Flood Mitigation through Waste Management in Rimuku, Mamuju, Indonesia

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ABSTRACT

This study examines the role of waste mismanagement, particularly of plastic and organic waste, in obstructing the drainage systems and intensifying flooding. Data from surveys and local observations reveal that the plastic waste is the most significant contributor to drainage blockages, followed by organic waste. With inadequate waste management infrastructure, the accumulation of these waste types in the drainage systems exacerbates the flood vulnerability, especially during heavy rainfall. The present research proposes an integrated, community-driven approach to waste management as a potential solution for reducing the flood risks. By leveraging the local resources, improving the waste sorting, and promoting the recycling practices, this strategy aims to prevent waste from obstructing the waterways and to reduce the overall waste volume. Additionally, the current study emphasizes the dual benefits of the waste reduction and flood mitigation, contributing to both environmental sustainability and urban disaster risk management. The findings underscore the urgent need for comprehensive waste management systems in disaster-prone areas, emphasizing the importance of community participation, waste-to-energy initiatives, and effective infrastructure. This research offers valuable insights for urban planners and policymakers, providing a practical framework for addressing the urban flooding through sustainable waste management practices in low-income, flood-prone regions.

Keywords-urban flooding; waste management; plastic waste; drainage blockages; flood mitigation

I. INTRODUCTION

Flooding is a persistent environmental and socio-economic challenge in urban and semi-urban areas, particularly in regions like Rimuku, Mamuju, where recurrent floods are exacerbated by inadequate waste management. Every year, 4.8-12.7 million tons of plastic enter the ocean from land-based sources. Accumulated waste in drainage systems obstructs the water flow [1-3], intensifying the impact of heavy rainfall and leading to severe inundation. Previous studies [4-6] have established a link between the waste mismanagement and the increased flood risk, underscoring the need for integrated waste management systems as a preventive measure against the urban flooding. Authors in [7], highlight how waste-derived supplementary cementitious materials can be effectively utilized in mortar production, offering a sustainable alternative that not only reduces the construction waste, but also supports the flood-

resilient infrastructure through improved material durability and performance. However, the potential of employing waste management as a targeted flood mitigation strategy remains underexplored, especially in low-income, disaster-prone communities. Mismanaged Plastic Waste (MPW) and urban flooding are urgent global challenges, particularly in the growing urban areas. MPW refers to the plastic waste that is improperly disposed of or left unmanaged, leading to environmental accumulation and contributing to drainage blockages [8-11]. Urban flooding, characterized by water inundation in densely populated areas, is often exacerbated by the poor waste management and the impacts of climate change. The strong correlation between the ineffective waste management and increased flood risk underscores the need for integrated waste management systems as a preventive measure.

Addressing the research gap, the present study investigates the implementation of waste management strategies in Rimuku, Mamuju, with the aim of reducing the flood risk. It proposes a community-driven approach that leverages the local resources and promotes waste reduction practices to mitigate the flood vulnerability. By emphasizing the dual benefits of the waste reduction and flood mitigation, this research introduces a novel perspective that integrates environmental sustainability with disaster risk management. In doing so, it contributes to the broader discourse on sustainable urban planning and climate adaptation, offering practical solutions that are both locally grounded and environmentally responsible. The interconnected environmental impacts of the plastic pollution, exacerbated by the climate change, highlight a complete cycle that extends from urban areas to ocean ecosystems. The climate change, as a fundamental factor, is characterized by increased temperatures resulting in the melting of polar sea ice. This process appears to release microplastics previously trapped in the ice, affecting the albedo effect and reducing the Earth's ability to effectively sequester carbon. The plastic production not only contributes to the greenhouse gas emissions, but also facilitates the proliferation of the plastic waste [6, 12-13]. This highlights the urgency of integrated waste management strategies that target both the drainage infrastructure and river ecosystems (Figure 1).

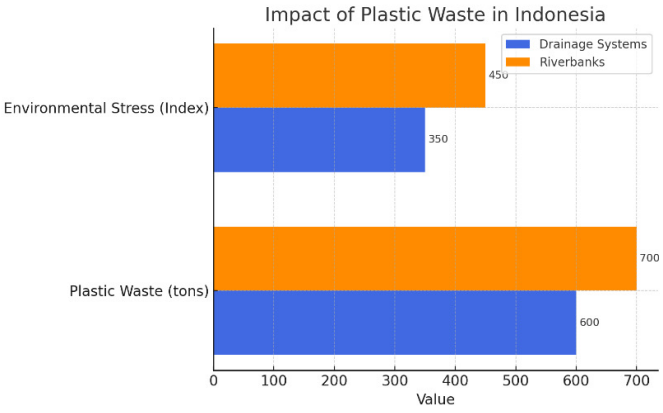

Fig. 1. Impact of plastic waste in Indonesia.

The comparison of the estimated volume of plastic waste and the environmental stress index in two urban environments reveals that the drainage systems accumulate approximately 600 tons of plastic waste, while the riverbanks accumulate 700 tons. In terms of the environmental stress, the drainage systems score an index of 350, whereas the riverbanks register a higher index of 450, indicating more severe ecological pressure. This reflects how the unmanaged plastic waste clogs the drainage networks while also causing broader ecological disruption along the riverbanks. Authors in [14-17] proceeded further, indicating the intensified rainfall as a direct consequence of the climate change, which leads to heavier and more frequent events. In urban areas, the increased rainfall exacerbates flooding, as the plastic waste accumulated in the drainage systems obstructs the water flow and reduces the drainage capacity. This blockage is depicted as a significant contributor to the urban flooding, which not only affects the infrastructure, but also increases the dispersal of the plastic waste [6]. The source of plastic pollution is traced to petroleum-based plastic production, represented as a source of carbon dioxide emissions. The riverbanks are more affected both in terms of the waste quantity and the environmental stress caused by the plastic pollution.

Poorly managed waste flows downstream to coasts, harming the marine life through ingestion and entanglement. The rising sea levels further spread this waste along the shorelines. This coastal plastic pollution is threatening mangrove ecosystems through plastic smothering. It decreases the health of mangrove forests, particularly through the smothering effects that impair the root respiration and hinder the natural regeneration. Authors in [1] highlighted the broader impacts of MPW in coastal zones, including the degradation of vegetation, such as mangroves, under increasing climate pressures. In [3], it was reported that poor urban drainage systems in coastal cities, like Makassar, exacerbate the accumulation of plastic waste near mangrove areas, leading to physical and biological stress on these ecosystems. Furthermore, authors in [18] emphasized that post-disaster waste mismanagement, including plastic debris, can severely disrupt sensitive habitats, such as mangroves, resulting in long-term ecological imbalance. In 2023, Mamuju Regency generated an estimated 52,124 tons of solid waste, based on data from the Environmental and Sanitation Agency (Table I). However, only approximately 11,453 tons were effectively managed, meaning the 21.97% of the total. The remaining 78.03% remained uncollected or untreated, contributing significantly to the environmental degradation, particularly in ecologically sensitive coastal areas. The continuous accumulation of unmanaged waste exerts pressure on the coastal ecosystems, such as mangrove forests, reducing their natural capacity to mitigate storms and tsunamis.

As these ecosystems become increasingly degraded, the region's vulnerability to the coastal disasters escalates. The high volume of waste generated is not matched by an adequate waste management infrastructure, leading to a heightened flood risk, particularly in Rimuku Sub-district, where flooding is a recurrent hazard. Additionally, poorly maintained drainage systems further exacerbate the problem, especially in densely populated residential zones within the urban center of Mamuju.

TABLE I. WASTE DATA OF MAMUJU REGENCY

No.	Year	Waste generation (tons)	reduction (tons)	Handlin (tons)	Total managed	% (+/-)
			Sorting	Transport	Sorting	Transport
1	2022	44,154	Tad	3,016.66	7,887.95	10,904.58
2	2023	52,124	Tad	3,661.22	7,792.26	11,453.49
3	Comparison (‘22&23)	7,970	Tad	644.56	95.69	548.9

The widespread practice of indiscriminate waste disposal has emerged as both a social and environmental concern, frequently causing drainage blockages and impeding the water flow during heavy rainfall events. Further analysis reveals that only 7.02% of the total waste is subject to sorting, while 14.94% is collected and transported to the final disposal site (TPA) by the sanitation fleet. These figures indicate critical deficiencies in the waste segregation and collection processes, underscoring the need for integrated and community-oriented waste management solutions to reduce the flood vulnerability and environmental stress.

These deficiencies in solid waste handling not only increase the flood vulnerability but also contribute to a broader environmental degradation. Improperly disposed wastes, particularly plastics, frequently enter the river systems and coastal zones, where they fragment into microplastics. The presence of microplastics in the marine ecosystems has far-reaching implications. The marine organisms ingest these particles, leading to bioaccumulation and potential health risks throughout the food chain. This environmental contamination is exacerbated in regions with inadequate waste infrastructure, where unregulated dumping is common. The relationship between the waste mismanagement and flooding is particularly pronounced in urban areas, where solid waste and drainage infrastructure are closely interconnected. Blocked drainage channels caused by accumulated waste restrict the water flow, intensifying the flood severity during the rainfall events. Conversely, effective waste management practices can significantly reduce the flood risks by maintaining unobstructed water pathways. This interdependence underscores the necessity of integrated strategies that address both the waste and water management.

II. MATERIALS AND METHODS

This study investigates the types of solid waste contributing to drainage blockages and evaluates the effectiveness of the current mitigation strategies aimed at reducing the flood impacts in Rimuku Sub-district, Mamuju Regency. The research employs a mixed-method approach, combining direct fieldwork, structured instruments, and stakeholder engagement to ensure the data validity and contextual relevance.

The methodology was conducted in five sequential stages:

- Field Observation and Waste Typing: Direct observations were conducted at key drainage sites to identify and quantify the types and volume of waste obstructing the water flow.
- Questionnaire Survey: Structured questionnaires were distributed to residents to collect quantitative data on household waste disposal behaviors and perceptions of the local waste management.
- Stakeholder Interviews: Semi-structured interviews with municipal officials, community leaders, and waste management personnel served as a validation instrument for triangulating the data sources.
- Triangulation and Data Validation: Data obtained from field observations, surveys, and interviews were cross-validated to enhance the internal consistency and minimize the bias. Both patterns and discrepancies across the data types were systematically assessed.
- SWOT-Based Thematic Analysis: A Strengths, Weaknesses, Opportunities, Threats (SWOT) framework was applied to thematically analyze the interview findings, identifying the institutional, policy, and community-level challenges related to the waste and flood management.

Unlike studies that rely exclusively on secondary data or perception-based surveys, this research integrates physical waste assessment, behavioral analysis, and institutional evaluation within a single framework. By quantifying the waste accumulation in drainage systems and correlating it with local practices and policies, the study provides a data-driven and replicable model for understanding the flood-related waste management issues in urban areas.

In addition to identifying the waste composition, the study examines the existing waste management interventions implemented by the local communities, government agencies, and related stakeholders. These include policy enforcement measures, public awareness initiatives, and community-based waste management programs aimed at preventing the waste disposal into waterways.

Quantitative data were analyzed to determine the frequency and spatial distribution of specific waste types, while qualitative data were coded and thematically analyzed to extract common issues related to public engagement, institutional coordination, and policy implementation. Through this comprehensive approach, the study aims to generate actionable insights and propose practical recommendations for strengthening the waste management systems as a flood mitigation strategy in Rimuku Sub-district and other high-risk areas in Mamuju Regency.

III. RESULTS AND DISCUSSION

The findings of this study reveal the transformative potential of integrated waste management strategies in reducing the environmental degradation and supporting the circular economic models. The implementation of recycling and waste-to-energy initiatives in urban areas has been shown to reduce

the volume of waste directed to landfills. Notably, organic waste, which constitutes the majority of municipal solid waste, has been effectively diverted to composting facilities, resulting in a significant reduction in the total waste volume.

Moreover, energy recovery methods, such as anaerobic digestion and incineration have contributed to lowering the greenhouse gas emissions while generating sustainable energy for local grids. These practices support the transition towards circular economy principles by transforming waste into valuable resources. In addition to the environmental gains, economic benefits, such as job creation and decreased raw material dependency, further emphasize the viability of these interventions.

The demographic composition of the respondents was characterized by the dominance of women, who constituted 79% of the sample, while men 21%. The most represented age category was 20–30 years, accounting for 45% of the participants. In contrast, individuals under 20 years and over 50 years each made up 14% of the total (Figure 2). Regarding the occupational distribution, the civil servants formed the largest professional group at 39.5%, whereas the cleaning staff, housewives, and freelancers each represented approximately 2.6–2.7% of the respondents.

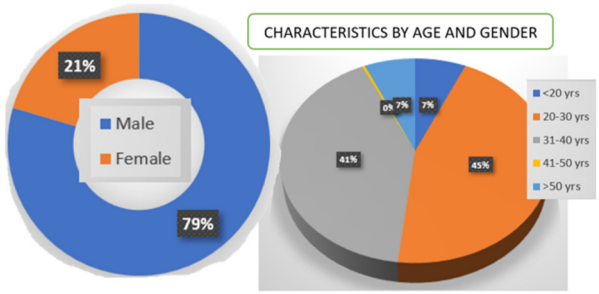

Fig. 2. Respondents' characteristics.

The survey results revealed that the plastic waste was the most frequently reported cause of drainage blockages in Rimuku (Figure 3), identified by 92.1% of the respondents. Organic waste, including food scraps and yard debris, was the second most cited type at 76.3%. In contrast, electronic waste (devices) was not reported by any participants, while soil and sediment waste was mentioned by only one respondent (0.25%).

Fig. 3. Waste blocking Rimuku's drainage channels.

These findings are quantified using a basic frequency formula (1), to find the Percentage of each Waste Type (PWT):

$$PWT=\left(\frac{\text{Respondents Indicating Type}}{\text{Total Respondents}}\right)\times 100 \quad (1)$$

Applying (1) to the sample of the 389 respondents yields the following distribution (Table II):

TABLE II. WASTE TYPE DISTRIBUTION

Type of waste	Number of respondents	Percentage (%)
Plastic	358	92.1
Organic	297	76.3
Electronic	0	0
Sand/Soil	1	0.25

The predominance of plastic and organic waste in drainage blockages suggests inadequate management and segregation practices. Plastics, known for their persistence and widespread usage in single-use items, are major contributors to the drainage congestion and urban flooding. Organic waste, while biodegradable, poses similar risks when improperly discarded. Conversely, the minimal presence of electronic and heavy inorganic waste implies more regulated disposal through formal systems or large-scale services.

These findings are consistent with those of [1, 3, 7, 9, 16, 17], where plastic was identified as a main urban pollutant, particularly in areas with insufficient waste infrastructure. Organic materials have similarly been identified as problematic in locales lacking composting initiatives. On the other hand, non-domestic waste, such as construction debris and electronics, are less frequently involved in such blockages due to the formal disposal mechanisms.

The internal analysis was conducted using an Internal Factor Evaluation (IFE) matrix to assess the strengths and weaknesses influencing the waste management system in the Rimuku Sub-district. The evaluation incorporated key factors identified through field observations and community responses, each assigned a specific weight, rating, and score (Table III).

TABLE III. IFE-MATRIX

Internal factors	Weight	Rating	Score
Strengths			
Community awareness	1.00	5	5
Waste management facilities	1.00	5	5
Waste bank program	0.75	3	2.25
Manual cooperation culture	0.50	3	1.5
Community and NGO involvement	0.75	3	2.25
Weaknesses			
Limited supporting infrastructure	1.00	3	3
Lack of environmental institution at the local level	0.50	2	1
Community participation is not optimal	0.75	3	2.25
No visible real efforts from the government	0.50	3	1.5
The mindset of community is still consumerists	1.00	1	1
Total			24.75

The results indicate that the community awareness and the availability of waste management facilities are the most

prominent strengths, both scoring 5. These factors play a pivotal role in enabling proper waste segregation, enhancing the participation in environmental programs, and supporting the reduction in landfill dependency. Supporting elements, such as the community-led waste banks with a score of 2.25, cultural cooperation practices (Gotong Royong) with a score of 1.5, and the involvement of NGOs with a score of 2.25, contribute positively to reinforcing the localized waste handling efforts. However, notable weaknesses include the insufficient infrastructure with a score of 3, absence of localized environmental regulatory bodies with a score of 1, and suboptimal public engagement in waste programs with a score of 2.25. These are further exacerbated by a lack of consistent governmental support with a score of 1.5 and a prevailing consumerist mindset with a score of 1, which hampers the long-term behavioral transformation toward sustainable waste practices.

The IFE score of 24.75 suggests that while the internal strengths provide a firm foundation for effective waste management, the existing weaknesses pose substantial constraints that require targeted intervention. As supported by [1, 8, 11], the public awareness significantly influences the waste sorting behavior and recycling participation. The availability of dedicated infrastructure, such as waste sorting stations and recycling centers, has been shown to correlate with reduced landfill loads and improved environmental outcomes.

Furthermore, the presence of waste bank programs that offer financial incentives has been linked to higher recycling rates in Southeast Asian countries, establishing both environmental and economic benefits. Traditional cultural values enhance the voluntary community mobilization, while the NGO involvement has proven vital in areas lacking governmental resources. These findings underscore the need for integrated policy and infrastructure development, community engagement strategies, and institutional support to advance the sustainable waste management practices in Rimuku.

IV. CONCLUSIONS

Flooding remains a pressing environmental and socio-economic concern in urban and semi-urban, areas such as Rimuku, Mamuju. The findings of this study confirm that inadequate waste management, particularly the accumulation of plastic and organic waste in drainage systems, significantly contributes to the increased flood vulnerability. The analysis of Mamuju Regency's waste generation, which reached 52,124 tons in 2023, reveals a substantial management gap, with only a limited portion of waste being effectively processed.

This study demonstrates that insufficient infrastructure, coupled with poor waste handling practices, exacerbates the blockage of drainage networks, intensifying the flood risks in densely populated and low-income communities. The results highlight the critical need for integrated waste management strategies that address both the environmental and disaster-related challenges.

A community-based waste management approach is proposed as an effective intervention. By promoting the local engagement in waste reduction, segregation, and recycling, such initiatives can help minimize the waste accumulation in drainage systems. Furthermore, the development of waste-to-energy programs and improved sorting mechanisms are identified as key components for reducing the pressure on the existing infrastructure.

The research underscores the importance of aligning waste management with flood mitigation policies as part of a broader urban resilience framework. It is concluded that sustainable waste management practices, which are rooted in community participation and institutional support, can serve as a viable solution to mitigate the urban flooding. These findings contribute valuable insights to the climate adaptation strategies and offer practical recommendations for policymakers aiming to enhance the environmental sustainability and disaster risk reduction.

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