

Assessing the Effects of Flood Waste on Municipal Solid Waste Systems: A Community Centric Approach to Waste Management

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Abstract

During a flood event the volume and complexity of municipal solid waste (MSW) increases, which presents considerable challenges to waste management systems that are already under stress especially in developing countries. This study investigates the impact of annual floods on municipal solid waste management systems in Limbe, Cameroon, focusing on community-based strategies. It employs a mixed-methods approach, combining quantitative data on waste composition and volume with qualitative data from resident surveys and interviews with officials. Findings reveal significant increases in waste volume during floods, inadequate waste disposal practices, and limited awareness of flood risk and waste management among residents. This study emphasizes the need to integrate flood waste management into the DWM framework and enhance the sustainability and effectiveness of the waste management system in the face of increasing climate-induced disasters.

Keywords

Solid Waste Management, Flood Waste, Community Engagement, Environmental Sustainability

1. Introduction

When a disaster strikes, increased waste will be created by the disaster. Around the world, all types of natural disasters are increasing. Natural catastrophes like floods exacerbated by climate change and urbanization have become more often and severe, and they have a significant impact on communities, infrastructure, and the environment. The Centre for Research on the Epidemiology of Disasters (CRED) reports that 7348 natural disaster incidents occurred globally between

2000 and 2019, nearly doubling since 1998-1999 (UNDRR, 2015). Over the past three decades, 38 million people have been impacted by 654 flood occurrences in sub-Saharan Africa alone, which have also claimed over 13,000 lives (Salami, Von Meding, & Giggins, 2017). Anthropogenic factors like rapid urbanization, unregulated informal settlements with low socioeconomic status and physically inadequate structures in the low-lying floodplain areas, neglect of waste management, and inadequate drainage system maintenance have significantly increased the risk of flooding in African cities (Salami, Von Meding, & Giggins, 2017; Douglas, 2017; Lucas, 2021).

Flooding has a significant effect on the ecosystem as well, producing much garbage. The types, volume and complexity of municipal solid waste (MSW) produced by floods has significantly grown, posing significant problems to already overburdened waste treatment systems, particularly in developing nations. Increased waste types and volumes from a disaster severely affect the existing solid waste collection and disposal systems. In most cases, solid waste management systems collapse due to the abrupt addition of massive amounts of waste produced due to a disaster (Aggarwal et al., 2023). If this waste is not carefully managed the presence of solid waste in the living environment and contamination of surroundings (air, water, land, etc.) exposes the affected communities to the risk of direct or indirect contact with the waste, leading to public health issues like the risk of a disease outbreak. Various other challenges, such as delays in rescue and relief efforts, the mixing of multiple streams of waste, and pilferage of hazardous waste, create unprecedented situations that need to be managed after any disaster.

Proper management of solid waste has been addressed in various international frameworks such as the 2030 agenda for Sustainable Development and the Sustainable Development Goals (SDGs), the Paris Agreement, the Basel Convention etc. Regarding Disaster waste management, the Sendai Framework for Disaster Risk Reduction (SFDRR) places a high priority on resilient critical infrastructure, which includes a disaster waste management system that can both withstand the shock of disaster events and serve well in post-disaster operations (UNDRR, 2015).

The city of Limbe is prone to annual floods and flood events increase the amount of waste generated each year. However, Limbe municipality faces several challenges regarding waste management including lack of finances, infrastructure, lack of policy implementation, and lack of awareness and poor perception by the public (Manga et al., 2008). Municipal Solid Waste Management (MSWM) is limited to waste collection and disposal on open dumpsites. Another illegal waste disposal method practiced by households in the Limbe municipality is dumping into water bodies, vacant land and most commonly backyard (Manga et al., 2008). In the face of increases in disasters, there is a need to reevaluate and develop effective waste management policies. There is a lack of research in this area in the Cameroonian context. Hence, this study is an attempt to draw focus on the issue of managing solid waste in post-disaster situations in the context of Cameroon

and to prepare conclusions, recommendations and way forward for managing wastes during and after the disasters. This study investigates the impact of annual flood waste on municipal solid waste system in Limbe, Cameroon, focusing on community-based waste management strategies. The hypothesis is that the Cameroon government has not set up an efficient Disaster Waste Management (DWM) framework and that current strategies are inefficient. The objectives are to analyze the government's handling of contemporary flood waste in Limbe and to draw attention to the necessity of reevaluating government strategies on flood waste management in Limbe city.

1.1. Overview of Limbe Municipality

The city of Limbe is situated in the southwest region of Cameroon's Fako Division near the seashore. Aside from being a popular tourist destination worldwide, it serves as Cameroon's leading agricultural and petroleum hub. Limbe is home to the only oil refinery, and most of the best areas for habitation are dispersed throughout the city on fields of bananas, palms, and rubber owned by the Cameroon Development Corporation (CDC). Limbe is also home to the Corporation's headquarters. Therefore, it is impossible to overstate the city's economic significance, which also explains the large number of economic migrants who put more strain on the city's already limited natural and man-made resources. Limbe has one of the greatest population densities in Cameroon, with 220 persons per km² and a surface area of 545 km². Its current population is 200,000.

Limbe is only ten miles from Dibuncha, which follows Cherrapunji in India as the second wettest place in the world. During the long rainy season (March-October), the region receives extremely heavy torrential rains, with June, July, and August seeing the highest average monthly precipitation of roughly 700 mm. Small streams inside the city run into bigger drainage beds, which then merge into the Limbe and Jenguele, two major rivers that pour into the Atlantic Ocean. During the rainy season, these rivers usually exceed their banks, resulting in flooding in low-lying communities that are only 1 - 2 meters above sea level. Although these are ideally the best areas for habitation, the city is devoid of well-designed drainage canals. Settlement relatively near the coast at sea level with shoddy, primarily wooden houses exacerbate the situation. Several studies have also blamed the intensity of flood events in Limbe to improper waste management leading to blockage of drainage systems (Wantim et al. 2023; Andin, 2012; Zurbrügg, 2013).

1.2. Overview of Contemporary Floods in Limbe Municipality

Over the years, the city of Limbe has been affected by several flooding events that have claimed lives and damaged properties as shown in **Figure 1**. The city is submerged in water every year between the months June and August, which is frequently marked by weeklong, intense rains. In certain areas, the water is more than a meter deep. Statistics show that the city has an average of five landslides and around 100 inundated dwellings annually, which greatly embarrasses local

government officials and municipal authorities while causing considerable distress to the local population (Lambi, Kometa, & Fombe, 2002; Ndille & Belle, 2014).



Figure 1. Showing flooding in Limbe (Source: Author's original picture).

In some years, the situation became so critical that it required national emergency alerts such as in 2001, 2007, 2013, 2014, and 2018 (Ewoko, 2010; Ndille & Belle, 2014). The worst-case situation to date happened in June 2001, when heavy rains caused a mix of landslides and floods, leaving over 30 landslide scars that destroyed 154 homes, killed 93 people and a significant number of livestock, and rendered over 233 people homeless (Lambi et al., 2002; Ndille & Belle, 2014). The 2007 and 2018 floods also recorded ~29 deaths and the destruction of over 80 houses with significant population displacement (Ndille & Belle, 2014). **Table 1** below shows the impacts of the 1990, 2000, 2001, and 2007 flood events. The rise in flood risk in Limbe city is connected to climate change, uncontrolled dumping of waste in open spaces (Manaf, Samah, & Zukki, 2009; Zurbrügg, 2013), and urbanization, which has led to the proportional increase of a catchment's impermeable surface area (Roudier et al., 2014).

Table 1. Showing the impact of various flooding events in Limbe, Cameroon.

Impact of Limbe floods	1990	2000	2001	2007	Total
Displaced households	32	79	233	63	407
Human deaths	10	14	93	12	129
Health cases reported	19	20	197	62	298
Destroyed buildings	16	33	154	83	289
Animal lost	206	147	834	244	1432
People rendered unemployed	51	107	438	79	675
Damaged roads and bridges	7	5	19	4	35
Water/electricity installation damage	15	8	54	6	83

(Data source: Ndille & Belle, 2014).

After the floodwater receded, a large amount of waste remained. Waterborne waste from neighboring flooded areas also accumulated and created a huge quantity of waste to be disposed of. One of the most serious problems during flood

events in Limbe is the waste disposed from the affected households. This included both small and large items such as damaged furniture, which are dumped in front of houses, along streets, or on empty land which caused environmental and sanitary problems in the form of offensive odors and contaminated wastewater. In addition, the delay in flood waste disposal can cause a detrimental impact on the recovery of peoples' livelihoods.

2. Research Methodology

To identify management strategies, problems, and challenges in flood waste management at the post-flood scenario, a mixed methods study was conducted. Primary data were collected using questionnaires and semi-structured interview while secondary data were collected through a thorough literature analysis. Interviews were conducted with residents who had personally experienced floods as well as professionals with expertise in flood risk management to gain a deeper understanding. Since the goal was to interact with people who had firsthand experience with floods, survey results were gathered from residents in both formal and informal communities in Limbe that were in flood-prone locations using simple random sampling methods. The flood-prone neighborhoods were identified using historic flood data. For each flood-prone neighborhood, a list of households including the population was provided by the local government. Afterwards, households were randomly selected from the list to answer the questionnaires and interviews. More details on the 2001 Limbe flooding catastrophe were included in secondary data because it was the single tragedy with the biggest number of fatalities, damaged homes, and impacted families. To learn about flood risk and flood waste management, questionnaires and semi-structured interviews were conducted with a total of 220 households in the flood prone areas. Out of the 220 questionnaires distributed, 200 were received. The demographic makeup of the respondents as well as other pertinent study data were gathered via the questionnaires. The questionnaires were distributed accompanied by a local guide resident who lived in each of the neighborhoods that were questioned. This was done in an effort to foster trust and motivate study participants. Ages between 18 - 65 were eligible to complete the questionnaire. The survey was administered from September to October 2024. The areas selected for this study were areas most prone to flood risk in Limbe. These areas are Cassava farms, Down Beach, Church Street, Mawoh Quarters, Newtown and Motowoh Quarters. These communities witness annual flooding during the peak rainy season months (June-August). To learn more about the difficulties with floods and waste management in the city, interviews were conducted with 18 public sector professionals who are knowledgeable in flood risk management. Because they directly carry out and somewhat influence the city's environmental management decisions, public sector workers were chosen. Several government agencies, academic institutions, and disaster research institute employed this set of individuals. Snowballing was the method used to enroll the experts.

3. Results

3.1. Demographic Characteristics of Respondents

Respondents' demographic information was obtained through questionnaires and presented as shown in **Table 2** and **Figure 2** below.

Table 2. Showing demographic characteristics of respondents

Characteristics	Respondent	Percentage (%)
<i>Gender</i>		
Male	82	41%
Female	118	59%
<i>Age</i>		
18 - 25	102	51%
26 - 60	66	33%
61 - 85	32	16%
<i>Marital status</i>		
Married	97	48.5%
Single	83	41.5%
Divorced	20	10%

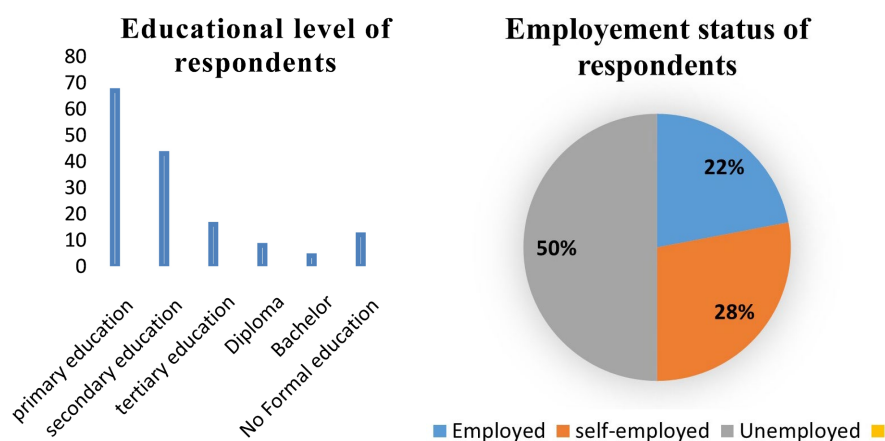


Figure 2. Showing educational level and employment status of respondents (Source: field study).

Majority of respondents (67%) indicated that they have completed primary education while 43% have attained secondary school and 16% have attained tertiary education. 8% have a certificate and a Diploma, 4% have a Bachelor while 12% have no formal education at all. The high proportion of respondents with basic education (67%), secondary (43%) and tertiary (16%) makes it more useful for new practices and ideas to be adopted in waste management in Limbe municipality and thus a higher chance of community participation as well.

3.2. Frequency and Severity of Flooding

Respondents in the flood prone areas were asked to indicate the frequency and severity of flooding events. Most respondents (75%) reported experiencing flooding at least once a year, with 30% suggesting several flood occurrences per year. Many locals (60%) blamed urbanization, climate change, and poor drainage systems for the rise in flooding that they have observed over the last several years. 70% of respondents think recent floods are more severe, with water levels in some places reaching 1 - 2 meters. According to locals, catastrophic floods caused major property damage, the loss of personal possessions, and disruptions to the infrastructure of the town (such as roads and bridges). 15% of respondents said their floods lasted longer than two weeks, while the majority said their floods lasted three to five days. Respondents pointed out that there were interruptions in their regular routines, such as work and income, with 40% of respondents pointing out that they lost money as a result of being unable to get to work. 35% of kids skipped school during a flooding event, and this in some areas went up to a month or two since most classrooms in the flood-prone areas were affected and cleaning up was not done in a timely manner. Half of the respondents said they had limited access to necessary services such as electricity, water, and healthcare. Another pertinent concern of the respondents is the lack of information on flood risk and the designated sites for shelter or safety. 90% of respondents indicated unawareness of shelters during a flood event, so they had no choice but to stay in their homes with flooded water and waste with no electricity nor water.

3.3. Accessibility of Information on Flood Risk and Flood Waste Management

For Cameroon, a critical need for the provision of accessible information on disaster risk and management was identified by the literature review. Because of this, the researcher included a question related to the accessibility of information on flood risk and flood waste management in the data collection tool for the respondents.

Flood risk and flood waste management information accessibility

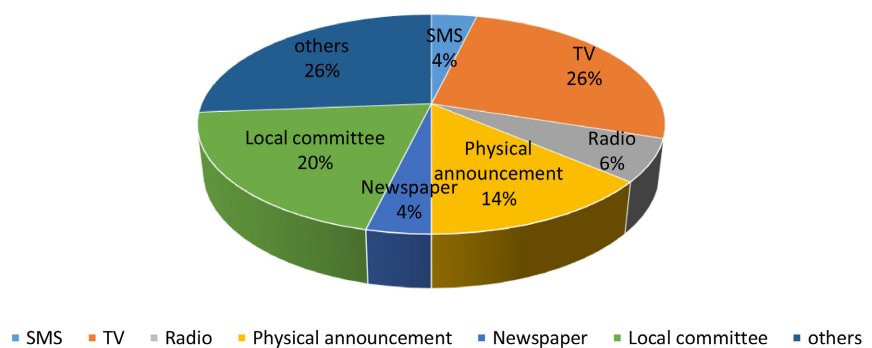


Figure 3. Showing flood risk and flood waste management information accessibility (Source: field study).

As shown in **Figure 3**, 26% of respondents indicated that they usually get the information on TV before a flood event. 14% indicated access to information through Physical announcements and 20% from local committees. Persons in the neighborhood who have already been informed usually make the physical announcements. Some respondents also belong to a local group or union and sometimes get information from those who are already informed during meetings. Just 4% of respondents indicated they could access information through SMS, though 70% of the respondents had a phone. Respondents who acknowledge getting some information indicate that the information was limited to when a flood will occur. 95% of respondents indicated they never received information on management-related strategies such as waste management, designated shelters, etc. Overall, the information collected and displayed in the pie chart above indicates widespread inaccessibility of flood risk information. The lack of awareness on flood risk and management related strategies indicate that existing communication channels are ineffective, and this may hinder proper preparation and response to flood risk and flood waste management. Engaging the community in Disaster Risk Management (DRM) and Disaster Waste Management (DWM) fosters a sense of ownership and responsibility.

3.4. Preference for Flood Risk Information Dissemination

Respondents were asked to select their preferred channels for receiving information. As shown in **Figure 4** below, most respondents (56%) indicated that SMS was the main preferred channel, likely due to its immediacy and accessibility. Television and community-based announcements were respondents' second preferred means of disseminating early warnings on flood risk management. Preference for TV was higher for younger respondents compared to older age groups who preferred community-based announcements. Female respondents showed a higher preference for community meetings (25%) compared to male respondents (15%). The use of local committees was also a preference. Respondents' preferences

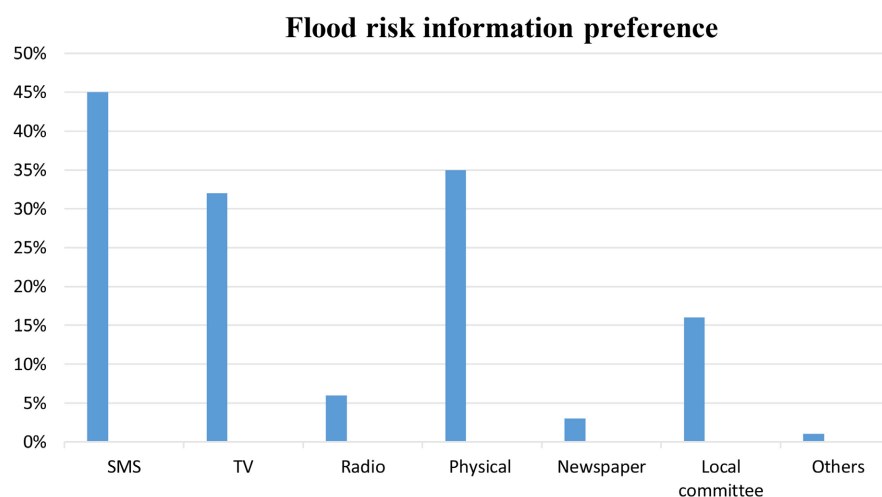


Figure 4. Flood risk information preferences (Source: field study).

could also be reflected in the number of people who own a phone or a television and belong to a community group or union. The results also indicate the necessity to employ a multi-channel approach to communication as depending on a single method may not be effective to reach out to all the segments of the population.

3.5. Type and Percentage Composition of Waste Generated during Flooding in Limbe

Different waste types require different management strategies. Knowing the types of waste and volume of waste generated can enhance effective resource allocation for waste collection. Flood waste includes municipal solid waste (MSW), commercial waste (which can include hazardous materials, metals, and chemicals.), and industrial waste generated both during and after flood events. Among these, the main type of flood waste that the municipal council of Limbe must deal with is MSW (including household hazardous waste). Respondents and municipal officials were asked to identify the types of waste generated during floods. According to the Municipal officials, the exact amount and composition of flood waste will depend on each flood event. However, similar types of waste are generated during every flood event. For example, according to the waste composition survey undertaken by the Municipal Council, the composition of waste generated during flooding in 2001 and 2018 was as presented in **Figure 5**. The types of waste generated were similar to the responses from respondents. However, estimated percentage compositions were obtained from the municipal council.

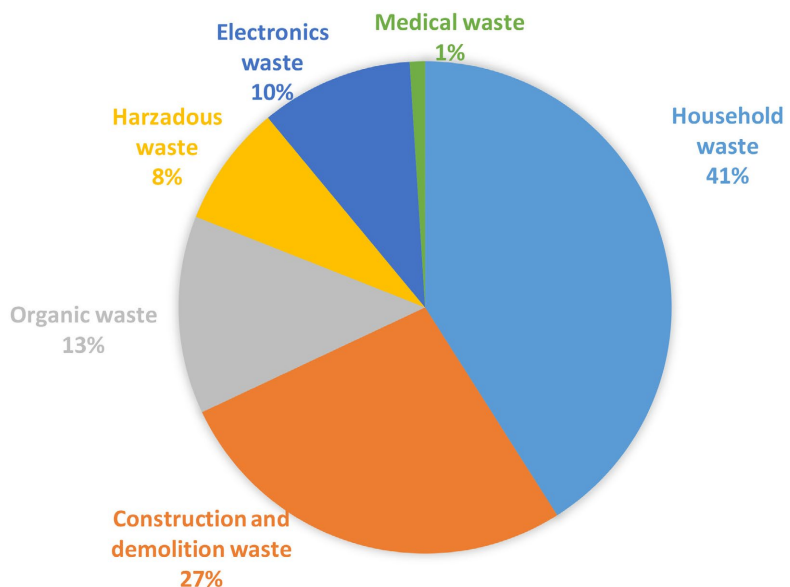


Figure 5. Types and percentage compositions of waste generated during the 2001 and 2008 flood event (Data source: Limbe municipal office).

According to the municipal data, 41% of the waste generated during the 2001 and 2008 flood events comprised household waste, including furniture, clothing, plastic bottles, bags, and packaging materials. 27% comprised construction waste,

10% comprised electronic waste such as televisions, household appliances, printers, etc., and 13% comprised organic waste, including plants, trees, shrubs, remains, silt, and mud. 8% includes hazardous waste, including batteries, asbestos, and radioactive materials, while 1% comprises medical waste. The current policies governing waste management in Cameroon and Limbe city are limited to waste collection, and disposal without incorporating waste segregation. With the increasing types of waste materials generated during a flood event and without any segregation, hazardous materials can mix with general waste posing environment and public health problems. There is a need to incorporate waste separation in the waste management framework and conduct effective public awareness campaigns to educate the public on the importance of waste separation and proper disposal especially in the mist of annual floods. This will require proactive planning, effective strategies for waste management and community engagement.

3.6. Amount of Food Waste Generated in the Flood-Prone Areas during the 2001 and 2018 Flood Events

Two sets of data were obtained from the municipal officials which includes, the amount of waste generated during normal situations in the flood-prone areas and total waste generated (which encompasses both normal waste and additional waste generated during flood events). Using the data for 2001 and 2018, the flood waste generated was obtained by subtracting the average waste generated during normal situations from the total waste generated as presented in **Table 3** below.

Table 3. Flood waste generated during the 2001 and 2018 flood event (Source: Limbe municipal office).

Area	Average waste during normal situation (2000/08-2001/08)	Total Waste generated from 2001/08-2002/07	Flood waste	Average waste during normal situation 2007/8-2008/08	Total waste generated 2008/08-2009/08	Flood waste
Down Beach	890 tonnes	2567 tones	1677	2020 tones	3045 tones	1025
Motowoh	M	2250 tonnes	1700	987 tones	1760 tones	773
Church street	630 tones	2056 tonnes	1426	1087 tones	1740 tones	653
Mawoh quarter	460 tones	789 tonnes	329	886 tones	1580 tones	694
New town	790 tones	2500 tonnes	1710	1665tones	1890 tones	225
Casava farms	770 tonnes	1900 tonnes	1130	1367 tones	1900 tones	533

Assessment of post-flood events has shown an increase in waste volume in all flood-prone areas, predominantly consisting of household waste, organic waste, and construction debris. 75% of respondents estimated a 50% increase in waste volume during flooding compared to customary conditions, leading to overflowing waste piles in affected areas. Increasing amounts of waste generated during a flood event may lead to higher costs for waste collection, transportation and disposal and may require additional resources and funding impacting local budget. Additionally, the existing infrastructure may be inadequate to handle the increase in waste generated leading to improper waste disposal practices which have tre-

mendous impact on the environment. The need for proper planning before and after a flood event cannot be overemphasized.

3.7. Awareness of Flood Waste Management Practices and Community Involvement

Respondents were asked whether they were aware of specific waste management practices during floods. The analysis identifies gaps that may need addressing.

Table 4. Showing respondents' awareness of flood waste management practices and involvement (Source: field study).

Awareness of practices	Percentage of respondents
Proper disposal of hazardous waste	21%
Proper disposal of medical waste	16%
Segregation of waste (Recyclables, etc.)	12%
Use of designated disposal sites	22%
Community clean-up initiatives	45%
None of the above	10%

As shown in **Table 4** above, some respondents (45%) were aware and involved in community clean-up initiatives; however, knowledge of proper disposal of hazardous waste and designated disposal sites was notably low. Most respondents indicated they have no information on how to separate the different waste materials generated during a flood and are unaware of designated disposal sites. Most of the time, the waste stays in the neighborhood in open areas for weeks after a flood. The community residents usually dispose of the waste by themselves in nearby bushes or in the backyard) to make way for passage. Ignorance of the risks associated with hazardous and medical waste might result in inappropriate disposal methods, such as disposing them in open spaces or waterways or combining them with ordinary home waste. and practices. The lack of awareness by residents can lead to increased littering and waste accumulation which can exacerbate flooding and pose health problems. [Mohamed et al. \(2010\)](#) highlight the importance of proper hazardous waste management practices, including segregation, storage, and treatment. Likewise, [Karki et al. \(2020\)](#) note the importance of community knowledge about healthcare waste to change perceptions. Lack of awareness can also hinder community preparedness and response to flooding. In all, the gap in awareness indicates that existing communications strategies are ineffective, which can hinder improvement in waste management.

3.8. Waste Disposal Practices during and after a Flood Event

Flooding can lead to the generation of significant amounts of waste including organic debris, hazardous materials and household items. Proper disposal is very crucial to prevent health hazards and Environmental contamination. Respondents were asked about their waste disposal practices during and after a flood event

providing insights into their understanding and practices.

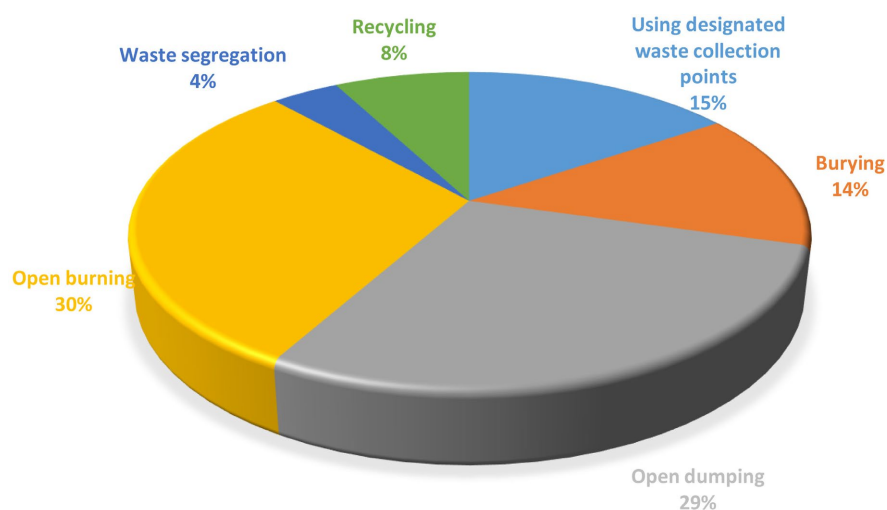


Figure 6. Showing waste disposal practices (Source: field study).

As shown in **Figure 6** above, participants indicated open dumping and open burning as the most common methods of disposing of waste after a flood event. Human health problems, water source contamination, damaging aquatic ecosystems are some main problems associated with open dumping. Flood water has the potential to transport garbage from open dump sites into neighboring rivers, lakes, and groundwater (Ferronato & Torretta, 2019). Likewise, burning garbage in the open releases dangerous pollutants into the atmosphere, including dioxins, carbon monoxide, and particulate matter (Mihai & Taherzadeh, 2017). Participants reported that during a flood, waste management facilities such as municipal waste bins are carried away, and the flood water prevents access to the designated disposal sites, and as such, it becomes difficult to dispose of their waste. However, most of the respondents indicated the urgent need to clean up their homes after a flood. This necessitates immediate waste disposal. A few respondents (8%) mentioned reusing or recycling some of their household goods that the flood had washed. It is essential to address the problems of open dumping, limited access to garbage collection services, and education to safeguard the environment and public health. Additionally, waste management issues must be incorporated into larger flood management strategies.

3.9. Perceived Challenges in Flood Waste Management

Respondents were asked to identify challenges they face regarding flood waste management.

The majority of respondents expressed disappointment with the inadequate municipal response, citing the lack of information about garbage disposal as a primary problem and the lack of resources such as waste collection bins as shown in **Figure 7**. During a flood event, the types of waste generated are different from the regular waste types, and it is important for residents to know how and where to

dispose of the various types of waste generated. Most respondents (70%) indicated a 50% - 70% increase in waste generated after a flood and lamented the lack of collection services during and after flooding events, resulting in residents using inappropriate waste disposal methods such as burning and disposing of waste in water bodies, which tremendously affect the environment and human health. 80% of respondents in the flood-prone areas reported increased incidents of illness, such as cholera and typhoid fever, following flooding events directly linked to exposure to contaminated waste. Respondents expressed a strong desire for municipal support, suggesting that educational outreach on proper waste disposal and flood preparedness is necessary. Respondents also deemed community-led initiatives necessary.

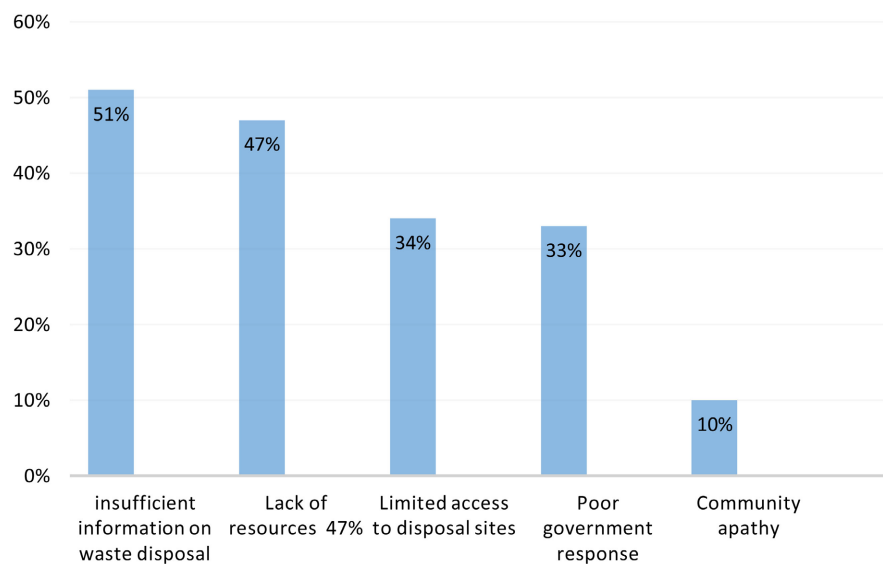


Figure 7. Flood waste management challenges (Source: field studies).

3.10. Proposals for Effective Flood Waste Management from Respondents

The main proposals from respondents were the need for flood information before a flood occurs and how to manage the waste generated. Most respondents mentioned that they are usually unaware of a flood event and that if they can get the information before the flood, it will help save lives and properties. However, some respondents indicated that they are usually aware of the flood event but have nowhere to go. Thus, there is a need for the local municipality to disseminate information on various sites designated for shelters and waste collection information post-flood events, as this will enable the locals to be engaged and participate in waste management.

3.11. Existing Policies and Strategies for Flood Risk Management and Flood Waste Management, Especially in Flood-Prone Areas

Interviews were conducted with key officials in the Limbe municipality and two

officials from the government regarding current policies and strategies for flood waste management in flood-prone areas. Findings show that the Cameroonian government has put in place a national policy framework to lower the risk of flooding and other disasters. This strategy highlights the need for community involvement and integrated approaches to disaster management. Developing emergency response plans and contingency plans, identifying susceptible groups and places through assessments, and promoting disaster preparedness education and awareness campaigns. In Limbe Municipality, waste management is limited to waste collection and disposal. Just 40% of the waste generated is collected. Furthermore, there exist no legal system to encourage waste segregation, hence waste generated by households is collected in one trash with all waste streams mixed together in next to disposal. Another illegal waste disposal method practiced by households in the Limbe municipality is dumping into water bodies, vacant land and most commonly backyard. Recycling is mostly done by the informal sector who depend on waste sales for a living. Limbe municipality faces several challenges regarding waste management including lack of finances, infrastructure, lack of policy implementation, and lack of awareness and poor perception by the public (Manga et al., 2008). These challenges are further worsened by increasing waste generation during a flood event.

In the face of annuals floods in Limbe municipality, several policies and strategies have been put in place. In order to control construction and land usage in flood prone regions, the Limbe City Council has passed regulations. Buildings in high-risk flood zones are prohibited in order to reduce damage and fatalities, and new construction must have adequate drainage systems to avoid water buildup. However, these restrictions are frequently not well enforced because of a lack of resources and insufficient oversight. The council has also developed an Integrated Flood Management (IFM) plan that outlines strategies for managing flood risks and key elements, including investment in drainage systems, flood barriers, and retention basins to manage storm water effectively and involve local communities in flood management planning and decision-making processes. While some infrastructure improvements have been made, one of the officials admitted that existing drainage systems deteriorated by improper waste management and illegal waste dumps are insufficient to handle heavy rainfall, leading to recurrent flooding. The local government collaborates with non-governmental organizations (NGOs) and international agencies (e.g., UN agencies, Red Cross) to enhance flood management efforts. Local authorities and communities are also trained in disaster preparedness and response.

The Limbe municipality has developed emergency response plans that outline procedures for evacuating residents and providing aid during flooding events. Key components include Early Warning Systems to provide timely alerts about impending floods and the designation of safe locations for residents to seek refuge during severe flooding as well as designated sites for flood waste disposal; despite the existence of these plans, many residents reported that they are unaware of

them, and communication during emergencies can be inadequate. There also exist local Initiatives aimed at flood resilience, including clean-up campaigns, organizing community efforts to clear drainage channels and remove waste that could obstruct water flow, workshops, and training sessions to educate residents about flood risks and preparedness measures. Even while these programs have increased awareness and camaraderie throughout the community, they frequently lack the resources and assistance that local governments need, such as budgetary restrictions that make it difficult to implement flood management plans effectively. Existing drainage and flood control infrastructure are often poorly maintained and insufficient to cope with heavy rainfall. Local regulations regarding land use and construction in flood-prone areas are not consistently enforced, leading to continued development in vulnerable zones. Many residents remain unaware of existing policies and strategies, limiting their ability to prepare for and respond to flooding events.

3.12. Flood Waste Management Challenges in the Limbe Municipality

With more emphasis on the 2001 flood event in Limbe municipality, which was one of the worst flood events ever, the municipal officials in charge of waste management and the private waste management company (HYSACAM) were interviewed to understand the challenges posed by flood waste and how flood waste is currently being managed in the city owing to the annual floods. During an interview, waste management officials were asked to assess and rate the existing waste management system before floods. According to interviews with municipal officials, the waste management system normally operates at 60% capacity leading to inefficient garbage collection. Flood occurrences cause damage to municipal garbage infrastructure, including vehicles, transfer stations, and waste bins. Flood waste builds up, there is more littering in public spaces, and waste collection is delayed as a result. During a flood event, waste collection during the first week reduces to about 30%, indicating a significant gap in infrastructure. Firstly, during the flood phase, many officers may be affected by the flooding and unable to commute to work, which may result in a shortage of staff needed to implement the operations. Secondly, equipment for flood waste collection, including waste collection trucks, heavy vehicles for transportation, and plastic bins for waste disposal, may have limited availability during flooding. Financial resources are usually unavailable to assist with the situation since the system adopts a top-down approach.

According to the officials, there is usually an attempt to increase waste collection during and after a flood event. However, logistical challenges often impede timely collection. The municipality usually utilizes designated waste disposal sites for flood waste. However, these sites are often overwhelmed during peak flood periods. Most flood waste is disposed of in landfills with minimal recycling efforts and primarily focusing on plastics and metals, but it is not scaled to meet the surge

in waste during floods. Safety protocols are being established by the municipality for waste collection during flooding, including Personal Protective Equipment (PPE), which is provided to waste collectors to protect against health hazards. Additionally, regular training sessions are provided to waste management staff on handling hazardous materials. The municipal officials also initiate various awareness campaigns to educate residents on proper waste disposal practices during flooding as well as clean-up campaigns. However, the reach and effectiveness of these campaigns are limited, and participation varies widely based on community organization and available resources. Various channels are in place to report waste management issues, but delay in response times and lack of policy implementation impacts frustration among residents and discourages good practices. Although the municipality claims to have taken steps to address flood waste management, there is disagreement over how successful these efforts have been.

During and after floods, waste management services are insufficient. The speed and effectiveness of waste collection are criticized by locals, especially after significant flooding. Respondents anticipate improved communication and more proactive actions from local government representatives. Significant obstacles, such as a lack of resources, problems with accessibility, and a lack of community involvement, confront Limbe's municipal approach to flood waste disposal. While efforts have been made to address flood waste, there is a pressing need for improved infrastructure, enhanced training, and better communication with residents to strengthen its waste management system and better protect the health and well-being of its residents during and after flooding events.

3.13. Flood Risk Governance and Waste Management in Cameroon

Several laws and decrees regulate Cameroon's disaster management system. Though most laws have been changed and updated over time, there still exists a lack of connection between disaster mitigation and the nation's development strategy, as well as a detailed plan for waste management following a disaster. With a greater focus on catastrophe response than on risk prevention and mitigation, the disaster management process in Cameroon often takes a top-down, hierarchical approach to the administration and execution of operations with various positions in disaster management undefined. The current laws primarily address catastrophe response, emergency preparedness, and recovery initiatives. Various implications can be drawn considering that the aspect of waste management after a disaster is not clearly stated in the framework as well as various information channels to the public on what should be done regarding flood waste management. Current waste management practices are limited to waste collection and disposal in open dumpsites. As such, after a disaster such as a flood event, it is common to see piles of waste in open spaces left unattended for weeks or months. Waste disposal into backyards and open bushes is also very common.

Municipalities and local councils oversee and enhance the quality of life for residents in their communities, including waste management. Although councils

play a significant role in local disaster management, their precise role in carrying out this duty is not mentioned in government legislation. According to the law, the councils' primary goals are to improve residents' quality of life and encourage local growth. In order to fulfill these responsibilities, they are entitled to request assistance from the general public, civil society organizations, other local and regional authorities, the government, and international partners. They are in charge of planning relief activities for people in need. Many councils, though, are constrained by the disaster management power structure and limited resources since the resources follow a top-down approach. Thus, in the event of a flood, they depend on the top authorities for financial aid and relief measures to manage the situation including flood waste which adds to the already strained waste management systems.

4. Discussion

Annual floods are common in Limbe municipality. According to the investigation, respondents in the flood prone areas of Limbe reported a 50% - 70% increase in waste volume during flood occurrences, indicating that flooding considerably raises the volume and complexity of trash output in the area. Organic elements (such as clay and trees), domestic debris (such as plastics, furniture, and clothing), construction waste, and hazardous waste are all included in the waste composition after a flood occurrence, which makes disposal more difficult. This increase is too much for municipal waste collection systems to handle, which frequently leads to uncollected waste and health risks. Furthermore, the existing infrastructure for waste collection and disposal is inadequate and is exacerbated during a flood event, leading to environmental and increased public health risks. However, unlike some other regions where proactive measures have been implemented, Limbe's response remains reactive, indicating a gap in strategic planning. The Limbe municipal waste management system is directly strained by the increasing amount and complexity of flood waste. Many locations remain unserved during seasons of high flooding because of the existing insufficient collection frequency. This inefficiency increases the health concerns connected with piles of unattended waste including vector-borne infections, in addition to causing an unsightly pile of waste. The municipality lacks finances and resources to handle the increasing volumes of waste generated during a flood event. The findings suggest that the municipal councils are constrained by the disaster management power structure and limited resources since the resources follow a top-down approach. Thus, in the event of a flood, they depend on the top authorities for financial aid and relief measures to manage the situation including flood waste which adds to the already strained waste management systems. The reliance on higher authorities for financial aid indicates a centralized decision-making process which slows down response time during emergencies. There is a need for a decentralized system where municipal officials can gain greater autonomy to allocate resources and promptly make decisions during crises.

The municipal response to flood waste management was found to face a number of difficulties, such as the need for sufficient drainage systems to manage the amount of water and garbage produced by flooding. Some respondents also blame the lack of drainage systems as the root cause of increase floods in the city. This suggests the need for institutional investment in drainage systems as a way of addressing flooding in the city. This will require proper planning and consistency in policy implementation.

Furthermore, there is a dearth of community involvement because many residents are unaware of information on flood risk and proper waste disposal practices during a flood event. After flooding, community involvement is crucial to efficient waste management. The municipality has launched various awareness initiatives. However, their effectiveness and reach are still restricted. 65% of residents felt uninformed on how to properly dispose of waste after flooding, according to results. The results indicate the necessity to employ a multi-channel approach to communication as depending on a single method may not be effective to reach out to all the segments of the population. It is also necessary to foster participatory approaches to engage the community in flood waste management. Educational initiatives and community cleanup efforts could boost community involvement and relieve the burden on municipal services by enabling residents to take an active role in waste management.

80% of respondents in the flood-prone areas reported increased incidents of illness, such as cholera and typhoid fever, following flooding events directly linked to exposure to contaminated waste. The prevalence of diseases during and after a flooding event has been heightened in literature. According to a study conducted by the Centers for Disease Control and Prevention (CDC) after Hurricane Katrina, outbreaks of norovirus gastroenteritis were reported (Center for Disease Control and Prevention, CDC, 2005). When American tourists visited Germany, they were exposed to flood water contaminated with raw sewage, which resulted in a norovirus outbreak. The results highlight the necessity of prompt implementation of suitable planning both before and after a flood. However, putting complete and cogent policies into practice is extremely difficult for many nations, especially those in developing nations (Yukalang et al., 2017). Waste management strategies may overlook the effects of poor waste management on flood risk, even though they frequently concentrate on collection, disposal, and recycling. There are several reasons for this disparity, such as political limitations, a lack of funding, and a lack of institutional competence (Mahajan & Vakharia, 2016). The absence of synergy between frameworks for flood risk management and waste management is one major issue. Several laws and decrees that govern Disaster waste management in Cameroon lacks detailed plan for waste management following a disaster as well as clearly define roles. The responsibilities of various actors in the disaster management framework are unclear. Although councils play a significant role in local disaster management, their precise role in carrying out this duty is not mentioned in government legislation. This suggests the need for integrated policy

frameworks and clearer definitions of roles to enhance disaster management.

By adopting a more holistic environmental approach that prioritizes the “3Rs” (reduce, reuse, and recycle), sustainable waste management practices can not only address environmental concerns but also contribute to economic development and social equity (Mahajan & Vakharia, 2016).

5. Conclusion

With an emphasis on community-based waste management, this study examines how flood waste affects municipal solid waste management systems in Limbe, Cameroon using a mixed methods approach. Findings reveal an increase of 50% - 70% of waste generated during a flood event, with the highest recorded during the 2001 flood. Although they differ in magnitude, the waste products produced by each flood are comparable. The inefficiency of present waste disposal methods, which are exacerbated during floods, puts the environment and human health at greater danger. Effective waste management measures are further hampered by inhabitants' ignorance of flood danger and post-flood waste management.

In order to safeguard the environment and public health, Limbe municipality must modify their waste management procedures in the face of increase frequency of disasters. There may be a severe shortage of resources to enable flood waste collection because of insufficient preparation. Firstly, during the flooding phase, many officers may be affected by the flooding and will not be able to commute to work, which may result in a shortage of staff needed to implement the operations. Secondly, equipment for flood waste collection, including waste collection trucks, heavy vehicles for transportation, and plastic bags for waste disposal, may have limited availability during flooding. Financial resources may not be immediately available to assist with the situation considering the top-down approach system of Cameroon. As such preparation before time is key. As a severe flooding situation becomes obvious, offers of donations and assistance need to be coordinated. Waste collection time and locations need to be announced effectively so that people will know how to store and dispose of waste during flooding events. These public management and administrative aspects are crucial for efficient operations. As for the technical engineering aspects, flooding will pose various technical and operational challenges. During the flood phase, many items, including electronic appliances, household items, and furniture, become soaked in floodwater, and most of these items become waste. Some people abandon this waste to floodwater. After the floodwater starts to recede, people start to dispose of their flood waste at Temporary Storage Sites (TSS) or beside roads, wherever space is available. Waste separation should be conducted at the TSS before transportation to the waste transfer stations. This makes the transportation of waste easier and promotes recycling. The peak of waste collection occurs immediately after the floodwater starts to recede, indicating that the municipality might need to dispose of huge amounts of waste from residents within a short period of time. This suggests the need to integrate flood waste management into Disaster Risk management framework and

clearer definitions of roles to enhance disaster management. It is also essential to seek knowledge on flood waste management through collaboration with international organizations and academic institutions. While efforts have been made to address flood waste, there is a pressing need for improved infrastructure, enhanced training, and better communication with residents. The use of multi-channel approach to communication will enhance effectively by reaching out to all segments of the population. There is a need for a decentralized system where municipal officials can gain greater autonomy to allocate resources and promptly make decisions during crises.

The municipality should seek additional funding to improve waste collection infrastructure and employee training. The increasing waste load during floods can be managed with improved drainage and garbage disposal systems. Improving public involvement in waste management initiatives can be achieved through fostering awareness on flood waste management and the implementation of community-led projects and educational campaigns. It is essential to create effective channels of communication to let locals know when waste will be collected and how to dispose of it properly during flooding. Limbe can strengthen its waste management system and better protect the health and well-being of its residents during flooding events by reevaluating and developing effective strategies.

Limitations

Easy access to historic and comprehensive data on waste generation, composition and management practices in Limbe was limited, making it difficult to investigate trends and impacts accurately. This study was not conducted immediately after a flood event, so it may not capture the full range of impacts to communities and respondents involved in this study. Such a study will complement the present study. The results are limited to residents in the flood-prone areas and may not represent the views and experiences of those living in non-flood-prone areas.

Authorship Contribution Statement

Sophie Ebot: writing—original draft, conceptualization, formal analysis, investigation, methodology, software, visualization, and writing—review & editing; and Prof. Ori Akemi—review, supervision, and validation. All authors approved this manuscript.

Ethics Statement

Ethics approval was obtained from Sophia University, Japan regarding the ethical aspects of this study. In addition, the participants provided their informed consent to participate in this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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