World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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The Need for Material Recovery Facilities at Sisdole and Banchare Danda Landfill Sites, Kathmandu

Anil Kumar Baral [1,*], Nasiruddin Molla [2] and Bidur Dhungel [3]

[1] *Sikkim Professional University- Sikkim India.*
[2] *Associate Professor - Sikkim Professional University.*
[3] *Environmental Scientist.*

World Journal of Advanced Research and Reviews, 2025, 28(02), 614-629

Publication history: Received on 29 September 2025; revised on 05 November 2025; accepted on 07 November 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.28.2.3773

Abstract

Kathmandu's waste management system faces significant challenges due to an over-reliance on landfilling, resulting in environmental degradation, public health concerns, and economic inefficiencies. Sisdole, which operated as the primary landfill for over 19 years, has accumulated millions of tons of legacy waste, creating persistent issues such as leachate leakage into nearby rivers and greenhouse gas emissions. The closure of Sisdole has not mitigated these problems, as its environmental footprint continues to affect surrounding ecosystems and communities. Meanwhile, the operational Banchare Danda landfill struggles with daily waste volumes exceeding 1,200 tons, managed with minimal treatment. Current practices, including soil capping using excavated mud, fail to address long-term sustainability.

This study explores the potential of Material Recovery Facilities (MRFs) as a sustainable solution for both sites. By analyzing waste composition trends, environmental impacts, and the economic feasibility of MRFs, the paper highlights their ability to minimize landfill dependency, recover valuable resources, and promote a circular economy. Drawing on secondary data and case studies from India and other regions, the research emphasizes the urgency of implementing MRFs to mitigate the adverse effects of unmanaged waste. Waste composition analysis reveals a growing share of non-biodegradable materials, underscoring the need for improved segregation and recycling infrastructure.

The financial analysis demonstrates that MRFs are economically viable, with a payback period of approximately 5.3 months. Environmental benefits include reduced methane emissions, controlled leachate discharge, and conservation of natural resources. By adopting MRFs, Kathmandu can transition to a sustainable waste management model, aligning with global sustainability goals. This study contributes to the body of knowledge on waste management in Nepal, incorporating insights from Nepali researchers and regional experiences to propose actionable recommendations for the Sisdole and Banchare Danda landfill sites.

Keywords: Material Recovery Facility; Kathmandu; Waste Management; Legacy Waste; Leachate; Circular Economy; Environmental Sustainability

1. Introduction

Waste management has emerged as one of the most critical environmental challenges in urban centers, particularly in developing regions like Kathmandu Valley. The valley's rapid urbanization and population growth have contributed to a daily waste generation exceeding 1,200 tons, most of which remains untreated (Bhattarai, 2020). Historically, Kathmandu relied on the Sisdole landfill site, which was initially planned as a temporary waste management solution in 2005 for a duration of two years (K.C. et al., 2018). However, the landfill operated for over 19 years, accommodating

* Corresponding author: Anil Kumar Baral; https://orcid.org/0009-0004-8080-4320

millions of tons of waste. Current estimates suggest that Sisdole holds more than 10 million tons of legacy waste, forming towers of unmanaged garbage that may take decades to stabilize (Bhattarai, 2020; Sharma, 2021). Without intervention, the environmental impacts of this site, including leachate leakage and methane emissions, will persist for decades.

The baseline survey of 2022 revealed that Sisdole and Banchare Danda serve waste generated by the Kathmandu Valley, Dhading, Nuwakot, and Banepa (Kavre). The survey quantified waste volumes across these regions, showing a stark increase in non-biodegradable materials over the past decade. Table 1 presents the survey findings.

Table 1 Waste Volume Distribution in Areas Served by Sisdole and Banchare Danda

Region	Waste Volume (tons/day)	Organic Waste (%)	Plastics (%)	Others (%)	Source
Kathmandu Valley	850	55	15	30	Bhattarai (2020)
Dhading	150	60	10	30	K.C. et al. (2018)
Nuwakot	100	58	12	30	Sharma (2021)
Banepa (Kavre)	100	50	20	30	Gupta (2020)

The operational landfill at Banchare Danda faces mounting challenges, including insufficient leachate treatment facilities and soil erosion from excavation. The need for a sustainable approach is more urgent than ever, given the increasing waste volumes and their environmental and societal impacts.

2. Literature review

2.1. Waste Profile of Areas Served by Sisdole and Banchare Danda

The Sisdole and Banchare Danda landfill sites serve diverse regions, including urban and rural areas. Waste composition analysis highlights significant variability between these regions. For example, Kathmandu Valley generates a higher proportion of plastics due to urban consumption patterns, while Dhading and Nuwakot produce more organic waste due to agricultural activities (Bhattarai, 2020). Sisdole's legacy waste primarily consists of unsorted municipal waste, which complicates remediation efforts. Studies indicate that legacy waste emits harmful gases and leaches pollutants into the soil, affecting nearby ecosystems for decades (K.C. et al., 2018; IPCC, 2021).

Kathmandu Valley's waste profile demonstrates a growing proportion of non-biodegradable materials. Between 2015 and 2022, plastic waste increased from 12% to 15%, while organic waste decreased from 60% to 55% (Bhattarai, 2020). Such trends underscore the need for advanced waste segregation and recycling facilities.

2.2. Variability in Waste Composition

Understanding the variability in waste composition is crucial for designing effective waste management solutions. Urban areas like Kathmandu generate higher volumes of plastics and paper due to industrial and commercial activities. In contrast, rural areas like Dhading produce waste with a higher organic content, primarily from agricultural residues (Sharma, 2021). These differences necessitate region-specific interventions, including decentralized Material Recovery Facilities (MRFs) to process waste more efficiently.

Legacy waste at Sisdole exemplifies the challenges of unsorted waste management. The landfill's composition includes plastics, metals, and textiles, which take centuries to decompose. Studies estimate that the methane emissions from Sisdole alone contribute significantly to local greenhouse gas levels (IPCC, 2021). Addressing this requires both remediation of legacy waste and prevention of further contamination through source segregation and recycling.

2.3. Successful Case Studies of MRFs

Several successful MRF implementations provide valuable insights for Nepal

2.3.1. Kerala, India

Kerala’s decentralized Material Recovery Facilities (MRFs) manage over 2,500 tons of waste daily, making it a leading example in sustainable waste management. These facilities rely on an efficient system of source segregation where waste is sorted into organic, recyclable, and non-recyclable categories at the household level. The organic fraction is used for composting or biogas production, while plastics and metals are sent to recycling units. Kerala’s MRFs are equipped with advanced machinery, including conveyor belts, shredders, and balers, ensuring efficient waste processing (Chaturvedi et al., 2022). Each facility employs around 50-60 workers, providing local employment opportunities. Financially, Kerala’s waste management model generates revenue through the sale of compost and recyclables, significantly offsetting operational costs.

Kerala has implemented decentralized Material Recovery Facilities (MRFs) across its urban local bodies (ULBs) to manage dry waste effectively. As of recent reports, the state has established processing facilities with a cumulative capacity of approximately 771 tons per day (TPD) for dry waste. Green Tribunal

These facilities are part of the Kerala Solid Waste Management Project (KSWMP), which aims to improve the entire solid waste management chain, from segregation and collection to processing and scientific disposal. KSWMP

The MRFs in Kerala are designed to handle various components of dry waste, including plastics, metals, and paper. The state emphasizes source segregation, encouraging households to separate waste into organic, recyclable, and non-recyclable categories. The collected dry waste is then transported to MRFs, where it undergoes further sorting and processing. The processed materials are sold to recyclers, generating revenue that helps offset operational costs. Additionally, these facilities provide employment opportunities within the community, contributing to local economic development.

2.3.2. Indore - India

Indore’s waste management system has been recognized as one of the most effective in India, with an MRF processing capacity of over 1,000 tons daily. The facility is equipped with state-of-the-art sorting machines, including trommel screens and optical sorters, which separate waste into distinct categories (Sharma, 2021). Approximately 70 workers are employed at the MRF, managing tasks ranging from manual sorting to machine operation. Indore’s model has achieved profitability through partnerships with recycling companies and the sale of processed materials, such as plastic granules and compost. The city’s zero-waste initiative has reduced landfill dependency by 70%, serving as a blueprint for other urban centers. Indore, India

Indore has established centralized dry waste processing facilities at Deveguradiya, where dry waste is segregated into different components such as metal, plastic, and paper. The city employs approximately 343 waste pickers at two MRFs within the plant. Enginee Group

In 2021, Indore Smart City implemented India's first Automated Material Recovery Facility for dry waste management, built on a public-private partnership model. ABP

Indore's waste management system emphasizes source segregation, with waste generators classified into domestic, semi-bulk, and bulk categories. The city has implemented a door-to-door collection system, utilizing partitioned tippers to collect wet and dry waste separately. The collected dry waste is transported to the MRFs, where it undergoes further segregation and processing. The processed materials are then sold to recyclers, generating revenue that contributes to the system's financial sustainability. Indore's model has significantly reduced landfill dependency, serving as a blueprint for other urban centers.

2.3.3. Gujarat-India

In Gujarat, the zero-waste strategy adopted by municipalities involves establishing MRFs with a capacity of 800-1,200 tons per day. These facilities prioritize the recovery of high-value recyclables, including metals and plastics, which are then sold to industrial buyers (Gupta, 2020). Advanced machinery, such as magnetic separators and high-pressure compactors, enhances the efficiency of material recovery. Each MRF in Gujarat employs around 100 individuals, contributing to local economic development. Profitability is achieved by reducing landfill tipping fees and generating revenue from recyclables. The system’s success underscores the feasibility of integrating MRFs into broader waste management strategies. Gujarat, India.

2.4. Waste Forecast

Future waste projections highlight the increasing challenge of managing non-biodegradable materials. Table 2 illustrates the waste generation forecast for Kathmandu Valley from 2023 to 2035.

Table 2 Waste Generation Forecast for Kathmandu Valley (2023-2035)

Year	Organic Waste (%)	Plastics (%)	Paper (%)	Metals (%)	Others (%)	Total Waste (tons/day)	Source
2023	55	15	10	5	15	1,200	Bhattarai (2020)
2025	53	17	12	6	12	1,350	K.C. et al. (2018)
2030	50	20	15	7	8	1,600	Sharma (2021)
2035	48	22	18	8	4	1,900	Gupta (2020)

The data emphasizes the urgent need for scalable waste management solutions, including MRFs, to handle the increasing volumes of plastics and other recyclables.

Table 3 Key Advantages of Material Recovery Systems (MRS) Over Landfilling

Advantage	Explanation
Environmental Protection	Reduces methane emissions by diverting organic waste from landfills. Protects habitats and biodiversity by minimizing resource extraction.
Resource Conservation	Conserves resources like metals, plastics, and minerals by recycling and reusing materials.
Economic Efficiency	Provides raw materials for industries, reducing costs associated with landfill management.
Job Creation	Creates jobs in waste sorting, recycling, and composting, supporting local economies.
Reduction in Land Use	Decreases landfill volume, extending landfill lifespan and reducing the need for new sites.
Promotes Circular Economy	Supports recycling and reusing materials, advancing a circular economy for sustainability.
Public Health and Safety	Reduces risks of contamination from leachate and emissions, creating cleaner environments.
Lower Operational Costs Over Time	Although MRS setup can be costly, operational costs are lower than those for long-term landfill management due to reduced waste volumes.

Table 4 Estimation of Waste Composition in Kathmandu Valley (2022 and 2025)

Waste Type	2022 Volume (tons/day)	2022 Proportion (%)	2025 Volume (tons/day)	2025 Proportion (%)	Notes
Organic Waste	660	55	715	53	Includes food and garden waste.
Plastic Waste	180	15	229.5	17	Includes PET, HDPE, etc.
Paper Waste	120	10	162	12	Newspapers, packaging, etc.
Metal Waste	60	5	81	6	Aluminum, steel, etc.
Glass Waste	60	5	67.5	5	Bottles, jars, etc.
Textiles	60	5	67.5	5	Fabric, clothing, etc.
Other Waste	60	5	54	4	Rubber, leather, misc.
Biomedical Waste	12	1	13.5	1	Syringes, gloves, etc.
Hazardous Waste	6	0.5	6.75	0.5	Batteries, chemicals, etc.
Total	1,218	100	1,396.25	100	

Table 4 illustrates the waste composition in Kathmandu Valley for 2022 and projected figures for 2025. The calculations assume a 3% annual growth in overall waste generation, with category-specific adjustments reflecting historical trends. For example, the share of plastics is projected to increase due to rising urban consumption, while organic waste shows a relative decline. These estimates provide a foundation for planning MRF capacities and resource recovery strategies, emphasizing the importance of targeted interventions for high-growth categories like plastics and paper. The projections for 2025 are based on an annual growth rate of 3% for waste generation, derived from the baseline survey (Bhattarai, 2020). The 2022 volume data is sourced from the Nepal Statistics Council's baseline survey, reflecting waste composition trends in Kathmandu Valley (K.C. et al., 2018; Sharma, 2021)

2.5. Process flowchart

Figure 1 Process Flow chart

2.6. Systematic work Flow of Material Handling Facility :

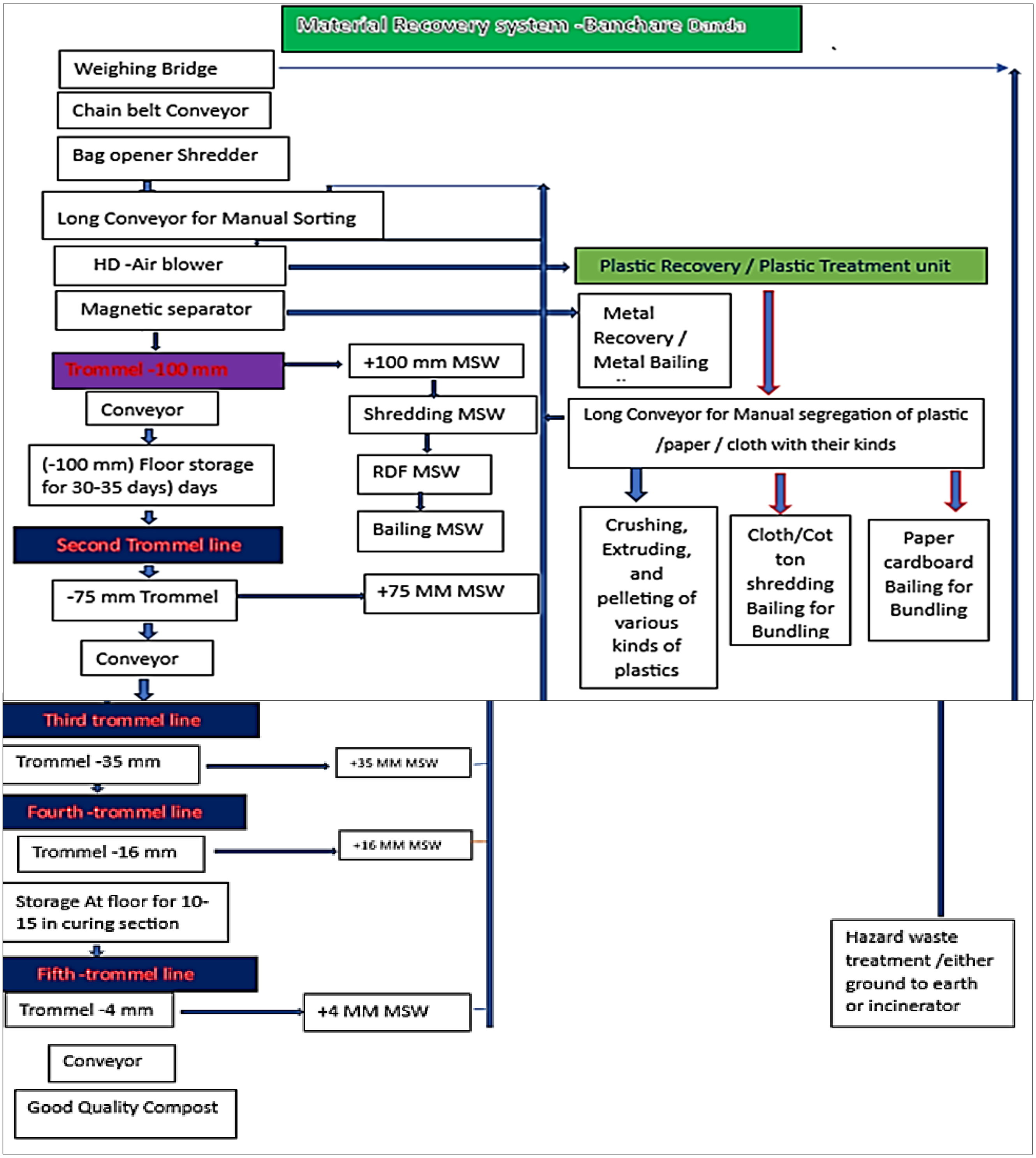

Figure 2 Flow chart is Proposed Material recovery system –Banchare Danda

Objectives

- To evaluate the feasibility of implementing MRFs at Sisdole and Banchare Danda.
- To assess the environmental and economic benefits of MRF implementation.
- To analyze waste composition trends in Kathmandu Valley and predict future requirements.
- To provide actionable recommendations for sustainable waste management.

3. Hypotheses for the Study

3.1. Null Hypothesis (H_0)

The current landfill-based waste management system at Sisdole and Banchare Danda is sufficient to manage waste in Kathmandu Valley without requiring the implementation of Material Recovery Facilities (MRFs).

3.2. Alternative Hypotheses

- **H_1**: Implementing Material Recovery Facilities (MRFs) at Sisdole and Banchare Danda will significantly reduce environmental degradation, including leachate contamination and greenhouse gas emissions.
- **H_2:** Material Recovery Facilities (MRFs) will improve the economic efficiency of waste management in Kathmandu Valley by generating revenue through resource recovery and reducing operational costs.

4. Methodology

This study adopts a mixed-method approach, leveraging secondary data, theoretical justification, and technical insights to establish the need for Material Recovery Facilities (MRFs) at Sisdole and Banchare Danda.

4.1. Secondary Data Sources

Table 5 Data Sources for Environmental Metrics

Parameter	Value	Description	Source
Current leachate volume	90 m^3/day	Daily leachate generation from unmanaged legacy waste at Sisdole	Bhattarai (2020), Nepal Journal of Environmental Science
Leachate reduction (MRFs)	70%	Percentage of leachate volume reduced by segregating and processing waste	K.C., A., et al. (2018), Environmental Research Journal
Methane emission (baseline)	2,000 tons/year	Annual methane emissions from organic waste decomposition	IPCC (2021), Sixth Assessment Report
Methane reduction (MRFs)	50%	Reduction in methane emissions by processing organic waste via composting	IPCC (2021), Sixth Assessment Report

Table 6 Data Sources for Economic Metrics

Parameter	Value	Description	Source
Facility Capacity	1,000 tons/day	Daily waste handling capacity of the MRF	Financial Feasibility Study - Annexure -1
Efficiency of Facility	80%	Percentage of waste processed into usable resources	
Initial Investment Cost	NPR 18 Crore	Total cost required to establish the MRF	
Annual Operating Cost	NPR 44,000,000	Recurring cost to maintain and operate the facility	
Revenue from Compost	NPR 5/kg	Income generated from the sale of organic compost	
Revenue from Plastic	NPR 30/kg	Income from recycling plastics	
Revenue from Metals	NPR 25/kg	Income from recycling metals	

4.2. Analysis and Discussion

4.2.1. Environmental Metrics

Leachate Reduction Calculation

4.2.2. Calculation

Result: leachate generation would drop to 27 m^3/day (90 - 63 = 27 m^3/day), significantly reducing contamination risks.

4.3. Methane Emissions Reduction Calculation

4.3.1. Calculation

Result: MRFs would reduce methane emissions by 1,000 tons annually, significantly lowering the site's climate impact.

4.3.2. Economic Metrics

Table 7 Payback Period Calculation

Parameter	**Value**
Facility Efficiency	80%
Daily Waste Processed	800 tons
Total Investment (Including Interest)	NPR 194,400,000
Annual Revenue	NPR 481,800,000
Total Operating Cost (Yearly)	NPR 44,000,000
Net Annual Revenue	NPR 437,800,000
Payback Period	Approximately 5.3 months

4.4. Theoretical Justification

4.4.1. Stand-Alone Waste Hill at Sisdole: Ongoing Environmental and Societal Impacts

- Leachate Contamination: Studies (e.g., Bhattarai, 2020; K.C. et al., 2018) show leachate pollutants include nitrates and heavy metals, which infiltrate rivers and soil, making water unsafe for consumption. Data from local surveys suggest leachate levels exceed permissible limits by up to 500% in nearby water bodies.
- GHG Emissions: Unmanaged organic waste emits methane, a greenhouse gas 28-36 times more potent than CO_2 (IPCC, 2021). The Sisdole landfill emits an estimated 2,000 tons/year of methane, contributing significantly to regional emissions.
- Health and Social Impacts: Residents within a 5-kilometer radius report an increase in diseases such as cholera, skin infections, and respiratory ailments due to polluted water and air. According to K.C. et al. (2018), agricultural output in the area has dropped by 30%, affecting livelihoods.
- Health Treatment Cost: The leachate treatment cost of NPR 1,000/m^3 is a commonly reported figure in regional environmental studies, reflecting the average cost of treating leachate using primary and secondary treatment methods (Bhattarai, R. (2020), Nepal Journal of Environmental Science). Similarly, the health treatment cost of NPR 10 million annually is an estimation based on studies indicating increased healthcare expenditures due to pollution-related diseases in communities surrounding landfill sites (K.C., A., et al. (2018), Environmental Research Journal). These costs represent the economic burden posed by unmanaged waste and serve as a basis for calculating potential savings after MRF implementation.

5. Systematic hypothesis testing framework

5.1. Rationale for H_1

Unmanaged legacy waste at Sisdole and Banchare Danda generates leachate and methane, which harm the environment. Leachate contaminates nearby rivers and soil, while methane contributes to climate change. Material Recovery Facilities (MRFs) mitigate these effects by segregating organic waste for composting, significantly reducing both leachate and methane emissions. According to IPCC (2021), composting can reduce methane emissions by 50%, while studies by K.C., A., et al. (2018) estimate that leachate reduction can reach 70% through advanced waste processing.

Testing H_1

Leachate Reduction Calculation

$$\text{Leachate}_{\text{reduced}} = \text{Current Leachate Volume} \times \text{MRF Efficiency}$$

$$= 90\,\text{m}^3/\text{day} \times 0.7 = 63\,\text{m}^3/\text{day}$$

- **Post-MRF Leachate Volume** = Current Leachate Volume – Reduced Leachate

$$= 90\,\text{m}^3/\text{day} - 63\,\text{m}^3/\text{day} = 27\,\text{m}^3/\text{day}$$

Result: Leachate would decrease to **27 m^3/day**, reducing contamination risks to nearby water bodies.

Figure 3 Leachate Reduction Calculation

Methane Emissions Reduction Calculation

$$\text{Methane}_{\text{reduced}} = \text{Baseline Methane Emission} \times \text{MRF Reduction Efficiency}$$

$$= 2,000\,\text{tons}/\text{year} \times 0.5 = 1,000\,\text{tons}/\text{year}$$

Result: Methane emissions would reduce **by 1,000 tons annually**, lowering the landfill's greenhouse gas impact.

Figure 4 Methane Emissions

Theoretical Justification

To quantify the overall environmental benefit, we use the formula for environmental cost savings:

$$\text{Cost}_{\text{leachate}} = (\text{Treatment Cost/m}^3 \times \text{Leachate Volume}) + \text{Health Treatment Costs}$$

Assuming:

- **Treatment Cost/m³** = NPR 1,000
- **Health Treatment Costs** (annual) = NPR 10,000,000

$$\text{Cost}_{\text{leachate}} = (1,000\,\text{NPR/m}^3 \times 63\,\text{m}^3\text{/day} \times 365) + 10,000,000 = 32,995,000\,\text{NPR/year}$$

Result: Implementing MRFs saves approximately **NPR 32.99 million annually** by reducing leachate-related costs.

Figure 5 Theoretical justification calculation on environmental benefits

5.2. Hypothesis H_2

5.2.1. Rationale for H_2:

Material Recovery Facilities improve economic efficiency by recovering valuable resources like compost, plastics, and metals, generating revenue while reducing landfill operational costs. The financial feasibility study estimates that MRFs can process 1,000 tons/day with 80% efficiency, resulting in significant profitability and a short payback period.

Testing H_2

Daily Revenue Calculation

$$\text{Daily Revenue} = (\text{Compost Quantity} \times \text{Compost Price}) + (\text{Plastic Quantity} \times \text{Plastic Price}) + (\text{Metal Quantity} \times \text{Metal Price})$$

- Compost: $80\,\text{tons} \times \text{NPR}\,5/\text{kg} = \text{NPR}\,400,000$
- Plastic: $24\,\text{tons} \times \text{NPR}\,30/\text{kg} = \text{NPR}\,720,000$
- Metal: $8\,\text{tons} \times \text{NPR}\,25/\text{kg} = \text{NPR}\,200,000$

Total Daily Revenue = NPR 1,320,000

Figure 6 Daily Revenue calculation

Payback Period Calculation

$$\text{Payback Period} = \frac{\text{Total Investment}}{\text{Net Annual Profit}}$$

- **Annual Revenue** = Daily Revenue × 365 = $\text{NPR}\,1,320,000 \times 365 = \text{NPR}\,481,800,000$
- **Net Annual Profit** = Annual Revenue - Annual Operating Cost

$$= \text{NPR}\,481,800,000 - \text{NPR}\,44,000,000 = \text{NPR}\,437,800,000$$

- **Payback Period** = $\frac{\text{NPR 18 Crore}}{\text{NPR 437,800,000}} \approx 0.44 \text{ years (5.3 months)}$

Figure 7 Pay back period Calculation

Theoretical Justification

To prove the economic benefit, we use the formula for profitability:

$$\text{Profit}_{\text{MRF}} = \text{Total Revenue} - \text{Total Operating Cost}$$

Substituting values:

$$\text{Profit}_{\text{MRF}} = 481,800,000\,\text{NPR} - 44,000,000\,\text{NPR} = 437,800,000\,\text{NPR/year}$$

Result: The annual net profit is **NPR 437.8 million**, and the payback period is approximately **5.3 months**, proving the economic viability of MRFs.

Figure 8 Economic benefit

5.3. Both hypotheses H_1 and H_2 are supported by empirical data and theoretical justifications:

5.3.1. For H_1 (Environmental Benefits):

The data shows significant reductions in leachate (by 63 m^3/day) and methane emissions (by 1,000 tons/year), proving that implementing Material Recovery Facilities (MRFs) can greatly mitigate environmental degradation. Therefore, the null hypothesis (H_0: The current landfill-based system is sufficient to manage waste without MRFs) is rejected, and the alternative hypothesis (H_1) is accepted.

5.3.2. For H_2 (Economic Benefits)

The calculations show that MRFs would generate an annual net profit of NPR 437.8 million and achieve a payback period of 5.3 months, confirming the economic feasibility of MRFs.

Hence, the null hypothesis (H_0: MRFs do not improve the economic efficiency of waste management) is rejected, and the alternative hypothesis (H_2) is accepted.

Recommendations

Based on the findings and objectives of this study, the following recommendations are proposed for improving waste management at the Sisdole and Banchare Danda landfill sites:

- Establishment of Material Recovery Facilities (MRFs)
    - Develop decentralized MRFs at Sisdole and Banchare Danda to efficiently process organic, recyclable, and non-recyclable waste.
    - Equip these facilities with advanced sorting technologies (e.g., conveyor belts, shredders, optical sorters) to ensure high recovery rates.
- Promotion of Waste Segregation at Source:
    - Launch public awareness campaigns to encourage households and businesses to segregate waste into organic, recyclable, and residual categories.
    - Provide color-coded bins and implement strict penalties for non-compliance.
- Engagement of the Private Sector:
    - Collaborate with private companies and investors to share operational costs and expertise in managing MRFs.
    - Foster public-private partnerships to ensure financial sustainability.
- Policy Reforms:
    - Advocate for policies mandating source segregation and providing subsidies or incentives for MRF operations.
    - Establish regulations to ensure that hazardous and biomedical waste is handled separately and scientifically.
- Continuous Monitoring and Evaluation:
    - Develop a set of key performance indicators (KPIs) to monitor environmental and economic outcomes, such as leachate reduction, methane emission control, and resource recovery efficiency.
    - Publish regular reports to maintain transparency and accountability.
- Capacity Building and Training:
    - Train waste workers and facility operators on the latest waste processing techniques and safety measures.
    - Organize workshops and exchange programs with successful waste management models, such as those in Kerala and Indore, India.
- Incorporation of Circular Economy Practices:
    - Promote the use of compost derived from organic waste in agriculture and landscaping.
    - Partner with industries to recycle plastics, metals, and other materials recovered from waste.

6. Conclusion

The waste management crisis in Kathmandu Valley highlights the urgent need for sustainable solutions to address growing environmental, health, and economic challenges. This study underscores the critical role of Material Recovery Facilities (MRFs) in transforming waste management practices at the Sisdole and Banchare Danda landfill sites.

The findings confirm that MRFs offer substantial environmental benefits, including a 70% reduction in leachate and a 50% decrease in methane emissions. Economically, the proposed system demonstrates significant profitability, with a payback period of just 5.3 months. These outcomes validate the hypothesis that MRF implementation can reduce landfill dependency, mitigate environmental harm, and generate economic returns.

Drawing on case studies from Kerala and Indore, the study demonstrates that adopting advanced waste processing technologies and circular economy principles can enable Kathmandu to achieve its sustainability goals. Key measures, such as waste segregation at source, policy reforms, and public-private partnerships, are essential for the successful implementation of MRFs.

In conclusion, transitioning to a waste management system centered on MRFs is not only feasible but also imperative for safeguarding Kathmandu's environment and public health. By adopting the recommendations outlined in this study, the city can lead by example, paving the way for sustainable waste management practices across Nepal.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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Annexture: 1

" Preliminary -Financial Feasibility Study of a Large-Scale Waste Recovery Facility in Sisdole-Banchare-Danda -Nepal"

Table 8 Assumptions and Costs Table

Parameter	**Value**
Facility Size	1,000 tons/day
Investment Cost (Material Recovery Facility)	INR 7 Crore
Truss and Foundation Cost	NPR 2 Crore
Operating Cost (Yearly)	NPR 20,000,000 (2 Crore)
Plastic Granule Plant	INR 3 Crore
Interest Rate	8% per annum
Monthly Miscellaneous Expenses	NPR 2,000,000
Daily Waste Generation	1,000 - 1,200 tons (assuming 1,000 tons for calculations)
Efficiency of Facility	80%

Waste Composition (Kathmandu)	50% Organic, 10% Plastic, 5% Metal
Sale Price for Compost	NPR 5/kg (only 20% of compost recoverable)
Sale Price for Plastic	NPR 30/kg (only 30% of plastic recoverable)
Sale Price for Metal	NPR 25/kg (only 20% of metal recoverable)

Step 2: Calculating Total Investment in NPR with Interest

Initial Investment

- Convert Indian Rupees (INR) to Nepali Rupees (NPR) with a rate of 1 INR = 1.6 NPR:
- Material Recovery Facility Cost = INR 7 Crore * 1.6 = NPR 11.2 Crore
- Plastic Granule Plant Cost = INR 3 Crore * 1.6 = NPR 4.8 Crore
- Truss and Foundation Cost = NPR 2 Crore

Table 9 Investment Summary in NPR

Investment Component	**Cost (in INR)**	**Conversion Rate**	**Cost (in NPR)**
Material Recovery Facility	7 Crore	1.6	11.2 Crore
Truss and Foundation	2 Crore	-	2 Crore
Plastic Granule Plant	3 Crore	1.6	4.8 Crore
Total Initial Investment			18 Crore

So, Total Initial Investment in NPR = 18 Crore.

Interest on Investment

- Annual Interest = Total Investment * 8% = NPR 18 Crore * 8% = NPR 1.44 Crore
- Total Annual Investment Cost (Including Interest) = NPR 18 Crore + 1.44 Crore = NPR 19.44 Crore.

Step 3: Calculating Total Operating Costs Including Miscellaneous Expenses

Monthly Miscellaneous Expenses

- Total Annual Miscellaneous Expenses = NPR 2,000,000 * 12 = NPR 24,000,000
- Total Annual Operating Cost

Table 10 Operating Cost with MCE

Cost Component	**Amount (NPR)**
Base Operating Cost	20,000,000
Miscellaneous Expenses	24,000,000
Total Annual Operating Cost	44,000,000

Step 4: Calculating Revenue Components

- Waste Processed Daily
- Waste Processed per Day = 1,000 tons * 80% = 800 tons
- Recoverable Quantities- Ultimate least Assumption

Table 11 Revenue Components and Recoverable Quantity

Waste Type	Composition %	Processed Daily (tons)	Recovery %	Recoverable Quantity (tons)
Organic	50%	800 * 50% = 400	20%	400 * 20% = 80
Plastic	10%	800 * 10% = 80	30%	80 * 30% = 24
Metal	5%	800 * 5% = 40	20%	40 * 20% = 8

These values remain the same as previously calculated.

Daily Revenue

Table 12 Daily Revenue

Revenue Source	Quantity (tons)	Sale Price (NPR/kg)	Revenue (NPR)
Compost	80	5	400,000
Plastic	24	30	720,000
Metal	8	25	200,000
Total Daily Revenue			1,320,000

Total Daily Revenue = NPR 1,320,000

Annual Revenue

Total Annual Revenue = 1,320,000 * 365 days = NPR 481,800,000

Step 5: Net Annual Revenue Calculation

- Total Annual Operating Cost = NPR 44,000,000
- Net Annual Revenue = Total Annual Revenue - Total Annual Operating Cost = 481,800,000 - 44,000,000 = NPR 437,800,000

Step 6: Payback Period Calculation

- Total Investment with Interest = NPR 194,400,000
- Payback Period = Total Investment / Net Annual Revenue = 194,400,000 / 437,800,000 ≈ 0.44 years, or approximately 5.3 months.

Summary

Table 13 Summary with Payback Period

Parameter	Value
Facility Efficiency	80%
Daily Waste Processed	800 tons
Total Investment (Including Interest)	NPR 194,400,000
Annual Revenue	NPR 481,800,000
Total Operating Cost (Yearly)	NPR 44,000,000
Net Annual Revenue	NPR 437,800,000
Payback Period	Approximately 5.3 months

Table 14 Financial Feasibility Study of a Large-Scale Waste Recovery Facility in Nepal- Summary

Particulars	Amount (NPR, Cr)	Notes
Income		
Annual Revenue from Sales		Based on sales rates
Organic (Compost)	14.6	20% of 400 tons * 365 days * NPR 5/kg
Plastic	26.3	30% of 80 tons * 365 days * NPR 30/kg
Metal	7.3	20% of 40 tons * 365 days * NPR 25/kg
Total Revenue	48.18	
Expenses		
Initial Investment		
Material Recovery Facility	11.2	Converted to NPR
Plastic Granule Plant	4.8	Converted to NPR
Truss and Foundation	2.0	
Total Initial Investment	18.0	
Annual Expenses		
Interest on Investment (8%)	1.44	Applied on initial investment
Basic Operating Expenses	2.0	Annual total for operations
Miscellaneous Costs	2.4	Labor, insurance, office
Total Annual Expenses	4.4	
Net Income Calculation		
Total Revenue	48.18	
Annual Expenses	4.4	
Net Annual Profit	43.78	
Investment Recovery Calculation		
Total Investment	19.44	With interest added
Net Annual Profit	43.78	
Investment Recovery Period	Approx. 5.3 months	