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Urban Drainage Systems and Implications on the Inhabitants and Physical Environment of Buea Urban Area, South West Region of Cameroon

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Abstract

Aim: Rapid urban and unplanned development and increased construction have significantly altered the surface coverage of many developing cities triggering environmental hazards with severe human health and environmental consequences. This study examines the impact of unplanned urban drainage systems on the environment and public health in Buea, Cameroon, to identify key challenges and propose sustainable solutions.

Methods: A mixed-methods design was used. 300 semi-structured questionnaires were administered to a sample selected by simple random sample from a population of 40,073. Field observations of 30 drainage systems, measuring their depth and width to assess runoff evacuation effectiveness against international standards, were conducted using measuring tapes and GPS for spatial data collection. In addition to purposive face-to-face interviews held with 15 key officials from the departments of urban planning and housing, environmental engineering, urban development, water management, and environmental protection of government-related delegations of ministries, parastatals and the municipal council, secondary data were gathered from diverse sources including council reports, news outlets, and academic literature. Quantitative data were analyzed using descriptive and inferential statistics (percentages and frequencies and chi-square) via Microsoft Excel and SPSS (Version 23.0) while qualitative interview data underwent thematic content analysis. Results revealed that 85% of respondents expressed dissatisfaction with the urban drainage system, citing poor infrastructure, inadequate waste management, rapid population growth, and government inaction as key issues.

Results: Major environmental consequences identified include stream pollution, soil erosion, and ecosystem degradation, correlating with increased reports of waterborne diseases among the population. The correlation values on the relationship between poor drainage facilities and environmental challenges and health effects if the residents were very strong and positive as indicated by (P Value=0.911 and P Value 0.815) respectively. The measurements on drainage capacity indicated significant deviations from recommended standards, hindering effective runoff evacuation.

Conclusion: The findings emphasize a critical urban drainage crisis in Buea, demanding immediate and integrated action from stakeholders.

Recommendations: The study recommends increased investment in infrastructure and reconstruction, stringent monitoring of the environment. Rigorous enforcement of urban planning policies with heavy fines for defaulters should be adopted as an immediate priority and public awareness campaigns on environmental sustainability (most urgent). Additionally, establishing partnerships with local and international agencies can improve drainage management and environmental resilience. Other African cities should adopt options for sustainable urban development provided in this study.

Keywords: *Urban drainage, environmental impact, public health, sustainable urban development, Buea.*

1. INTRODUCTION

The concept of long-term environmental sustainability gained significant traction with the Rio Declaration and Agenda 21 of the United Nations in the early 1990s, emphasizing the careful integration of technical, economic, and social aspects in development. Today, there is a global consensus, supported by institutions like the World Bank (2018), advocating for an integrated approach to urban water systems. This perspective necessitates considering the interconnectedness of surface water, groundwater, water quality, quantity, and ecology. Consequently, the pursuit of sustainability in urban water management has spurred an increased interest in source control and open drainage solutions for stormwater within urban environments (Geldof & Stahre, 2006). Infrastructure is the basic equipment and structures (such as roads, bridges, buildings, water lines, and sewer systems) that are essential for functional, healthy, and vibrant communities (USEPA, 2024). To function properly, infrastructure must be maintained, repaired, or replaced at the end of its life cycle. Because stormwater runoff has become one of the leading causes of water pollution in urban environments, and community leaders and decision-makers are faced with making decisions on how to best manage stormwater in their communities (USEPA, 2024). Urban drainage systems are therefore vital components of water infrastructure, designed to prevent disruptions to transportation, mitigate material damage from heavy rainfall, and safeguard public health and the environment in cities for inclusive and sustainable cities (Silveira, 2001).

Rapid urban development and increase in construction have significantly altered the surface coverage of many cities, resulting in a rise in impervious surfaces such as roofs, streets, and pavements with severe health and environmental consequences. These changes act as barriers against rainwater infiltration into the soil, leading to a substantial increase in surface runoff (Cemiloglu *et al.*, 2023; Silveira, 2002), which converges in low-lying areas, frequently resulting in flooding and discomfort to ecological components and human health. The surge in surface runoff can also overwhelm existing natural and artificial water channels like streams, gullies, and ditches, exacerbating riverside flooding and pollution. Historically, drainage works were often not prioritized as essential infrastructure for urban development and organization (Matos, 2003). While traditional rainwater systems aimed to improve water flow efficiency by directing it to downstream water bodies, this approach has proven insufficient in the face of rapidly expanding cities and increasing soil impermeability, leading to the emergence of new flood hotspots and the need for ever-larger channeling systems (Silveira, 2002).

Managing surface runoff has become a critical task in civil engineering and urban planning, as it can mitigate damage and provide opportunities for utilizing excess water (Cemiloglu *et al.*, 2023). However, traditional flood control and guidance systems tend to be extensive and expensive for many urban governments, prompting researchers to explore cost-effective alternatives that consider all design parameters and variables. In addition, climate change presents serious concerns, especially in low- and middle-income nations where increasing urbanization increases vulnerability to flooding, due to their geographic and socio-economic conditions. This is particularly true for the northern parts of Cameroon, the North West and the South West Region. These climate impacts have resulted in substantial economic losses, equivalent to approximately 3% of the region's GDP attributed to urban flooding (World Bank, 2023).

Recent decades have witnessed a significant spatial divergence in approaches to urban drainage between developed and developing countries. In developed countries, a notable shift towards Sustainable Urban Drainage Systems (SUDS) has gained momentum since the late 20th century (Geldof & Stahre, 2006; Monachese *et al.*, 2024). Green infrastructure practices can

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be a viable option for managing stormwater in highly urbanized areas where development density is desired and off-site mitigation of storm-water runoff is not a preferred alternative. Integrating green infrastructure elements into broader transportation and community connectivity improvements can significantly reduce the marginal cost of storm-water management by including it within larger infrastructure capital improvement projects. This paradigm, often manifesting as Low Impact Development (LID) in North America, SUDS in the United Kingdom, and Water Sensitive Urban Design (WSUD) in Australia and New Zealand, emphasizes mimicking natural hydrological processes through decentralized, site-specific interventions.

According to UN Guidelines for Sustainable Urban Drainage Techniques, a key instrument for achieving Sustainable Development Goals (SDGs) 11 and 13, stakeholders should empower the population to positively transform urban landscapes by: implementing tax incentives for properties with rainwater retention, detention, infiltration, and reuse systems; establishing and regularly deploying teams for the cleaning and maintenance of both micro-drainage (gutters, inlets, manholes) and macro-drainage (channels, canals, detention basins); adopting Land Use Management as a tool to restrict development in floodplains, including controlling construction in outcrop areas and expropriating land within major riverbeds for flood containment due to increased urbanization (waterproofing); creating essential parks for the preservation of watercourses, groundwater recharge zones, and increased permeability through green spaces, riparian reforestation, and urban parks, which also enhance quality of life and promote infiltration, percolation, and evapotranspiration; incentivizing the use of infiltration ditches alongside infrastructure like streets, parking lots, and housing; and promoting "GREEN" certification for ecologically efficient projects adhering to socio-environmental standards, disseminating these to the public to encourage practices and projects meeting criteria such as energy efficiency and rainwater reuse (Senes *et al.*, 2021).

These spatial strategies prioritize infiltration, detention, and treatment of stormwater at the source, aiming to reduce runoff volume and improve water quality before it enters receiving water bodies (Fletcher *et al.,* 2015). For instance, according to Monachese *et al.* (2024), effective SUDS design integrates different components such as permeable pavements, green roofs, and rain gardens, tailored to the local context. Evidence suggests that well-designed SUDS can mitigate peak flows, reduce runoff volumes, and purify water. However, barriers to widespread adoption for many communities include lack of awareness, upfront costs, and regulatory complexity, operation and maintenance (Monachese *et al.,* 2024; United States Environmental Protection Agency -USEPA, 2024). Overcoming these will require collaborative stakeholder action to prioritize education, policy support, and funding opportunities or using roads and right-of-ways as locations for green infrastructure implementation which could alleviate access and maintenance concerns (USEPA, 2024).

Conversely, many developing countries, including regions in Africa and parts of Asia and Latin America, often grapple with a different set of spatial and socio-economic realities that influence urban drainage practices (Parkinson & Tayler, 2003). In China for instance, Li *et al.* (2024) observed that Hezhai rarely experienced flooding disasters in the past and have begun to frequently suffer from floods due to unreasonable reconstruction activities such as ground hardening and pond filling caused by urbanization. Hence, rapid and often unplanned urbanization leads to the proliferation of informal settlements in flood-prone areas and along natural drainage pathways, limiting the space available for implementing modern, spatially extensive SUDS solutions (Parkinson & Tayler, 2003). Furthermore, the lack of adequate investment in infrastructure, coupled with challenges in waste management and sanitation,

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often results in the contamination of storm-water runoff, making the direct application of developed-country SUDS approaches complex and potentially counterproductive (Voskamp &Van de Ven, 2015).

While the principles of sustainable drainage are increasingly recognized, their adoption in developing countries is often hindered by factors such as limited financial resources, inadequate technical expertise, weak institutional frameworks, and the dominance of traditional (Sangaré & Thibault, 1998) (rapid conveyance) sanitary philosophies (Sangaré & Thibault, 1998; Monachese *et al.,* 2024). Spatial planning in these contexts often struggles to integrate drainage considerations effectively, leading to continued reliance on centralized, often undersized, and poorly maintained conventional drainage networks (Tchindjang *et al.,* 2020; Ojuku *et al.,* 2022). Therefore, while the global discourse on urban drainage increasingly favors sustainable, spatially integrated approaches, the practical implementation and spatial characteristics of these systems are significantly shaped by the distinct developmental contexts of developed and developing nations. Cameroon, as one of the most rapidly urbanizing nations in Africa, holds significant future economic potential, heavily reliant on the competitiveness of its cities such as Yaoundé, Douala, Limbe, and Buea. The United Nations projects that by 2050, 70% of Cameroon's population will reside in urban centers (UN, 2018; World Bank, 2020). This rapid urbanization necessitates the implementation of proper drainage systems to manage water movement effectively, as many Cameroonian towns, including Buea, Yaoundé, Bafoussam, and Dschang, face considerable environmental and human challenges related to urban water and sanitation management.

The situation in Buea is particularly critical due to its unique geographical context. Located on the slope of Mount Fako, the highest peak in Central and West Africa and situated within the equatorial zone, Buea experiences high rainfall, moderate temperatures, and significant surface runoff, further influenced by socioeconomic activities such as settlement expansion and agricultural practices. These factors have shaped the area's drainage system, often resulting in informal and artificial constructions (Anyinkeng *et al.*, 2020). Buea receives a substantial average annual rainfall, ranging from approximately 2800 mm to over 4000 mm in some mountainous areas, which, combined with a rapid urbanization rate estimated at a 42% population increase in peri-urban areas in 2020, has significantly exacerbated drainage challenges. This has led to recurrent floods in neighborhoods like Buea Town, Bova, and Bokwai Boduma, Mile 17, Molyko, with notable events in March 2023 and March 2020 causing casualties, displacement, and substantial damage to property and infrastructure, underscoring the urgent need for improved drainage systems as recognized by urban administration and the national government.

While the challenges of urbanization and drainage are evident in Cameroon, there is a need for more focused research specifically analyzing the current state of urban drainage systems in Buea and their direct implications on both the local inhabitants and the physical environment. Existing studies often provide broader overviews of urban development or focus on specific aspects of water management in other Cameroonian cities. For instance, Ojuku *et al.* (2022); Tchindjang *et al.* (2020) indicate that urban expansion in Yaoundé, Cameroon has frequently outpaced the strategic development and maintenance of essential drainage infrastructure, significantly exacerbating flood risks in vulnerable urban centers Also, the authors noted that increase in bare surfaces due to deforestation for development and settlement increases surface runoff. Neba *et al.* (2019) corroborated these and highlighted the challenges of managing storm-water runoff in mountainous urban areas of Cameroon, emphasizing the need for context-specific drainage solutions, while Nkemasong (2014; Nkemasong *et al.* (2022) noted

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specific vulnerabilities of Buea to inadequate drainage due to its unique topography and high rainfall patterns.

According to the Shelter Cluster of NGOs in NWSW Cameroon, the impacted area covered approximately 13.52 square kilometers and included around 2,760 buildings (Shelter Cluster, 2023). The report highlights that 52% of households faced a shortage of essential household items, between 100 and 107 people were displaced or left homeless, 73% of households saw negative impacts on their businesses or livelihoods, 64% lacked access to safe drinking water in the immediate aftermath, and 28% experienced deteriorating shelter conditions (Shelter Cluster, 2023). Similar flood hazards were observed in the Kumba and Mutengene-Likomba areas within the South West Cameroon Coastal Plain between July and September 2022 (Nkemasong et al., 2022). To make matters worse, these cities are characterized by a considerable number of informal settlements, where approximately 60% of the urban population resides under precarious conditions, often lacking access to basic services and adequate infrastructure (Ministry of Environment, Protection of Nature and Sustainable Development, 2020).

Building upon these broader and localized insights, this study aims to provide significant contributions to the existing literature, particularly within the developing country context as it explicitly investigates and quantifies the direct and indirect implications of the *specific characteristics* of drainage systems (or lack thereof) on the daily lives, health, and economic well-being of its inhabitants, as well as the degradation of its immediate physical environment (e.g., water pollution, soil erosion). The unique location of Buea on the slope of Mount Fako, characterized by high rainfall and steep topography, presents distinct drainage management challenges that may not be fully captured by broader studies on urban drainage in developing countries, which often focus on flatter terrains or different climatic zones (Sangaré & Thibault, 1998). This study will provide context-specific insights relevant to similar mountainous, high-rainfall urban environments which could provide empirical evidence and facilitate understanding of the challenges and impacts of urban drainage in Buea, directly informing stakeholders in the development of targeted and effective strategies for sustainable urban development.

2. MATERIAL AND METHODS

2.1 Study Area

The main focus of this research is the Buea urban area, located within the municipality of Buea in the Fako Division, South West Region of Cameroon. It has a surface area of 870km square and is situated in the Eastern slope of Mount Cameroon between Latitude $4^0$12 to $4^0$31 North of the Equator and Longitude $9^0$09 to $90^0$12 of the Greenwich Meridian as shown in Figure 1.

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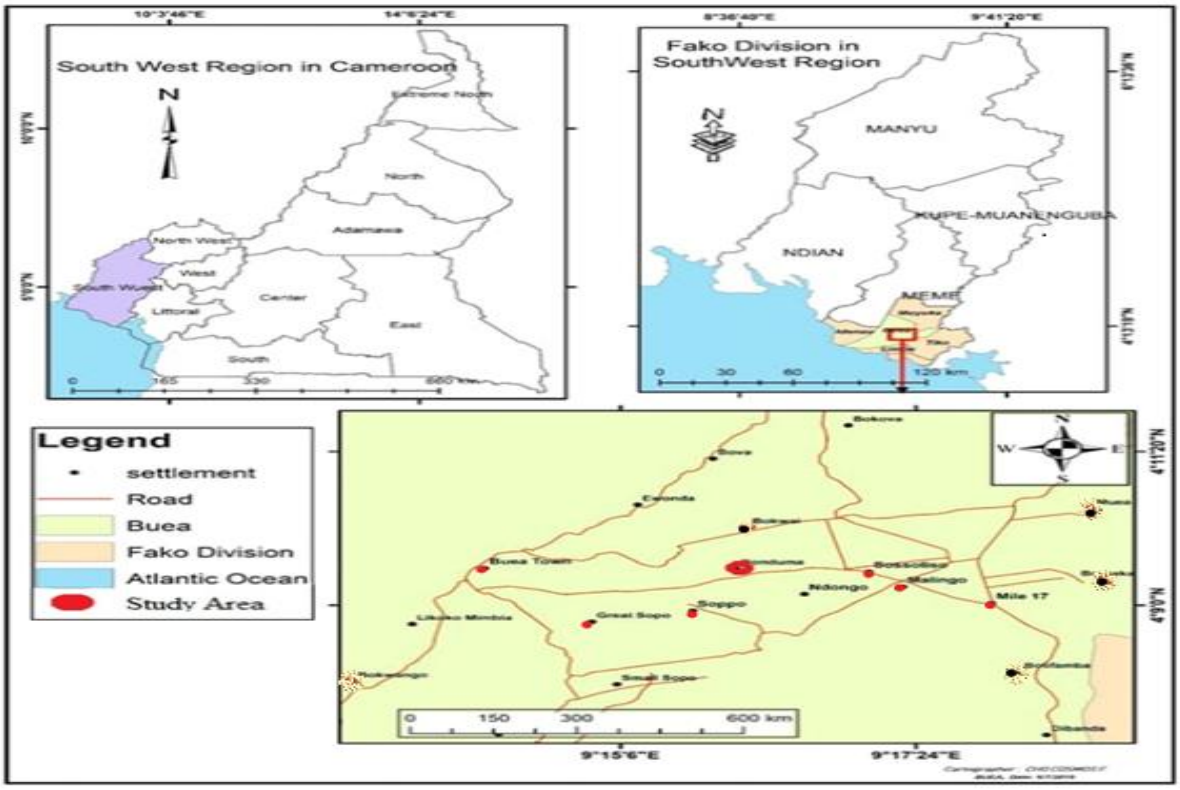

Figure 1: Sampled Location in Buea Urban Area, Fako Division of the South West Region of Cameroon

Source: Adapted from the Administrative Map Unit of Cameroon, 2023

Buea Urban Area has a population of about 300,000 inhabitants that is according to the 2013 census carried out by the Cameroon government and, an elevation of 850m (2,850 ft) above sea level (Nsah, 2017). It is bounded to the west by Mount Cameroon, to the east by Tiko Sub DIVISION, to the North by Muyuka Subdivision and to the south by Limbe Subdivision. The Urban area of Buea consists of neighbourhoods like Mile 16, Mile 17, Muea, Molyko, Great Soppo, Buea Town, Bonduma, Clack Quarters, GRA, and Federal Quarters.

2.2 Methods

2.2.1 Sampling Techniques

This study adopted cross-sectional survey research involving both quantitative and qualitative research methods to investigate the characteristics, quality and challenges of urban drainage systems in the Buea Urban Environment. The qualitative design established conclusions on indicators based on observations and visual/textual data, unlike the quantitative techniques tangibly measure indicators and draw conclusions based on the numbers, sizes, or frequency of occurrences. This study employed a stratified sampling technique and sampled neighbourhoods like Molyko, Great Soppo, Bunduma, and Clark Quarters among others which cut across the upper areas, mid-slope and lowland elevation areas respectively within the study town. Instruments such as structured questionnaires, digital cameras, measurement tape, Global Positioning System (GPS), interviews and observation guides were used to get reliable data. Buea Urban Area represents the target population including neighbourhoods like Buea Town, Bonduma, Great Soppo and Molyko. Based on the figures from the census bureau, population studies estimate as well as UN growth rates for African cities, the population of the Buea Urban

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Area is approximately 300,000 inhabitants with the population of male at 49 % (147,000) and that of female approximately 51% (153,000) in 2013. The Communal Development Plan (CDP) of Buea estimated the population of Buea at 171,000 inhabitants and the urban population was put at 57% of the total population (CDP Buea).

According to CDP Buea, the population of age group 16 and above makes up 65% of the population. In line with this, therefore, the target population consists of 111,150 inhabitants residing in the Urban Area of the Buea. Going by the United Nations norm adopted by Cameroon, an average household size is 5.2 persons (UN, 2018). It was on these bases that the sample population of this study was selected. Also, the study purposely targets 15 officials from urban planning and engineering departments within the town of Buea such as the Buea council and sub-divisional delegation of Urban and Housing Development (MINDHU) including the Hygiene and Sanitation Company (HYSACAM) to collect data related to urban drainage systems and management. Within each of the four neighbourhoods with an estimated population size of 40,073 inhabitants, respondents were selected using simple random sampling and were classified following topographic criteria as steep (Buea Town and Great Soppo 930 meters above sea level), gently sloping areas (Bonduma 748 meters above sea level) and Molyko 532 meters above sea level). Concerning urban planning stakeholders, key staff within the departments holding relevant positions within the sub-divisional delegations were selected for face-to-face interviews through a purposive sampling technique especially those holding relevant positions relating to urban drainage issues and management.

The formula to determine the sample size for the study was achieved from the procedure developed by Krejcie and Morgan, (1970). This is expressed as follows:

$$s = \frac{X^2NP(1-P)}{(d^2(N-1)+X^2P(1-P)}$$

Where: s = required sample size.

X^2= the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N = the population size.

P = the population proportion (assumed to be 0.50 to provide the maximum sample size).

d = the degree of accuracy expressed as a proportion (0.05).

Based on the estimated population of 40,073 inhabitants, the sample size adopted is 300 respondents for this study. Table 1 shows the number of questionnaires administered in the different neighborhoods via a proportion-sampled method based on population estimations.

Table 1: Questionnaires administered to the different neighbourhoods

Neighbourhoods	Total population	Altitudes (Meters above sea level	Sampled Population (%)
Molyko	20,570	532	150
Great Soppo	13,745	921	70
Buea Town	2,059	964	50
Bonduma	3,699	732	30
Total	**40,073**	**-**	**300**

Source; Fieldwork, 2024

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2.2.2 Data Collection and Field Procedures

Primary data for this study were obtained from the administration of 300 semi-structured questionnaires to households within the study area, these questionnaires were divided into four sections targeting the four urban settlements of the study area addressing the socioeconomic and demographic characteristics of the respondents, patterns of drainage systems, challenges, implications and sustainable options. Also, structured interviews were carried out with 15 key personnel within each related department dealing with urban planning, water management, and environmental engineering were interviewed on the patterns, challenges and effectiveness of urban planning strategies in dealing with the challenges of drainage systems in the town using interview guides. Furthermore, field observations were made to identify some drainage characteristics and a total of 30 drainage systems were observed in the four different neighbourhoods of the town.

In addition to the field observation exercises carried out, measurements on drainage capacity (depth and width) and their effectiveness in evacuating runoffs after rainfall were carried out in the four sampled neighbourhoods within the town and compared with international recommended standards. The width and depth were measured using measuring tapes. Coordinates and picture collections were vital for this study and were taken during the fieldwork exercise with the use of GPS to show the actual location, latitudes, longitudes and height of each sampled site. Secondary data were obtained from varied sources including the Buea Council, new papers, the internet, previous research projects and the regional delegate of Housing and Urban Development amongst others which aligned to the impacts of poor drainage systems on the environment and the measures to manage and enhance sustainability in urban drainage systems.

2.2.3 Data Processing and Analysis

The study adopted both qualitative and quantitative data analytical techniques and, quantitative analysis entails the use of both descriptive and inferential statistics. Questionnaires were analyzed employing percentages, relative frequencies and frequencies. These statistics were calculated using Microsoft Excel version 16 and the Statistical Package for the Social Sciences (SPSS Version 23.0). In the case of qualitative data from recorded interviews, they were transcribed, sorted and classified using Microsoft Excel after which, thematic or content analysis was applied. The drainage maps were analyzed using Arc GIS software and the values calculated were transferred to Excel for compilation and further analysis.

Chi-square verified at a 0.05% level of significance was used to test the significant relationship between variables. The Chi-Square formula is expressed as follows:

$$\chi 2 = \Sigma \frac{(O - E)2}{E}$$

Where: χ^2 designates chi-squared statistic; *O* represents "observed" values (those that occur actually); *E* for "expected" values (those that would occur). These expected values were calculated as follows.

$$E = \frac{(CT - RT)}{GT}$$

Where: *CT is* the column total for each category*; RT* for the row total for each category; *GT* is the overall number of respondents. In this case, the degree of freedom (df) is calculated as Degree of freedom (df) = (Number of Columns – 1) * (Number of rows-1). The hypotheses were tested at 0.05% level of significance at a particular degree of freedom. Furthermore, the Pearson Product Moment Correlation was used to accomplish the relationship between poor urban drainage systems and its major health and environmental challenges. Analyzed data were presented as text and in the form of tables, graphs such as bar graphs, line graphs, scatter graphs, compound bar charts and pie charts. Also, data was collected from the field in the form of maps and photographs accompanied by their geo-referenced coordinates and areas where they were taken to show the various road drainage systems such as gutters/ drains in various neighbourhoods. Before the study was conducted, written consent was obtained from the Divisional Officer (SDO) of Fako and other related Divisional delegations of urban planning and the Mayor of the town and approval was obtained from these authorities. The participants were informed about the purpose of this study that the information obtained will not be used outside the study and the confidentiality of their personal information will be protected.

3. RESULTS

3.1 Socioeconomic and Demographic Characteristics of the Respondents

Given the socio-demographic profile statistics of the respondents in Table 2, the age group was more of those between 26-36 years (41%), followed by the age group 37-47 years (25.6%) and the least the age group of 60+ (6.7%). The sample consisted of 55% males and 45% females. Most respondents were married (50%), followed by singles (30%), and widows (1.7%). Equally, only a few respondents had primary education (3.4%) whereas, approximately 33.3% attained an advanced level of education. The second major group of respondents was made up of first-Degree holders followed by those with a Master's degree as supported by 40% and 8.3% of the respondents respectively. Furthermore, 51.7% were the indigenes of the area while migrants made up 48.3% of the representative population. As concerned individual's duration of stay in the Buea Urban Area, the majority have stayed for more than 10 years as indicated by 46.7% of the sampled population, 45% claimed that they have stayed between 6-10 years while the least were those who have stayed for less than 5 years (8.3%).

Table 2: Socio-economic and Demographic Profile of Respondents

Variable	Category	Frequency	Percentage (%)
Age	15-25	30	10
	26-36	123	41
	37-47	77	25.6
	48-59	50	16.7
	60+	20	6.7
Sex	Male	165	55
	Female	135	45
Marital Status	Single	90	30
	Married	150	50
	Divorce	40	13.3
	Widow	15	5
	Widower	5	1.7
Education Level	Primary level	10	3.4
	Ordinary level	30	10

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	Advanced level	100	33.3
	Bachelor's Degree	120	40
	Masters' Degree	25	8.3
	Others	15	5
Region of origin	Indigene	155	51.7
	Migrant	145	48.3
Duration of Stay	<5	25	8.3
	6-10	135	45
	10+	140	46.7
Reasons of Residence	Business	50	16.7
	School	160	53.3
	Civil Servant	70	23.3
	Others	20	6.7
Occupation	Unemployed	50	16.7
	Self-employed	100	33.3
	Civil servant	75	25
	Private Sector	45	15
	Others	30	10

Source: Fieldwork, 2024

Further investigations on the reasons as to why individuals have chosen to settle in this Urban Area revealed that the majority (53.3%) were for educational purposes, 16.7% settled for business purposes 23.3% for civil activities and the least were for other duties such as leisure and vacations as indicated by 6.7% of the respondents. As concern the amount of money spent during the recovery stage of floods, a significant majority of the respondents (33.3%) indicated that their estimated expenditure during periods of flood ranges between 200.000 FCFA - 300.000 FCFA while 18.3% indicated that they usually spend from 101,000FCFA-200.000 FCFA. 51000 FCFA -100.000 FCFA and 300.1000 FCFA -400.000 FCFA were indicated to have been spent by the majority of the respondents as supported by 15% and 13.3% of them respectively. The least (3.4%) were those who spent below the sum of 25.000 FCFA.

3.2 Spatial Distribution of Drainage Systems

To fully address the patterns of the drainage system within the Buea Urban Area, certain aspects were taken into consideration including the spatial distribution, structures and quality of drainage systems. However, to begin with, it is vital to present the spatial distribution of the main drainage system categories (Figure 2). On the landscape, natural drain systems consist of rivers and streams whose flow and movements are influenced by many factors including the geography of the environment and anthropogenic forces. Concerning the information presented in Figure 2 which depicts the nature of the urban drainage systems of Buea, the area is found on the slope of Mount Cameroon with intervening slope plates within some parts of the town such as the GCE Board and the Mile 17 areas. Naturally, the Buea urban area is well-drained. Four main river systems drain through Buea including the Likoko, Ndongo, Mile 18 and Kokoe streams which flow from the south towards to northern part. Based on the natural influence on drainage patterns, rivers take their rise from the mountain and rain downward passing through settlements like Soppo, Muea, Molyko, Mile 16 and Mile 17. The main watercourse is the Ndongo River, a stream that takes its rise from Mount Cameroon and flows downwards cutting across Buea from Buea town, through Bonduma and Molyko to Mile 16. The other natural drains are the valleys of seasonal tributaries of the main drainage system.

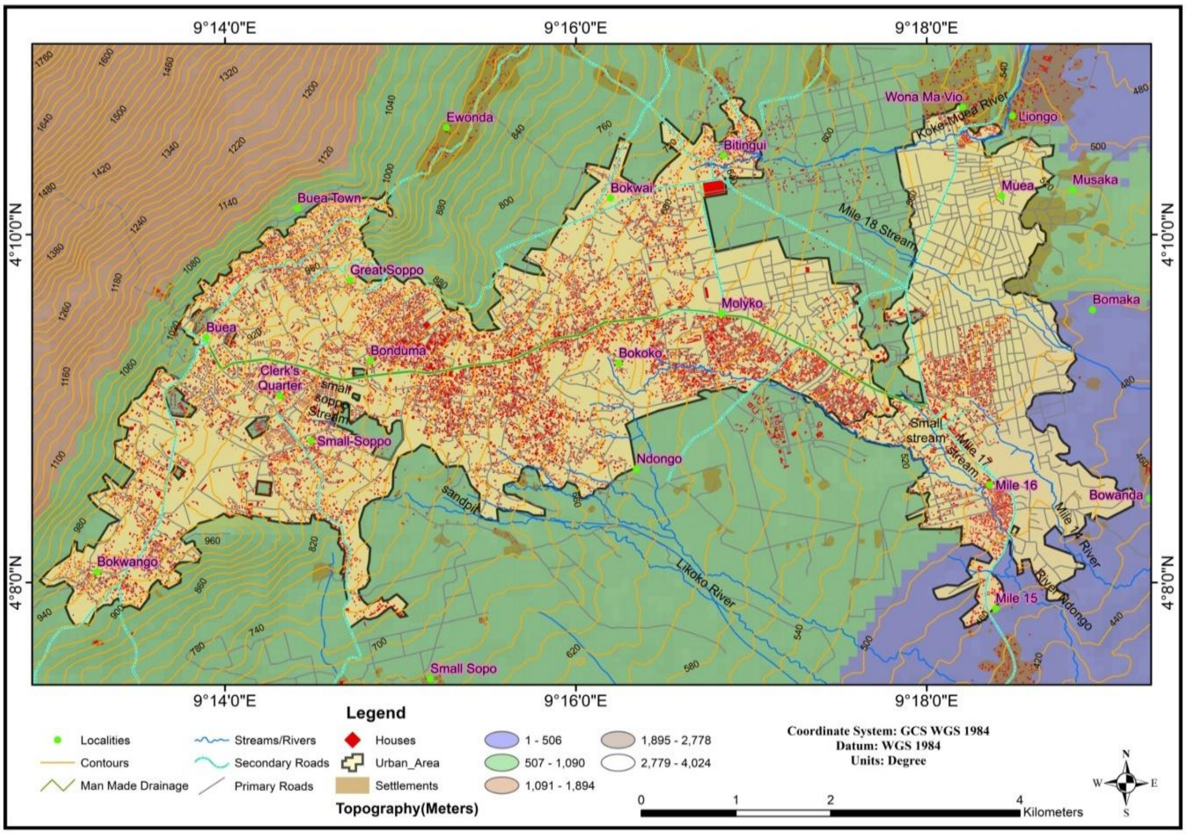

Figure 2: Drainage Pattern in the Buea Urban Area

Source: Adapted & Digitalized by Kandem (2021)

These streams and their tributaries constitute the main natural drain system of Buea. The spatial spread of these drain systems has been influenced by the nature of relief characterized by a juxtaposition of gentle and steep terrain. Due to the fast rate of urbanization, coupled with diverse economic activities, most of the natural drainage channels have been tampered with or composed. The tributary streams have dried off and their valley colonized by anthropic construction and new developments. As a result, artificial drainage channels have been developed over time. However, these channels have proven ineffective in managing surface runoff. Consequent to this action, today in the town there have been two categories of drain systems, the natural being valleys either wet or dry and man-built gutters.

3.3 Characteristics of Drainage System

One of the major factors responsible for the malfunctioning of these drainage channels is the unplanned nature of housing infrastructure and construction around drainage areas as well as reckless waste deposition in these drainage channels. Furthermore, there are some contact points where there is often the convergent of runoff generated within different quarters of the town. Within some of these points, the artificial drainage channels are too narrow and shallow to contain the surface water. This has resulted to the clogged as well as blockage of the artificial drainage channels by eroded sediments. Mile 17, CGCE Board, Bunduma Gate and part of Soppo are good examples of these affected areas. However, there are some areas with well-constructed artificial drainage systems capable of containing surface water from storms

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including the University Campus of Buea, the Governor's Office, Buea Town and OIC. Through a comprehensive field survey, the Buea urban drainage systems were statistically analyzed and the results are presented in Table 3.

Table 3: Characteristics of Drainage Channels within the Buea Urban Area

S/N	Area	Latitude	Longitude	Structural Quality			General Comments During Field Survey
				Depth (Cm)	Width (Cm)	Area (Cm^2)	
1	UB	N:4.149777^0	E:9.28732^0	81.5	72.5	5,530	Passable and in good condition
2	Malingo	N:4.156267^0	E:9.28803^0	90	82	150	Passable but, need expansion
3	Check Point	N:4.159082^0	E:9.28042^0	30	36	5,9932.5	Totally blocked by eroded materials
4	GCE Board	N:4.159437^0	E:9.27564^0	0	0	7,280	Totally blocked
5	Bunduma	N:4.157885^0	E:9.26836^0	29	54	1,537	Shallow and need proper cleaning
6	Mini Cocket	N:4.156824^0	E:9.26498^0	50	57		Partly blocked by mud
7	OIC	N:4.154473^0	E:9.25762^0	120	260	30,500	In a very good condition
8	Central Police	N:4.153676^0	E:9.25266^0	300	300	10,890	In a good condition
9	Buea Town Market	N:4.156369^0	E:9.23157^0	115	100	11,231	Good and passable
10	Slaughter House	N:4.161492^0	E:9.24597^0	130	73	1,2341	Completely destroyed and needs reconstruction
11	New Road	N:4.161224^0	E:9.24647^0	45	103	1.342	Partly blocked and needs cleaning
12	Street 8	N:4.160915^0	E:9.24682^0	43	103	1,231	Passable
13	Mile 17	N:4.150554^0	E:9.29921^0	0	0	00	Totally absent and need a new one
Total				**1,033.5**	**1,240.5**	140,624	
Average				**79.5**	**95.42**	21,634	
UN Standard Mean				**130m**	**120m**	15,600	

Source: Fieldwork, 2024

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Table 3 shows the spatial characteristics and qualities of drainage channels within the Buea Urban Area averaging 79.5cm in depth and 95.42cm in width. Some areas such as Soppo (OIC), Central Police and Buea Town have a good drainage system as compared to Molyko, Mile 17, Malingo and Check Point. Bunduma and Soppo on the other hand have drainages in critical conditions. A significant majority of respondents accepted the availability of drainage systems but a few improved ones were found along the main road and within some roads linking Government Residential Areas and offices while the majority were unimproved.

In the course of the study, a detailed investigation on how adequate the drainage systems were distributed and efficient in the evacuation of the run-off generated within the town, the majority 82% of respondents indicated dissatisfaction strongly agreeing that most of the drainage systems were uncovered while only 18.3% were satisfied with the drainage system of the town as they were covered however the types of materials used varies significantly due to government and stakeholders priorities, corruption and level of income.

From Table 3, the mean dimensions of drains in the Buea Urban Area are at depths of 79.5, a width of 95.42 and a carrying capacity of 21,634. Spatially, the various drains are not the same thus their differences in terms of flow transfer propensities. Therefore, the analysis of field data revealed that most of the drains were constructed by using concrete materials as revealed by (41.7%) of the sampled respondents, followed by stones materials (31.7%), bare surface materials (21.6%) and brick materials (5%) as noted by respondents respectively. It should however be noted that no part of the drainage system has been made with steel due to hugged investment, material, technical and engineering processes required. Further investigation on the structure of drains noted that different neighbourhoods within the study area had diverse drainage systems which differed in terms of depth, design and resistance to flooding (Figure 3).

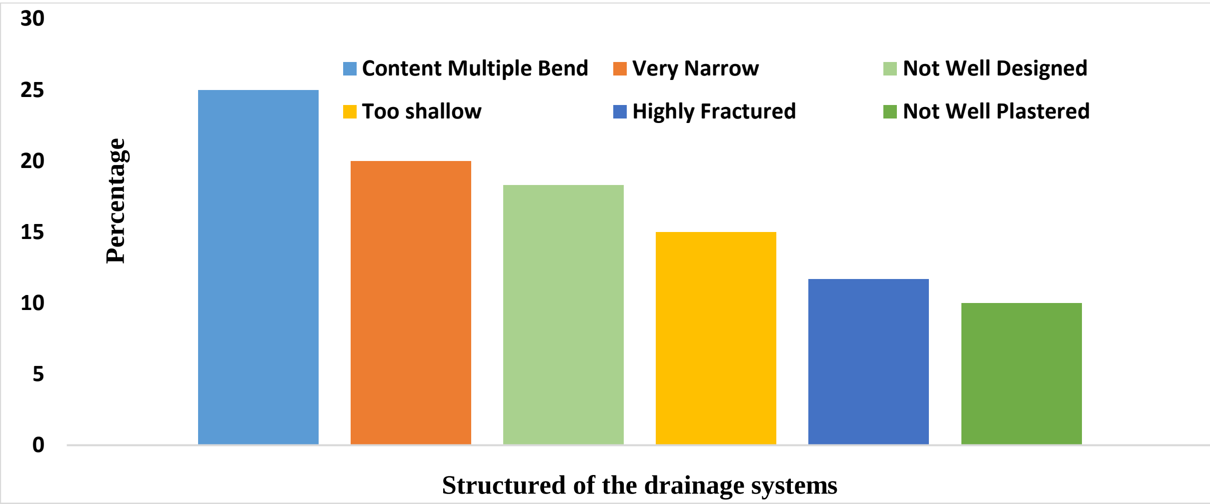

Figure 3: Nature and Structure of Drainage Systems

Source: Fieldwork, 2024

From Figure 3, 25% of the respondents attributed that many of the drainage systems were too shallow, 20% of the sampled population also advocated that most of the drainage systems were very narrow while 18.3% claimed that they were not well designed. 15% confirmed that some of the drains contained fractures and the least were those who said that most of the drains were not well plastered. Field survey also revealed that areas with better drainage facilities were the University of Buea Campus and parts of the GRA premises, while areas with the worst drainage

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facilities were found around the CGCE Board, Old Police Station in Molyko and part of Mile 17 car park as presented on Plate 1.

Plate 1: Lack of Drainage Infrastructure at Mile 17

Coordinates: N04009.018'/, E009017.954'/, 1749ft

Source: Fieldwork, 2024

In assessing and evaluating how satisfied individuals are, with the pattern of the various drainage systems in the Buea Urban Area, the majority had different opinions on the status of the present drainage systems as presented in Figure 4 during the field survey.

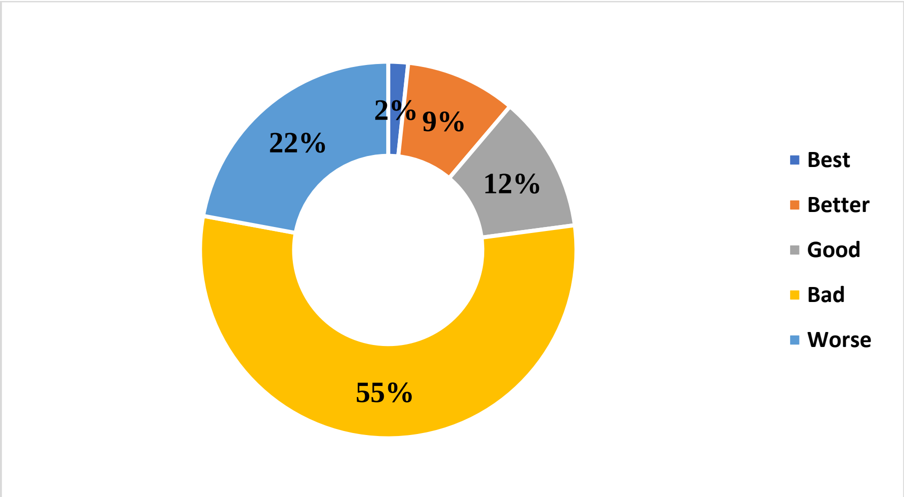

Figure 4: Respondents' Opinions on the Status of the Drainage System

Source: Fieldwork, 2024

Figure 4 disclosed that 55% of respondents consider a greater part of the drainage systems in the Buea Urban Area as bad. Approximately, 12% of respondents confirmed that the drainage systems are good and the least were those who said it was the best as evidenced by 2% of the sampled population. Plate 2; shows the poor nature of the drainage systems along parts of the

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Buea Main roads along the main road leading to Buea Town. The urban drainage systems within the Buea Urban Area are diversified with clear evidence that the different localities in the Buea Urban Area have different structures of urban drainage systems which are not up to standard in terms of quality, size and patterns.

Plate 2: Water diverting from the Main drainage channel at Buea Town Neighbourhood

Coordinates: N04009.018'/, E009017.954'/, 1749ft

Source: Fieldwork, 2024

Hence, with a degree of freedom 5 and an alpha value of 00.5, the calculated value of 4.6 was greater than the table value of 2.015, the results from the analysis of field data show that there is a significant variation in the state of drainage systems across different neighbourhoods in the study area (P value=2.015). That is, while other neighbourhoods have excellent, better, or good drainage systems others are experiencing bad, average or worse drainage systems, especially during the peak period of the rainy season (July to September).

3.4 Causes of Poor Urban Drainage Systems

The Buea Urban Area, located at the foot of Mount Fako, experiences heavy rainfall. The majority of respondents reported that the urban drainage system is inadequate to handle large volumes of runoff and struggles to withstand floodwaters. Respondents highlighted that they grapple with seasonal solutions each year to control inundating water often with little or no success. A significant majority (91.7%) of the respondents pointed out that the Buea Urban Area is not well drained while only 8.3% claimed that the area is always well drained due to multiple factors (anthropogenic and physical) as presented in Figure 5.

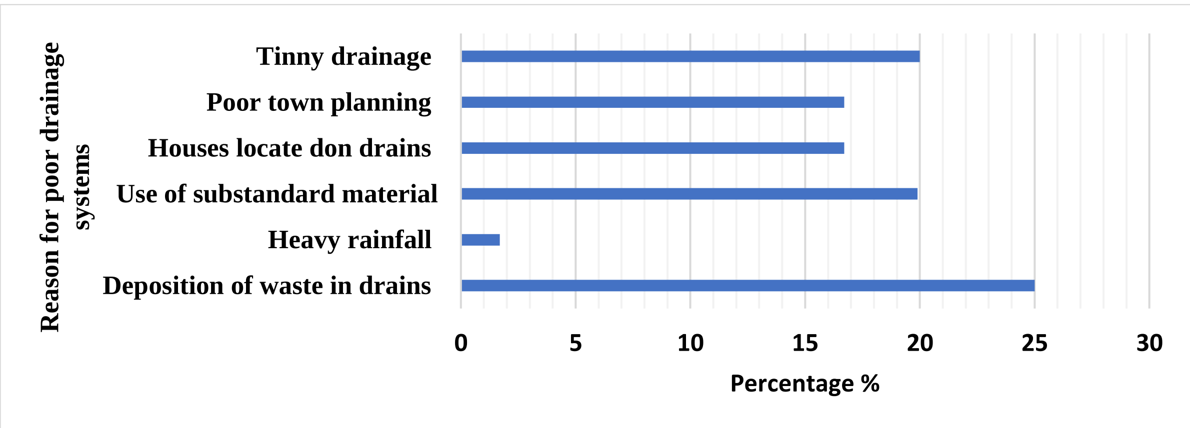

Figure 5: Reasons for the Poor drains

Source: Fieldwork, 2024

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Figure 5 presented a significant majority 25% of respondents noted poor waste materials deposited into gutters followed by 20% of them complaint about the tiny drainage system, 16.7% attributed the incidence to both poor planning of the town as well as houses which are usually sited on most drainage coverts. The least were those who stood for the heavy rainfall as supported by 1.7% of the exemplified population. Plate 3 indicates the tiny nature of drainage is the cause of water overflowing into unwanted areas as shown by the arrow. As such, this resulted in passage inaccessibility and the disturbance of activities carried out within the Buea Urban Area.

Plate 3: Evidence of Poor a Drain in Molyko Neighbourhood

Coordinates: N04009.563', E009016.805' 2039ft

Source: Fieldwork, 2024

Based on the method of waste disposal as a trigger of drainage issues in the study area, results revealed the diverse manner of waste disposal by respondents ranging from dumping waste along the road side, in drainage culverts or drainage channels as presented in Figure 6.

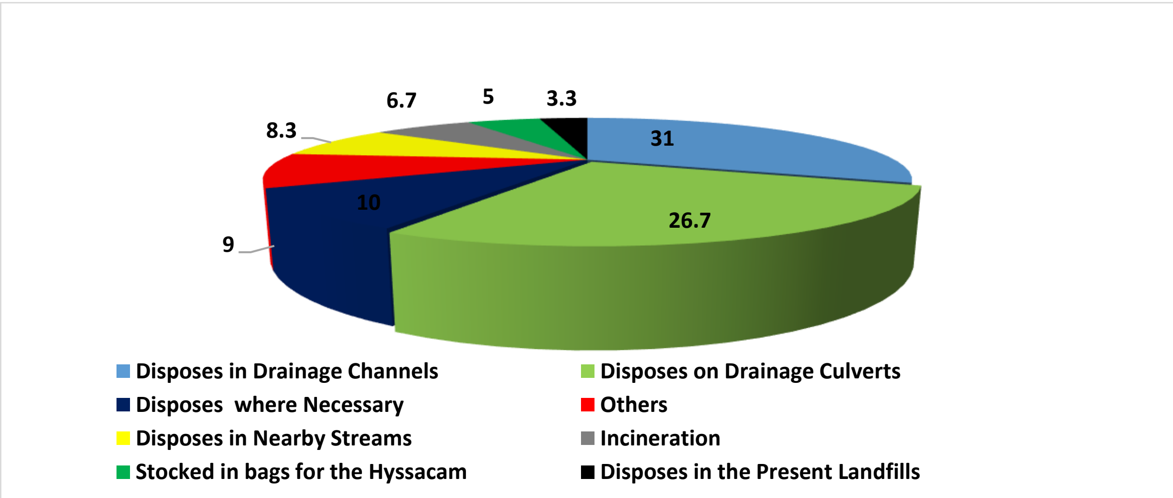

Figure 6: Waste Disposal Practices among Residents of the Buea Urban Area

Source: Fieldwork, 2024

Figure 6 revealed that a significant majority (31%) of respondents accepted that they usually deposited their waste materials into the drainage channels, 26.7% claimed that they always deposit theirs on drainage culverts while 10% said they do deposit their waste materials where necessary. Further investigations revealed that 8.3% of the respondents deposited their waste materials into nearby streams while 6.7% did incineration. 5% unveiled information that they always stock their waste materials in bags for the HYSACAM to come and collect and the least (3.3%) were those who deposited their waste materials directly on landfills.

Significantly, it was less risky to say that the urban drainage systems within the Buea Urban Area were not of standard and were more susceptible to the anthropogenic and denudation forces prevailing within the Urban Area. Consequently, an investigation was conducted to determine the factors contributing to the inadequate drainage infrastructure in the Buea Urban Area, with the findings illustrated in Figure 7.

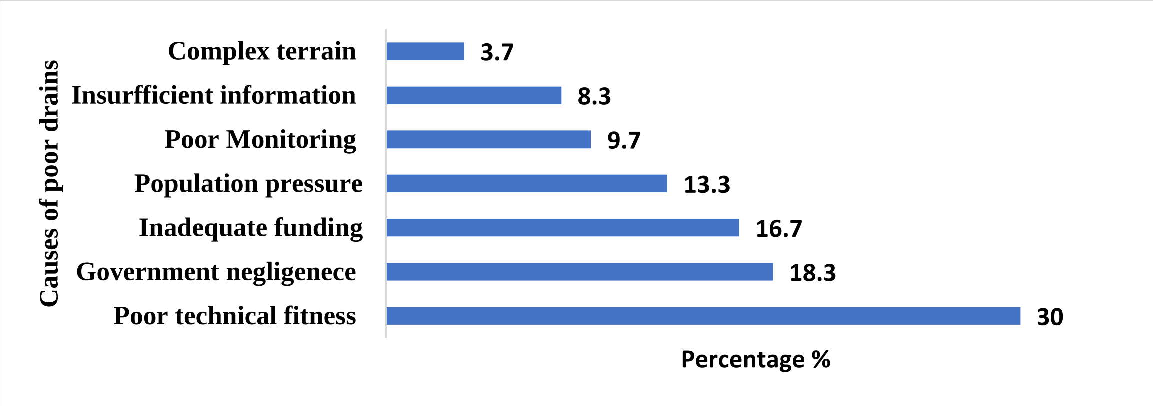

Figure 7: Key Determinants of the Emergence of Deficient Drainage Systems

Source: Fieldwork, 2024

Figure 7 revealed that the major reasons for the rapid depreciation of the urban drainage facilities were poor technical expertise, and government negligence as indicated by 30% and 18.3% of the sampled population respectively. 16.7% of the sampled population pointed at the inadequacy of funds while 13.3% attributed it to population pressure. 9.7% were also for poor monitoring and the least were those for the complexity of the urban landscape as supported by 3.7% of the representative population.

3.5 Implications of Poor Drainage Systems on Environment and Human Health

To investigate the implications of poor urban drainage systems in the environment and health of the inhabitants in Buea Urban Area, an overwhelming majority (96.8%) of the respondents accepted that they have faced many issues that were caused by the poor nature of the drainage systems, 2.2% of the respondents said they have never been affected flooding due to poor drainage systems and 1% of the sampled population was neutral. Hence, environmental issues emerging from poor urban drainage systems included, soil erosion, minor landslides and the deposition of debris (Figure 8).

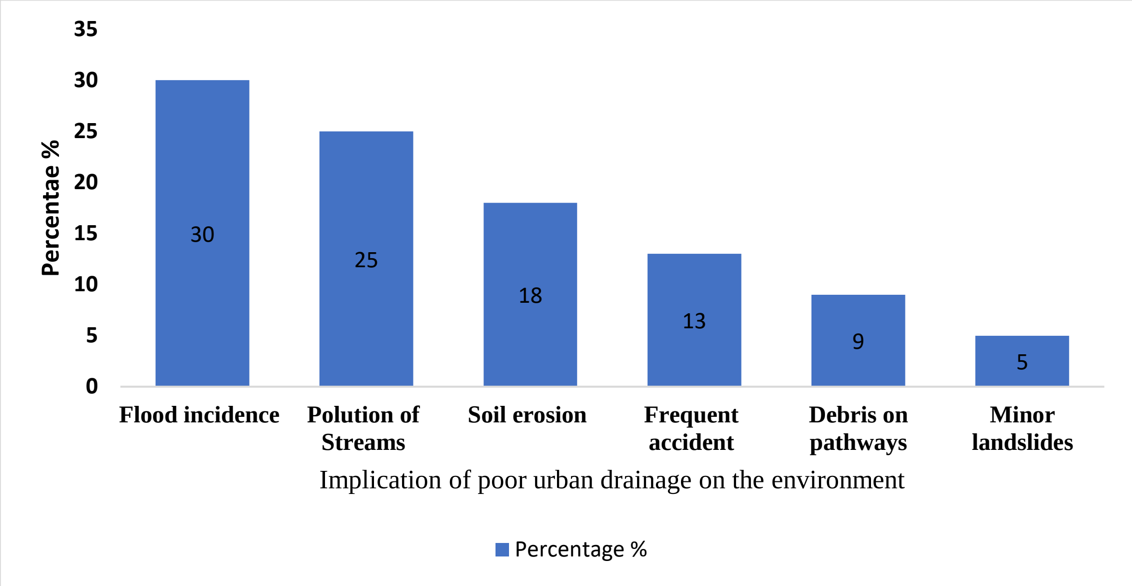

Figure 8: Environmental implications of poor Urban Drainage System

Source: Fieldwork, 2024

Given the information presented in Figure 8, a significant majority (30%) of the respondents claimed that the biggest issue stemming from poor urban drainage systems was the incidences of flood especially those around Sandpit, Soppo, and Buea Town who accepted that at times they are affected by frequent flash flood incidences which occurs in the months of July and August while the second environmental issue was pollution as indicated by 30% and 25% of the sampled population. 18% of the representative population also pointed at stream soil erosion while 13% pointed to the frequent incidence of accidents along the highway paths. 9% of the sampled population attested to the spread of debris on the road paths while those that said it caused a minor landslide were represented by 5%. No constructed drainage at the gateway into Buea as on plate 1 above often leads to the blockage of one lane of the road which has led to increasing traffic congestion, a hindrance to pedestrian movements and accidents. Further investigation into the challenges caused by floods in the Buea urban space uncovered the following issues **(**Figure 9).

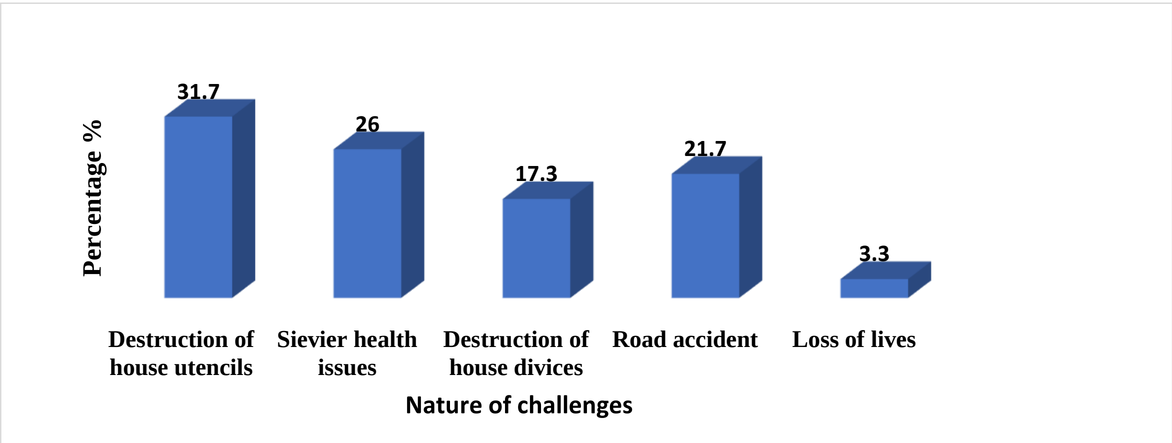

Figure 9: Perceived Challenges of Flood Incidences by Respondents

Source: Fieldwork, 2024

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Concerning the information presented in Figure 9, most of the urban dwellers mentioned that during periods of intense and frequent flash floods, such as the one that occurred in August 2021, most of their household materials such as utensils are usually damaged as supported by 31.7% of the sampled population while 26% of them said that it usually caused them to face severe health situations. 21.7% of the sampled population also said that it causes incidences; most of their household devices are usually damaged as indicated by 17.3% of the sampled population. 21.7% of them said that during floods there are often road accidents occur while the least 3.3% attributed it to the deaths of humans

Plate 4: Heaps of Eroded Materials Deposited by Runoff around the Central Police Station at Buea Town supervised by the Municipal Authorities

Coordinates; N04008.961'/ E009014.281'/ 292Tft.

Source: Fieldwork, 2024

Plate 4, shows heaps of waste materials deposited at the entrance to the General hospital after a heavy downpour which could not be contained by the drainage systems on March 08th, 2020. It also led to the destruction of the fence around the police station in Molyko due to head debris carried by runoff. Many houses were flooded with inundation runoff after the heavy downpour in the area with severe implications on many households properties and belongings especially in neighbourhoods along the Regional Hospital Junctions area stretching towards Memos Banquet Hall, and Part of Soppo, Bondoma and Buea Town, the Presbyterian Church Synods office area on the road to Buea Town, the Cameroon GCEB and the Government Technical School Campus in Molyko, the University of Buea Junction and the Mile 17 Round About.

This situation was exacerbated by the increasing construction along natural drain pathways and forceful divergence of natural drains by urban developers despite strict enforcement of urban planning norms prohibiting such acts. It was observed that major roads have been destroyed due to a high volume of runoff materials flooding down from Buea Town at a high altitude towards Bonduma and Molyko Neighbourhoods typically located at lower altitudes. These help to intensify the speed of the runoff and given the small size of drains beside the roads to accommodate the waters, the water turns to flow directly on the road thus destroying the road infrastructures resulting in potholes that cause accidents. The majority of the respondents said that there were more health issues as indicated by 51.7% of the sampled population while 48.3% claimed that there were more environmental issues. Apart from water-related diseases, significant major health issues obtained during the field investigations were diarrhea, cholera and skin diseases **(**Figure 10).

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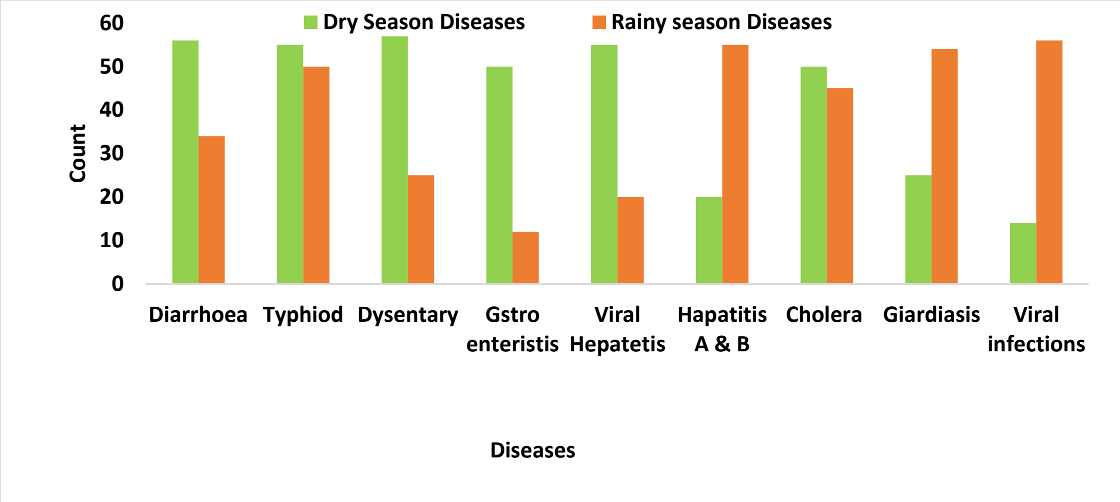

Figure 10: Seasonal Health Issues Resulting from Poor Drainage Systems

Source: General Hospital Statistics (2023)

According to the General Hospital Statistics and discussions with some health experts, the low quality and the depreciation of most drainage systems within Buea usually result in the inundation of runoff into nearby surroundings and the creation of stagnant poles of water randomly within the town, there have been fledgling health issues like Diarrhea, Typhoid, Dysentery, Viral Hepatitis and Cholera occurring mostly in the dry seasons while Hepatitis A and B, Giardiasis, Viral Infections and cholera also occur more during the rainy season. Most of these health issues exist in quarters such as Mile 17, Old Police Station in Molyko and around the General Hospital entrance where run-off frequently diverts into the nearby surroundings. Based on the Pearson Product Moment Correlation on the relationship between causes of poor urban drainage systems and environmental effects, results noted a statistically strong positive significant relation (P value=0.815) between the causes of poor urban drainage facilities and its effects on the environment because correlation values lie between -1 and 1(Negative correlation) and 1 (Positive correlation).

Table 4: Correlation Poor Urban Drainage Facilities and Environmental Consequences

		Major Causes	Environmental challenges
Environmental challenges	Pearson Correlation	0.815**	1
	Sig. (2-tailed)	0.000	
	n	300	300

***. Correlation is significant at the 0.01 level (2-tailed).*

Source: Fieldwork, 2024

Table 4 show that, the coefficient value was 0.815, where correlation is significant at 0.01 level (2-tail). The correlation coefficient value of 0.815 indicated that there was a very strong positive correlation between the causes of poor urban drainage facilities and its effects on the environment because correlation values lie between -1(Negative correlation) and 1 (Positive correlation). Based on the Pearson Product Moment Correlation on the relationship between causes of poor urban drainage systems and the health effects of the inhabitants, results noted a statistically strong positive significant relation (P value=0.911) between the causes of poor urban drainage facilities and its effects on human health because correlation values lie between -1 and 1(Negative correlation) and 1 (Positive correlation).

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Table 5: Correlation between Poor Urban Drainage Facilities and Health Consequences

		Major Causes	Health Effects
Health Effects	Pearson Correlation	0.911**	1
	Sig. (2-tailed)	0.000	
	N	300	300

***. Correlation is significant at the 0.01 level (2-tailed).*

Source: Fieldwork, 2024

From the Results in Table 5, the result of correlation coefficient value was 0.911, where correlation is significant at 0.01 levels (2-tail). The correlation coefficient value of 0.911 indicated that there was a very strong positive correlation between the causes of poor urban drainage facilities and their effects on health because correlation values lie between -1(Negative correlation) and 1 (Positive correlation). Therefore, the continuous disposal of waste materials into the various drainage channels, poor urban planning and the haphazard construction of houses have resulted in the emergence of major environmental and health issues such as soil erosion, pollution as well as typhoid and cholera.

4. DISCUSSIONS

Based on the patterns and causes of poor urban drainage systems, findings revealed that drainage systems within the Buea Urban Area were randomly developed with some areas lacking adequate drainage systems. Further findings revealed that most of the drainage systems were unimproved with many of them clogging and without culverts which have acted as a recipe for the inundation of runoff unto the surface and the surroundings. Also, many of the drainage systems were made up of different materials which were of poor quality with some containing merely bare rocks. Such drains are susceptible to cause erosion and ultimate results of which are sedimentation problems in nearby water bodies. These findings were in line with those of Manawi *et al.* (2020) who in assessing the causes of urban floods noted that drainage systems were not well designed and constructed. She also noted that drainage facilities were mostly made up of sub-standard materials which could not resist the pressure exerted on them by the severe runoff caused by torrential rainfall in the area.

Most of the drainage systems were also found to be very narrow in size, too shallow and contained multiple sharp bends. All these have favored the slow evacuation of runoff during torrential rainfall in the Buea Urban Area. Due to this, there have been frequent incidences of flash floods even during periods of short-duration of rainfall in this Urban Area. Also, the fracturing of most of the drainage systems has blocked the way out of runoff to peripheral environments and therefore has brought in many challenges within the urban milieu. Ameen (2016) in assessing the challenges of urbanization in Sylhet City Bangladesh noted that, with population pressure and rampant construction of houses, there was limited space to design well-functioning drainage systems and this had implications on the sizes and the capacity of the drainage facilities. Li *et al.* (2024) in their study on the impact of urbanization on surface runoff and flood prevention strategies in Hezhai, China noted that the increase in the impervious ratio has obvious effects on the total runoff, peak runoff, and runoff coefficient and the reconstruction of ponds and canals has a notable impact on flooding.

Findings also revealed many factors responsible for the poor drainage systems within the Buea Urban Area. These factors are both anthropogenic and physical in their nature. But the most devastating factor amongst these factors as supported by the majority of the sampled population is poor waste disposals in the various drainage systems which is due to population pressure. The unavailability of landfills to contain waste materials within the Buea Urban Area has

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caused many of the urban dwellers to deposit their waste materials into nearby drainage facilities that have blocked them. Also, there have been the haphazard constructions of unauthorized houses which have blocked most of the pathways of runoff within the Buea Municipality especially within quarters in Soppo, Bunduma and Molyko. These findings were in line with the study of Sule (2001) in Nigeria who noted that in most cities like Lagos, Calabar and Ibadan, drainage systems were blocked due to the careless disposal of waste materials by the surged population inhabiting these areas. Adeyinka *et al.* (2008) also noted in their study that the most degraded drainage facilities within major African cities such as Lagos were due to the disposal of waste materials into nearby drainage facilities. Many of these cities have inadequate landfills where tons of waste materials generated by the surged population could be disposing.

The finding revealed equally that, most of the materials used in the construction of these drainage systems are of sub-standard. For instance, along the Bitwingi road (from Molyko right up to the Central Market) there has been evidence of sub-standard materials. As most drains constructed along these pathways have not stayed up to 6 months before developing fractures, during excess rainfall, manifestation through a flood is usually evident around the Molyko Old Police station and the Mile 17 roundabout toward Molyko. As concerns the torrential rainfall, Mowla and Islam (2013) noted in a study in Dhaka highlighted the need for authorities to design most drainage systems taking into consideration the pressure generated by an external force. Also, poor drainage connectivity was another major cause of poor drainage in the Buea Urban Area.

The upper parts of the Buea Urban Area have rough topography with many meandering drainage channels downslope. This has made the construction of the drainage facilities very difficult as there are many points to construct to connect the various merging points of the runoff. Thorough investigations unveiled information that the multitudinous population number in this area, coupled with the absence of a well-engineered landfill where individuals can dispose of their waste materials, have caused most of the population to always dispose of their waste materials along and across most drainage channels, roadside and in nearby streams which has a lot of implications on the environment and the population. This finding was in line with that of Sarwar (2005) who noted in a study that massive population growth which had been experienced along the coastal zones of the Bangladesh City has added more stress on the urban drainage facilities. He noted that most drainage facilities were blocked by waste materials generated from both industrial and domestic activities.

The study also revealed some aspects contributing to the development of poor urban drainage facilities within the study sites. Findings revealed some of these major factors to be; poor technical fitness, government negligence and inadequate funding for the development of these drainage facilities. Still, those in charge of the development of most drainage facilities were found to have limited skills to carry out the task and therefore cannot develop long-lasting drainage systems. Government negligence of policy implementation towards the improvement of the urban drainage facilities has worsened the situation coupled with the absence of a perpetual monitoring system on various drainage systems. These findings were directly related to that of Yinkfu *et al.,* (2023) who examined the implications of human adaptation measures to biophysical constraints on the Eastern slope of Mount Cameroon and noted that the poor development of most urban facilities results from poor technical fitness, inadequate funds as well as government negligence.

Based on the implications and measures to cope with poor urban drainage systems within the Buea Urban Area, results revealed that the leaking, fracturing and ineffectiveness of the

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drainage systems in the Buea Urban Area were found to have severe health challenges on the inhabitants as well as environmental challenges. Detail investigations revealed that most severe health challenges were a result of the incidence of flood and they were mostly waterborne diseases in nature such as cholera, diarrhea, typhoid and dysentery. Areas with dilapidated and warned-out drainage facilities, there is always the inundation of runoff on the surface and into the various surroundings like the Soppo, Mile 17 round-about and Molyko around the old Police station were allergic to the afore-mentioned water diseases. These findings are true with that of Mark *et a*l. (2001) who investigated the effects of poor drainage facilities and noted that the challenges of flooding were not new but they were more cases of environmental and health hazards such as soil erosion and waterborne diseases respectively, which were multiplying each day as urban drainage facilities were warning out. It is however to be noted that the inundated water debt within some parts of this city was approximately 50-70cm.

Furthermore, during the study, it was also noted that there were serious environmental issues linked to poor urban drainage systems within the Buea Urban Area. Poor drainage systems which were evidenced by the frequent incidence of floods had the resulting consequences on the nearby streams through pollution, soil erosion, mudflow and the spread of debris along the main road and the pedestrian ways. Chemical waste materials from nearby clinics, pharmacies and hospitals were found in some nearby streams used by the population such as that of Ndongo and Muea Rivers. Most of the top soils within areas close the main roads where urban horticulture and viticulture were being practiced were found to be carried away by runoff inundating from depreciated drainage systems. These results corresponded to that of Chiaga *et al.* (2019) who in assessing the challenges of water supply and the way forward in the Buea Urban Area noted that reliable streams were frequently contaminated due to the runoff water that usually emerges from the dilapidated urban drainage systems.

Taking into consideration how supportive and promising the Buea Urban Area seems to be to its inhabitants as confirmed by majority of the sampled population, results from discussions with focused groups, interviews, interrogations and questionnaires revealed that, strict roles, effective urban planning, waste management schemes, strict monitoring of the drainage systems and the provision of funds by the government toward the improvement of urban drainage systems be done in order to sustain urban drainage facilities. Ashley *et al.*, (2008) noted that to ensure efficient and effective urban drainage systems stakeholders should ensure infrastructural upgrading, employment of technical staff, and the provision of funds in addition to transparency and monitoring of the systems.

5. CONCLUSIONS

The rapid growth of the Buea Urban Area, characterized by increasing population, infrastructural development, and economic activity, underscores the critical importance of well-structured and high-quality drainage systems for urban sustainability. The current unsatisfactory state of drainage infrastructure (85% rate), marked by poor development, uneven distribution, and widespread dilapidation, is demonstrably undermining the well-being of inhabitants and the integrity of the physical environment. The significant financial burdens incurred by individuals due to recurrent flood damage, coupled with frequent accidents resulting from damaged drainage facilities which cause severe health and environmental effects, highlight the urgent need for stakeholders' effective intervention. While personal and collective coping mechanisms are employed by residents, their limited and temporary success underlines the systemic nature of the problem, attributable to factors such as government negligence, financial constraints, technical deficiencies, and population pressure.

Considering the manifold challenges linked to poor drainage, including soil erosion, environmental degradation, poor health conditions, unstable development, and an unsustainable environment and the inability of the drainage systems to align with standards norms, it is evident that neglecting the urban drainage systems will have severe long-term consequences on the environment and the rapidly growing denizens. Despite Buea's continued population growth driven by social amenities, favorable climate, educational institutions, and fertile agricultural land, the living standards of its burgeoning population in line with the storm-water infrastructure risked remaining low, exacerbated by escalating health and environmental challenges stemming directly from inadequate drainage systems.

6. RECOMMENDATIONS

In the face of these crisis these, a positive trajectory is still achievable. The reversal and minimization of these detrimental impacts, along with the restoration of sustainable urban drainage systems, hinges on the immediate and adequate actions of the Buea Urban Area authorities. Significant and sustained efforts, aligning with the recommendations outlined, are paramount to address the challenges hampering sustainable urban drainage management and to ensure genuine sustainable urban development for Buea. This requires a concerted and multi-pronged approach encompassing robust government and policy interventions, proactive public awareness and community engagement, strategic infrastructure development, and effective waste management strategies. Only through such comprehensive and diligently implemented measures can Buea safeguard the well-being of its inhabitants and the long-term health of its physical environment.

Government and Policy Interventions

Significant efforts are required from government authorities in the Buea Urban Area to address the challenges hampering sustainable urban drainage management and ensure sustainable urban development. This necessitates the provision of dedicated annual funds for the development and reconstruction of new drainage facilities especially by the Ministry of Urban Development and Housing (MINDHU). Furthermore, authorities including the Ministry of Environment, Nature Protection and Sustainable Development (MINPADD) as well as the Municipal Council of Buea must ensure constant monitoring of the drainage system before, during, and after construction or maintenance. Adequate and good-quality recruitment of technically fit personnel is crucial for the effective development and maintenance of robust drainage systems. Critically, the Council and the MINDHU should rigorously enforce building permit regulations to prevent unauthorized construction, particularly the rampant construction of houses along watercourses and drainage channels. Key defaulters of these measures should be subjected to heavy fines as a means of promoting environmental sustainability and deterring harmful practices.

Public Awareness and Community Engagement

To foster a culture of environmental responsibility and practices, workshops should be organized to educate the public on the importance of environmental sustainability and the impact of their actions on the drainage system. Technical support, such as the donation of trash cans, should be provided by environmental organizations to the public to facilitate the easy and sustainable disposal of waste materials. The careless disposal of waste materials into the drainage systems must be strictly avoided by the Public, and clearly defined penalties should be levied on those who violate this crucial aspect of urban sanitation. Moreover, the population should be actively encouraged and empowered to regularly and thoroughly take responsibility

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for cleaning the various drainage channels within their immediate localities to prevent waste materials from blocking the channels, thereby enhancing overall living conditions.

Infrastructure Development

To effectively manage storm-water and prevent flooding, concerted efforts must be directed towards infrastructure development. This includes widening and expanding existing drainage systems to increase their capacity to handle significant water volumes. Adequate funding and meticulous planning are essential for the successful implementation of these infrastructure upgrades. Furthermore, the use of durable and high-quality construction materials should be prioritized to ensure the longevity and effectiveness of the drainage facilities, reducing the need for frequent repairs and reconstruction.

Waste Management Strategies

Effective waste management strategies are integral to maintaining a functional urban drainage system. Different methods of waste disposal, beyond simply using the drainage channels, should be actively encouraged, and funded, and their implementation fostered. HYSACAM (or the relevant waste management body) should create new and adequately managed landfills for the proper deposition of collected waste. Concurrently, there needs to be more intensive sensitization of dwellers to respect urban laws and adopt responsible waste disposal practices to promote overall urban sustainability and environmental quality.

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