.1 Waste Generation by Region

Waste generation rates depend on economic affluence, but there are significant regional variations. The Table 1 shows per capita waste generation by region:

Table 1: Waste Generation by Region

Region	Waste generation Per Capita (kg/capita/day)		
	Lower Boundary	Upper Boundary	Average

AFR	0.09	3.0	0.65
EAP	0.44	4.3	0.95
ECA	0.29	2.1	1.1
LAC	0.11	5.5	1.1
MENA	0.16	5.7	1.1
OECD	1.10	3.7	2.2
SAR	0.12	5.1	0.45

Sub-Saharan Africa (AFR) produces about 62 million tonnes of waste annually, with per capita rates ranging from 0.09 to 3.0 kg/day. The highest waste generation rates are usually found in island nations due to tourism and better waste tracking systems [2], [4].

The East Asia and Pacific (EAP) region generates approximately 270 million tonnes of waste per year, while Eastern and Central Asia (ECA) produces at least 93 million tonnes [2]. Latin America and the Caribbean (LAC) generates 160 million tonnes, with per capita values ranging from 0.11 to 5.5 kg/day.

Similar trends can be observed in the Middle East and North Africa (MENA), where total waste generation reaches 63 million tonnes per year [4]. OECD countries account for 572 million tonnes of global waste production, with an average of 2.2 kg/capita/day [2], [5]. South Asia (SAR) produces about 70 million tonnes per year, with per capita rates of 0.12 to 5.1 kg/day (Figure 1).

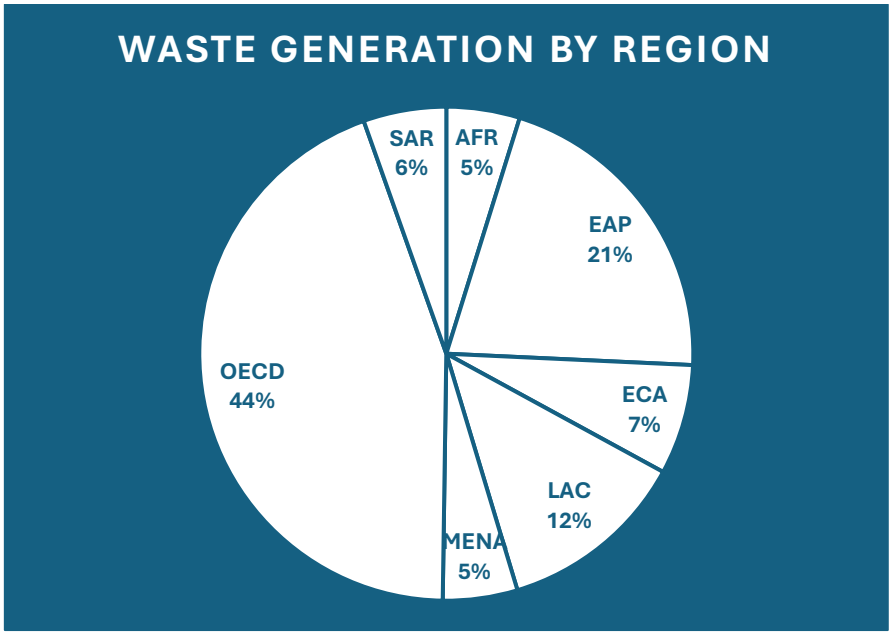


Figure 1: Waste Generation by Region (in Percentage)[2], [4], [5]

1.3.2 Global Composition of Solid Waste

The total solid waste production worldwide is estimated at 2.01 billion tonnes. A significant portion of this is organic waste, including food scraps, vegetation, and animal remains. Since organic waste decomposes easily, it forms the largest component of waste in many developing nations, particularly those reliant on agriculture [2], [4], [6].

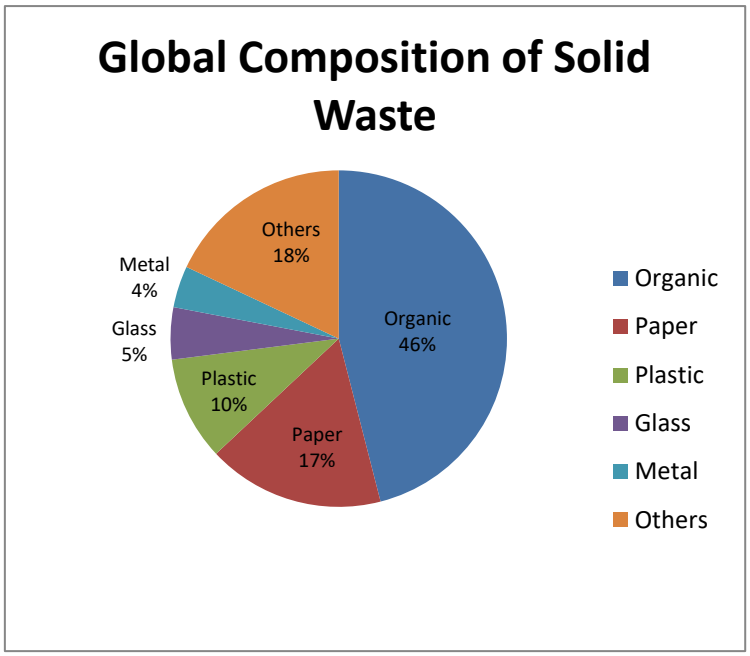


Figure 2: Global Solid Waste Composition [7], [8]

Paper waste, though biodegradable, also contributes significantly to the total waste. On the other hand, inorganic waste such as plastics, metals, and glass decomposes very slowly and poses serious environmental risks [8].

Plastic waste, in particular, is a growing global concern. More than 8 million tonnes of plastic end up in the world's oceans every year, harming marine life and ecosystems [7]. Burning plastic releases toxic gases like nitrogen oxides, sulfur dioxide, and polycyclic organic matter, which contribute to air pollution and health hazards [2], [9], [10](Figure *2*).

1.4 Sources of Solid Waste

Solid waste comes from multiple sources, including:

- **Industrial waste** (factories, manufacturing units)
- **Agricultural waste** (farm residue, food processing waste)
- **Institutional waste** (schools, hospitals, offices)
- **Municipal waste** (households, packaging waste)
- **Sewage sludge** (treatment plant residues)

All these sources together form Municipal Solid Waste (MSW), which requires proper management to minimize environmental impact [1], [2], [4].

1.5 Problems Due to Improper Waste Management

Improper waste disposal poses significant threats to both the environment and public health. One major concern is the uncontrolled decomposition of biodegradable waste, which emits foul odors and attracts disease-carrying pests such as insects and rodents [2]. This not only creates unsanitary conditions but also increases the risk of disease transmission. Additionally, hazardous substances from improperly discarded waste, such as batteries, pesticides, and electronic waste, can leach into the soil and contaminate groundwater, endangering drinking water supplies. The open burning of waste is another critical issue, releasing toxic gases like dioxins and heavy metals into the air, which contribute to respiratory illnesses, cancer, and overall air quality degradation[9]. Beyond health and environmental risks, improperly managed waste also causes aesthetic damage. Accumulated garbage in public spaces diminishes the visual appeal of communities and can negatively impact property values, further discouraging investment and development in affected areas.

1.6 Objectives

The main objectives of this study are:

1. To analyze the current solid waste management system in Dinajpur City and evaluate its effectiveness.
2. To suggest improvements that enhance environmental sustainability and public health.

By addressing these objectives, this research aims to contribute to a more effective and efficient waste management system in the city.

2 Literature Review

2.1 General

We human beings in our day to day activities keep generating solid waste, sometimes knowingly and sometimes unknowingly. This waste pollutes the environment and also affects human as well as animal health. Different researches have shown its harmful effects, some to extreme extents. To minimize these effects of solid waste, various laws and policies are being implemented throughout the world with different waste management techniques.

2.2 Background of Study

According to the World Bank Group (2025), waste generation rates are increasing globally. In 2016, the world's cities generated 2.01 billion tonnes of solid waste, amounting to a footprint of 0.74 kilograms per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050 [6], [11].

As per Global Waste Management conference in 2017, Municipal Solid Waste (MSW) generated by SAARC countries per capita is shown in Figure *3*.

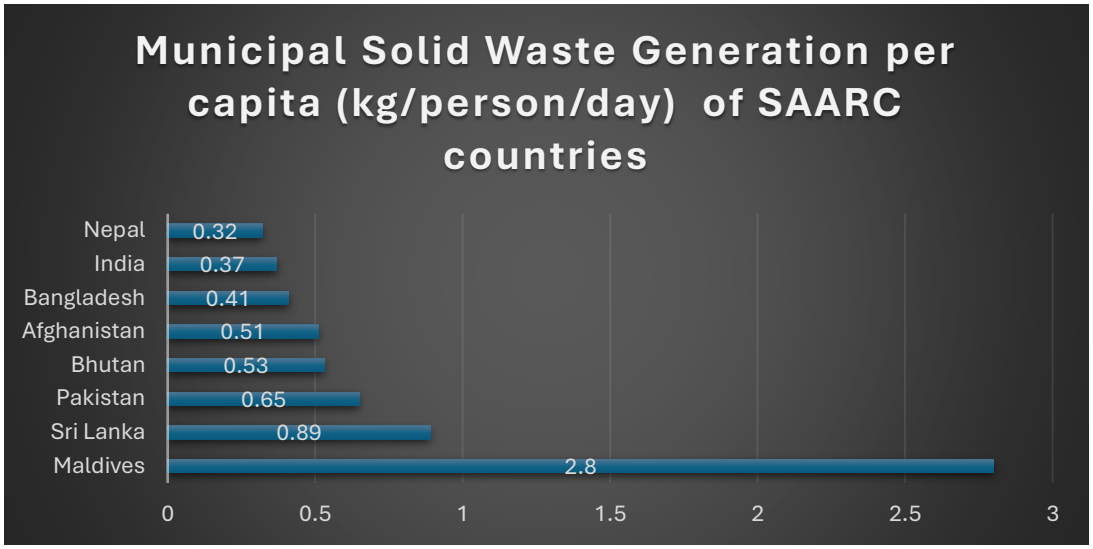


Figure 3: Municipal Solid Waste generation of SAARC countries per capita (Source: Global Waste Management Conference 2017)

SN Chadar and Keerti Chadar (2017) state that solid waste generated from households, industries, hospitals, etc., if not managed properly, causes various diseases in humans such as bacillary dysentery, diarrhea, amoebic dysentery, plague, salmonellosis, trichinosis, endemic typhus, cholera, jaundice, hepatitis, and gastroenteric diseases, among others, creating hazardous effects [12].

Proper solid waste management is a great challenge for developing countries with limited capital. Philemon Kirunda Mukisa (2009), in a study on public participation in solid waste management in Kira Town Council, Uganda, found that the government is less attentive towards solid waste management. The local public is willing to solve the problem of generated solid waste but lags behind due to poor knowledge and awareness [13].

Self-solid waste management is an effective policy. Due to the Pollution Control Act, each industrial actor is responsible for its own waste in Oslo, Norway. Hye Jung Choi (2016) mentions that this policy has been developed

through cooperative efforts among different actors and communities. This effort should be enhanced to create a more effective solid waste management system, increasing reuse and recycling practices [14].

Municipal solid waste (MSW) characterization across socioeconomic residents is necessary for planning sustainable solid waste management. E.B. Tambea and her team (2016) showed that a higher educational level and a job with a high-income earning potential influence the composition of waste generated in Kumba City. Educational attainment enhances the earning potential of individuals, improves quality of life, and subsequently affects the quantity and type of waste generated [15].

Municipal solid waste generation depends on factors such as population, climate, urbanization, and socioeconomic criteria. Arti Pamnani and Meka Srinivasarao (2014) describe that the current MSWM practices in India are inadequate. They noted that while efforts are being made to improve MSWM in major cities, due attention is not given to medium and small-scale towns. The current regulations (MSWM Rules, 2000) are stringent, but deficiencies exist in policy implementation. Non-compliance in MSWM is largely due to a lack of training, financial constraints, poor planning, and weak leadership [16].

A. Ahsan and his team (2014) state that rapid urbanization and population growth in the major cities of Bangladesh result in massive MSW generation, and authorities struggle to manage it effectively with the existing management system, economic support, human resources, infrastructure, and technological capabilities. A door-to-door collection system needs support from all stakeholders with proper awareness, motivation, and commitment campaigns [17].

3 Methodology

3.1 Study Area and Data Collection

This study took place in Dinajpur Municipality, a rapidly growing urban area struggling with solid waste management (SWM) issues. To get a clear picture of the current SWM system, we collected both primary and secondary data.

- **Primary Data**: We conducted field surveys, observed waste management practices firsthand, and interviewed key people like municipal officials, waste collectors, and local residents. This helped us understand things like how much waste is produced daily, how efficiently it is collected, how it's disposed of, and whether the community is actively involved in waste management.
- **Secondary Data**: We also reviewed municipal records, government reports, and past research studies. These sources provided useful insights into existing policies, waste management facilities, and how waste trends have changed over time.

3.2 Sampling and Survey Design

To get a fair and balanced understanding of SWM in Dinajpur Municipality, we used a stratified random sampling method. This ensured that different group, households, businesses, and institutions, were included so we could see how waste generation and disposal practices vary.

- **Survey Instruments**: We used structured questionnaires and focus group discussions (FGDs) to gather both numbers and opinions on SWM practices.
- **Key Survey Focus Areas**:
    - How much waste is generated daily per household, business, and institution.
    - Common methods of waste disposal and how often waste is collected.
    - Public awareness, attitudes, and participation in waste management efforts.

3.3 Waste Characterization and Analysis

To assess the composition of solid waste, samples were randomly collected from different waste disposal sites. The waste was categorized into:

- Organic waste
- Plastics
- Paper
- Glass

- Metals

The weight and volume of each type were measured. Additionally, seasonal changes in waste composition were observed through periodic waste audits. Data collection was done carefully, but sometimes errors in sorting might have occurred.

3.4 Functional Elements of a Solid Waste Management System

A well-functioning SWM system has several key steps, all working together to ensure waste is handled efficiently from the moment it's generated to its final disposal (Figure *5*). The main components include:

- **Waste Generation and Storage**: Waste is produced and temporarily stored at homes, businesses, and institutions.
- **Collection and Transportation**: Waste is picked up and transported to designated sites.
- **Sorting and Processing**: Recyclables and organic waste are separated to maximize resource recovery.
- **Recycling and Treatment**: Techniques like composting, anaerobic digestion, and material recovery help reduce waste volume.
- **Final Disposal**: Non-recyclable and residual waste is sent to landfills or disposed of using other safe methods.

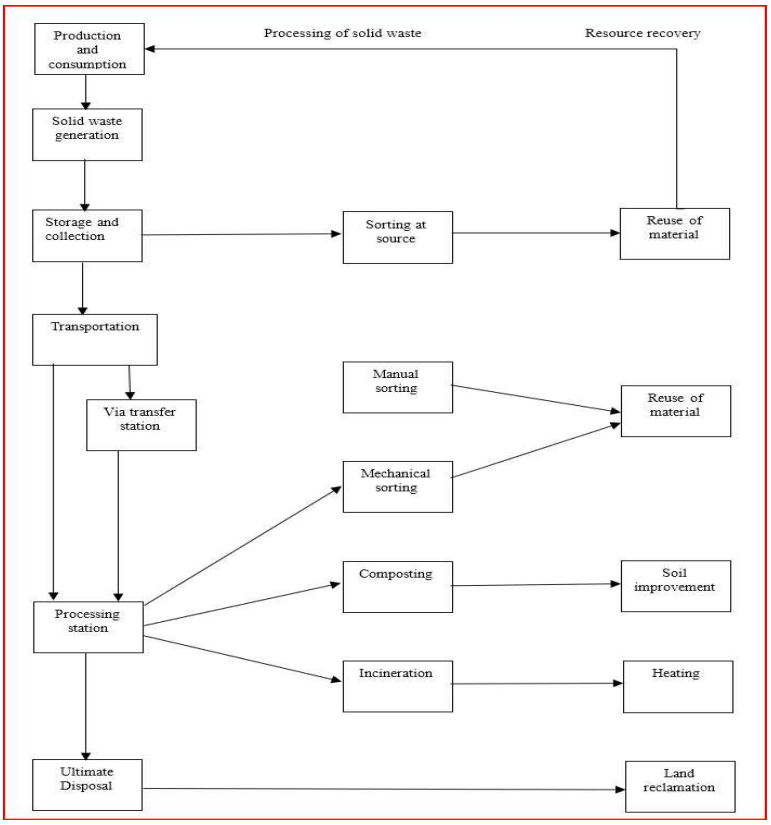


Figure 4: Functional Elements of a Complete Solid Waste Management System

3.5 Assessment of Existing Waste Management Practices

We evaluated the current SWM system in Dinajpur Municipality by looking at several operational and infrastructure-related aspects:

- **Efficiency of waste collection and transportation**: We checked how frequently waste is collected, how well the system covers different areas, and whether services are reliable.

- **Availability and condition of waste bins**: We assessed how many waste bins were available, how easy they were to access, and whether they were well-maintained.
- **Landfill management and disposal techniques**: We examined how landfill sites were being managed, their environmental impact, and whether they were sustainable.
- **Role of informal waste pickers and recyclers**: We looked at how waste pickers contribute to recycling and waste recovery.

3.6 Identification of Challenges and Possible Solutions

From our field observations and data analysis, we identified several key problems with the existing SWM system in Dinajpur:

- **Lack of proper waste segregation**: Most households and businesses don't separate their waste, making recycling and disposal more difficult.
- **Limited public involvement**: Awareness about waste management is low, and people aren't very active in related initiatives.
- **Inefficient collection and disposal**: Waste isn't collected frequently enough, transportation is poorly organized, and landfills aren't managed properly.

To fix these issues, we suggest the following solutions:

- **Encourage waste segregation at the source**: Awareness campaigns and small incentives can help people sort their waste properly.
- **Improve waste collection and disposal infrastructure**: More waste bins should be installed, collection routes optimized, and landfill management upgraded.
- **Promote community-led waste management**: Involving residents, businesses, and organizations can make waste disposal and recycling efforts more effective.

3.7 Data Analysis and Interpretation

We analyzed the collected data using both numerical and descriptive methods to better understand SWM in Dinajpur Municipality.

I. **Quantitative Data Analysis**:
   - **Descriptive Statistics**: We used SPSS and Excel to summarize key figures like waste generation rates, disposal habits, and public involvement levels.
   - **Inferential Analysis**: We conducted correlation and regression analyses to explore how factors like income levels and household size impact waste production.

II. Qualitative Data Analysis:
   - **Thematic Analysis**: We grouped responses from FGDs and interviews into common themes to highlight challenges, public perceptions, and possible improvements.
   - **Comparative Analysis**: We compared our findings with successful waste management models from other places to identify best practices and practical solutions

3.8 Aerobic Composting Process

Aerobic composting is a sustainable method for managing organic waste, converting biodegradable materials into nutrient-rich compost (Figure *6*). The process involves:

1. **Waste Preparation:** Collection and sorting of organic waste.
2. **Decomposition:** Microbial activity breaks down waste under controlled moisture and oxygen conditions.

3. **Maturation:** Further stabilization of compost, ensuring optimal nutrient content.
4. **Final Product:** Ready-to-use compost for agricultural and horticultural applications.

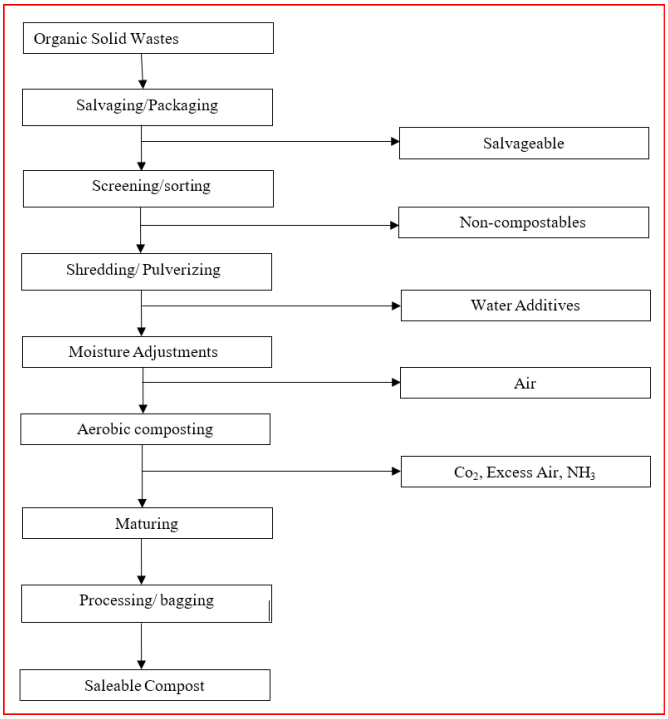


Figure 5: Flow Diagram Showing the Basic Process of Aerobic Composting [18]

4 Data Collection and Survey

4.1 Data Collection

The following data were collected during the study:

4.1.1 Study Area

Dinajpur Municipality is located east of the railway station. The municipal office occupies an area of 1.5 acres and the city is in 23.5 sq. km with population of 13,220 (Table 2).

Table 2: General Data on Dinajpur City (Source: Dinajpur Municipality, Banglapedia, 2024)

Parameter	Value
Area	23.5 sq. km
Number of Wards	12
Total Population	13,220
Area	354.73 sq. km
Number of Cities	1
Number of Wards	12
Number of Mahallas	80
Number of Unions	10
Number of Villages	207
Total Population	484,597
Literacy Rate	64.3%

Dinajpur City is the only urban center within Dinajpur Upazila and is responsible for managing solid waste generation for the entire Upazila (Table 2).

4.1.2 Municipal Solid Waste Management

Municipal solid waste in Dinajpur City is managed through the following processes:

Solid Waste Collection

Waste is collected from 150 designated collection points, most of which are open. Some areas, however, do not have access to waste collection services. Waste collection typically occurs between 7:00 AM and 2:00 PM, but in areas with high organic waste production, collection occurs between 6:00 AM and 11:00 AM. The city does not follow a strict schedule for waste collection; instead, waste is collected when collection points reach near-full capacity. Seasonal variations do not impact the collection schedule. Waste is collected from various sources, including households, institutions, hospitals, markets, and commercial establishments. The collected waste includes plastics, metals, glass, wood, dead animals, medical waste, paper, e-waste, and organic waste (Table 4).

Table 4: Municipal Solid Waste Collection (Source: Dinajpur Municipality)

Parameter	Value
Volume of Waste	9-11 tons
Number of Collection Points	150
Collection Time	6:00 AM - 2:00 PM

Vehicles and Workforce

The city employs approximately 100 workers for solid waste collection. The waste is transported using six non-compacting vehicles with varying capacities (Table 5).

Table 5: Number of Vehicles and Their Capacity (Source: Dinajpur Municipality)

Vehicle Capacity (tons)	Number of Vehicles
1	1
1.5	2
3	3

Waste Processing and Disposal

Dinajpur City lacks both transfer and processing stations, so all collected waste is transported directly to two designated dumping grounds located at Matasagor and Lalbag. The Matasagor site receives waste from four vehicles, which make four trips daily from Sunday to Thursday, two trips on Friday, and three trips on Saturday. The smaller Lalbag site receives waste from two vehicles following the same schedule (Table 6).

Table 6: Collection Frequency per Day (Source: Dinajpur Municipality)

Day	Number of Trips
Sunday	4
Monday	4
Tuesday	4
Wednesday	4
Thursday	4
Friday	2
Saturday	3

4.2 Waste Management System Analysis

During the survey, various collection points, dumping sites, local conditions, and problems faced by residents were observed (Figure 7). The condition of workers and available tools was also assessed.

Condition of the City

The city's solid waste management system is inadequate. Many of the waste collection vehicles are old and frequently malfunction. Workers lack proper tools and personal protective equipment (PPE), such as gloves, boots, and masks, which puts them at significant health risk.

Collection Points

Field observations revealed that the number of waste deposition sites exceeds the officially designated collection points. The number of collection points with proper dustbins is significantly lower than reported by the municipality. Due to the open collection system, waste sites become feeding points for animals and birds, posing potential health risks. Additionally, irregular waste collection results in waste piling up for long durations, leading to unpleasant conditions in the locality.

Dumping Sites

The two official dumping sites in Dinajpur City are in poor condition. The largest dumping ground, located near Matasagor pond, is surrounded by residential areas. Both animals and local residents frequently enter the site, knowingly or unknowingly exposing themselves to health hazards. Septic tank waste is indiscriminately mixed with solid waste at this site. Waste is not segregated before disposal, leading to the accumulation of medical waste, organic waste, and e-waste in a single location.

The smaller dumping site at Lalbag faces similar challenges. Despite the municipality's claim of only two disposal sites, municipal waste trucks have been found dumping waste in multiple unauthorized locations.

Problems Faced by Residents

The irregular solid waste collection schedule has resulted in waste accumulation at collection points, causing unpleasant odors and attracting flies. Residents living near dumping sites are the most affected. Many suffer from health issues such as diarrhea, cholera, dysentery, typhoid, and skin infections like scabies. The situation worsens during the rainy season, as waste sometimes enters homes. Despite repeated complaints to municipal authorities, residents report receiving no assistance.

Condition of Locality

A significant portion of the population does not benefit from the city's solid waste management system. As a result, waste is disposed of haphazardly, with people either discarding it in open spaces, burning it, or dumping it into nearby canals, rivers, or ponds. Public awareness regarding waste management and its environmental impact is severely lacking. Moreover, neither the local government nor relevant authorities have implemented any awareness programs to educate the community on proper waste disposal practices.







Figure 6: Solid Waste Collection and Processing in Dinajpur Municipality.

Condition of Waterbodies

The open dumping practices and unmanaged leachate runoff in Dinajpur Municipality pose a severe threat to local aquatic ecosystems and surface water bodies. Field observations revealed that solid waste and septic tank effluent are frequently dumped in close proximity to major water bodies, notably near the Matasagor pond and nearby drainage canals. During the monsoon season, surface runoff washes organic waste, heavy metals, and hazardous substances directly into these water channels, resulting in water discoloration, noxious odors, and frequent blockages.

To empirically evaluate the extent of contamination caused by nearby waste dumping, surface water samples were collected from key waterbodies adjacent to primary disposal points (including the Matasagor site) and analyzed in the laboratory. The physical, chemical, and biological parameters were tested against the Surface Water Quality Standards prescribed by the Environment Conservation Rules (ECR) of Bangladesh (Table 3).

Table 7: Physico-Chemical Water Quality Analysis of Selected Waterbodies in Dinajpur

Parameters	**Sample-1**	**Sample-2**	**Sample-3**	**Sample-4**	**Average**
pH	7.42	7.85	8.1	7.63	7.75
DO (mg/L)	0.15	0.21	0.18	0.14	0.17
TDS (mg/L)	520	680.5	740	615.5	639
NO_3–N (mg/L)	14.2	18.5	16.8	12.9	15.6
P (mg/L)	9.4	14.1	11.3	8.8	10.9
Alkalinity (mg/L)	210	285	310	245	262.5
COD (mg/L)	210	340	295	275	280
Hardness (mg/L)	310	420	380	330	360
TSS (mg/L)	52	88.5	74	61.5	69
Boron (mg/L)	1.8	2.9	2.4	2.1	2.3

The laboratory results presented in Table 7 demonstrate alarming degradation of surface water quality caused by unmanaged waste dumping and leachate infiltration. Most critically, the Dissolved Oxygen (DO) levels across all sampled locations dropped to near-anoxic conditions, averaging just 0.17 mg/L (ranging between 0.14 mg/L and 0.21 mg/L). This is drastically lower than the minimum limit of 5.0 mg/L mandated by Bangladesh Environment Conservation Rules (ECR) for aquatic life, indicating severe biological stress and an inability to sustain fish and benthic organisms.

This severe oxygen depletion is directly reinforced by high Chemical Oxygen Demand (COD) levels, which average 280 mg/L (peaking at 340 mg/L in Sample-2). These elevated values confirm a massive burden of oxidizable organic matter from municipal waste and septage effluent. Furthermore, elevated concentrations of Nitrate-Nitrogen ($NO_3^- - N$, average 15.6 mg/L) and Phosphorus (P, average10.9 mg/L) highlight significant nutrient loading from raw sewage, creating high risks for toxic algal blooms and systemic eutrophication. The presence of Boron (average 2.3 mg/L) and Total Dissolved Solids (TDS, average 639 mg/L) further reflects unmonitored greywater and detergent runoff entering the aquatic environment. Collectively, these parameter spikes confirm that nearby open dumping grounds directly compromise local water bodies, rendering them ecologically dead and hazardous to public health.

5 Recommendations for Improvement

5.1 General

Dinajpur City faces several challenges in solid waste management. The gaps in the system can be addressed through the following measures:

5.1.1 Public Awareness

One of the most effective ways to manage waste is by involving the people who generate it. The city authorities, with government support, should educate residents about solid waste, its harmful effects, and proper ways of disposal. Public awareness campaigns should encourage people to reduce waste production, especially inorganic waste. Since Bangladesh is an agro-based country, farmers should be trained in composting techniques to utilize organic waste effectively. Additionally, the government should promote reusing and recycling among locals.

Advantages:

- Encourages public participation in waste management
- Reduces the overall waste generation
- Minimizes improper disposal and littering
- Increases people's willingness to pay for waste management services
- Maximizes the reuse and recycling of materials

5.1.2 Storage and Collection

Dinajpur City has about 150 collection points, most of which are open. Waste is typically collected from roadsides, but this method is inefficient. The city should implement a communal collection system, where waste from individual households is deposited at a designated collection point and then transported by municipal trucks. To make this system more effective, the following should be ensured:

- A well-maintained collection schedule for municipal trucks
- Collection containers should be placed in open areas
- Containers should have lids to prevent water accumulation and animal interference
- Regular cleaning of collection sites
- Placement of containers at reasonable distances for easy accessibility

Advantages:

- Cost-effective in the context of Bangladesh
- Suitable for serving a large population

- Prevents insect and pest breeding
- Reduces water pollution, especially during rainy seasons
- Controls unpleasant odors

Additionally, the collection process needs better scheduling, considering:

- Peak activity hours of residents
- Seasonal variations
- The type and amount of waste generated

5.1.3 Transportation

Currently, Dinajpur City lacks compaction vehicles, and waste is transported using non-compaction trucks and tractors. While compaction vehicles may not be necessary at this stage, the number of transport vehicles should be increased to ensure timely waste collection. The transportation route should be planned in such a way that the trucks are fully loaded by the time they reach the disposal site.

5.1.4 Transfer Station

The existing disposal site in Dinajpur is not suitable for landfill use. However, it can be converted into a transfer station, given its location—just 3 km from the city center. Establishing a transfer station would reduce transportation costs and improve efficiency. Other municipalities in the Dinajpur district should also consider setting up transfer stations, as processing waste at a single location would be more cost-effective.

Additionally, small businesses involved in recycling should be granted access to the transfer station for collecting reusable materials for a small fee. This would not only promote recycling but also help generate funds and reduce the overall waste burden.

5.1.5 Processing Station

Processing is a key function of solid waste management, as it prepares waste for further recycling and disposal. A processing station should be established where waste can be sorted and processed more efficiently.

Sorting Methods:

- **Manual Sorting**: Involves separating waste based on its type (e.g., biodegradable vs. non-biodegradable, dry vs. wet).
- **Mechanical Sorting**: Uses machinery to separate materials like plastic, metal, and glass.

Using both manual and mechanical sorting would improve efficiency and reduce errors, even though it may slightly increase costs.

Composting

Composting is a natural process where organic waste decomposes under controlled conditions. It helps in reducing landfill waste and produces organic fertilizer for agricultural use. Given that Bangladesh is an agro-based country, composting is a highly beneficial waste management method [20].

Key Composting Methods for Dinajpur:

- **Vermicomposting**: Uses earthworms (e.g., Eisenia foetida) to break down organic waste into nutrient-rich compost. Local farmers can easily implement this method with minimal investment.
- **Windrow Composting**: Suitable for large-scale waste management, this method involves piling biodegradable waste into rows and aerating them periodically. This technique is cost-effective and can be continued throughout the year if sheltered properly.

Benefits of Composting:

- Reduces landfill waste

- Converts waste into useful organic fertilizer
- Minimizes foul odors from waste decomposition
- Reduces landfill gas emissions

5.1.6 Sanitary Landfills

A sanitary landfill is an engineered waste disposal site designed to minimize environmental and health risks. Unlike open dumping, sanitary landfills involve proper planning, lining to prevent groundwater contamination, and regular waste compaction [21].

For Dinajpur, a trench-type sanitary landfill would be the most effective solution. This system can handle large volumes of waste and, if managed properly, would minimize pollution. Key features of a proper sanitary landfill include:

- Leachate treatment to prevent groundwater contamination
- Landfill gas collection and venting systems
- Proper site selection to avoid human settlements
- Regular compaction and covering of waste

Since Dinajpur currently relies on open dumping, transitioning to a sanitary landfill system is essential to address pollution and health hazards.

5.2 Challenges in Improving Solid Waste Management in Dinajpur

Despite these recommendations, several challenges could hinder progress:

1. **Lack of Funding**: The government may not allocate sufficient funds for waste management improvements. Securing consistent financial support could be difficult.
2. **Municipal Cooperation**: Different municipalities may not agree to share a common waste disposal site. A coordinated regional approach is needed.
3. **Public Attitude and Participation**: Changing people's mindset towards waste management is challenging. Implementing fines for improper waste disposal could help encourage responsible behaviour.
4. **Landfill Site Selection**: Finding a suitable landfill site may be difficult due to opposition from local residents. Offering proper compensation might help mitigate resistance.

6 CONCLUSION

After evaluating field observations, municipal data, and empirical laboratory analyses, it is evident that while Dinajpur City attempts to manage its municipal solid waste, the existing infrastructure and practices remain largely inadequate. A significant portion of daily waste generation remains uncollected, accumulating in public spaces and informal dumping sites. The city's operational capabilities are severely constrained by a critical shortage of transport vehicles, non-existent waste processing facilities, and an absence of systematic waste segregation at the source. Consequently, collected waste is deposited directly into open dumping grounds most notably near Matasagor pond and Lalbag which lack essential engineering safeguards like leachate collection liners or environmental monitoring.

A major finding of this study is the severe impact of open dumping and raw septage disposal on surrounding surface water bodies. Laboratory testing confirmed that nearby aquatic ecosystems are in an extreme state of degradation, characterized by near-anoxic conditions (average DO of 0.17 mg/L) and elevated Chemical Oxygen Demand (average COD of 280 mg/L). Furthermore, high concentrations of Nitrate-Nitrogen (15.6 mg/L) and

Phosphorus (10.9 mg/L) demonstrate significant nutrient pollution, posing severe risks of eutrophication, aquatic life collapse, and waterborne disease outbreaks among surrounding residents. Uncontrolled dumping has also clogged municipal drainage channels, aggravating localized flooding during monsoon seasons.

Addressing these complex challenges requires a coordinated, multi-tiered strategy involving municipal authorities, regional bodies, and the public. At the policy and administrative level, local authorities should establish regional resource-sharing initiatives, secure capital investments for modern waste collection fleets, and transition from open dumping to a centralized transfer station paired with an engineered, trench-type sanitary landfill. Concurrently, implementing decentralized aerobic composting and vermicomposting can divert significant organic fractions away from landfills, generating marketable organic fertilizer for the agricultural sector. Finally, fostering community engagement through targeted public awareness campaigns and enforcing waste segregation at the household level will be crucial to building a sustainable, resilient, and environmentally sound solid waste management system in Dinajpur.

Declarations

Clinical trial number: not applicable.
Ethics approval: not applicable.
Consent to participate: Verbal informed consent was obtained from all participants prior to the survey.
Consent to publish not applicable.

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