Research Article

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Environmental Consequences of Unregulated Sanitation Practices in Urban Watercourse Neighborhoods in Sub-Saharan Africa: A Case Study of Yaoundé City Cameroon

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Abstract

Rapid urbanization and population growth in developing countries are driving people to settle in high-risk areas. Indeed, because of the very high cost of land in city centers, people prefer to settle in non-Aeficandi areas sometimes. Consequently, this choice results in inadequate sanitation due to the lack of access to basic services, and in turn to poor waste management. The residents of Yaoundé, particularly those living in precarious neighborhoods near urban watercourses, face the challenges of unregulated management of both liquid and solid waste. This situation contributes to the degradation of the urban landscape. The aim of this study is to assess people's sanitation practices concerning both solid and liquid waste management, examining their impacts on the living environment and susceptibility to environmental diseases. The research methodology encompasses direct field observations, comprehensive documentary research, and surveys of 250 households within the study area. The findings show that people mainly deposited their solid waste in the watercourses that run through their locality and wastewater in the yard or on street. Most latrines are built in proximity to watercourses with holes for the overflow of faeces. As consequences of these practices, the results showed hydrosystem pollution, environmental degradation marked by flooding, and high vulnerability to diseases such as malaria, diarrhea, typhoid fever, respiratory infections and cholera.

Keyswords: *Waste management, Pollution, Urban watercourse, Environmental degradation, Sanitation*

1. Introduction

In Africa, particularly in developing countries, the continuous rise in urban population is significantly impacting the environment. The population growth in major cities is leading to a more densely populated urban landscape, directly contributing to uncontrolled urban sprawl. According to Rhouma *et al.* (2019), the global population, currently at 7.2 billion, is projected to reach 8.1 billion by 2025 and 9.6 billion by 2050. This rapid demographic growth and uncontrolled urbanization in the major cities result in adverse health conditions through the production of massive volumes of waste. The majority of African cities in the sub-Sahara are experiencing high demographic and spatial growth, which is leading to an increase in the complexity of household waste management (Ngnikam & Tanawa, 2006a).

As outlined in the 2016 report by the World Health Organization (WHO, 2016), sanitation encompasses the provision of facilities and services for the safe disposal of urine and feces, including the secured management of excreta through activities such as removal, disposal, transport, and reuse of waste. Nevertheless, in developing countries, waste management practices often diverge from these principles. Thus, the United Nations Development Program (UNDP) stated that sub-Saharan Africa is trailing behind the global progress in achieving the Millennium Development Goals (MDGs), especially concerning sanitation. The report highlights that in 2011, while 90% of the population in North Africa had improved access to sanitation, only 30% of the population in sub-Saharan Africa did (WHO, 2013). Indeed, the settlement of populations in so-called non-Aeficandi has resulted in the absence of basic services. Consequently, there is a proliferation of unregulated disposal of household waste, wastewater, and excreta along streets, public spaces, watercourses, and in close proximity to people. These practices yield detrimental effects on human health, soil quality, and natural resources, with severe consequences for aquatic environments. Poor hygiene conditions in many urban areas has a lasting impact on life quality and human well-being, providing favorable conditions for the development of pathogens responsible for numerous vector-borne diseases (Doumont & Libion, 2006). Surface waters are affected by inappropriate sanitation practices, particularly when communities living near aquatic ecosystems use them to dispose their waste (Kodjo *et al.,* 2019; Koffi, 2009). Thus, the environment and health conditions in urban landscape of developing countries are threatened (Hiligsmann *et al.,* 2002). To this end, the lack of sanitation in many African cities is leading to landscapes where multiple and varied interactions between health and environment are occurring (Sy Piermay et al., 2011). This insalubrity leads to the proliferation of diseases such as respiratory infections, malaria, cholera, dermatoses, typhoid fever, etc. (Prüss-Üstün *et al.*, 2008).

About 3.8 million Cameroonians, lack access to adequate sanitation (Katte *et al.*, 2003). Yaoundé, the political capital city of Cameroon, is not excluded from unhealthy living conditions. The city is currently undergoing a rapid demographic expansion, with an estimated population of nearly 4 million (Ndam et al., 2023). According to the Yaoundé city council (CUY) the urban landscape is densely populated, including informal settlements that encompass 60% of the city's total area and accommodate almost 70% of its population (CUY, 2023). In these informal settlements, which include wetlands intended for the drainage of excess water, we are witnessing an increase of illegal open dumps. The management of these illegal dumps is becoming more and more challenging. Because of different mentalities and lack of basic services, people living in precarious housing areas are managing their waste independently. They either incinerate or bury them, dumping them in gullies, streets or watercourses, resulting in the so-called environmental diseases proliferation. In front of this scenario, the government has established regulations governing the household waste management, public health, hygiene, and environmental concerns. Despite these regulations, there is a prevailing indifference among the population towards the household waste management issues. This indifference has contributed significantly to the escalation of both solid and liquid waste production in urban areas, consequently leading to environmental degradation. Yaoundé, known as the city of seven hills, has also undergone quite spectacular urban development (Djatcheu, 2022). The rugged terrain of the city poses difficulties for collection services, notably for the Hygiene and

Sanitation in Cameroon company (HYSACAM), which can only manage to collect 4,000 tonnes of waste daily out of 16,000 tonnes produced. As a result of these inadequate collection services, the urban landscape is littered with heaps of waste and unauthorised dumps, due to the rejection of people living in these areas, who resort to various methods to dispose of their waste. This prompts the question of how people living in risk areas, particularly those near watercourses, manage both their solid and liquid waste. In addition, we questioned ourselves about the methodologies used by the residents to dispose their waste and the subsequent environmental and health issues. The objective is to scrutinize the waste management practices of these populations and shed light on the impact of such practices on their living environment and health conditions.

2. Literature Review

2.1 Sanitation in Developing Countries

Access to sanitation is a top priority for developing countries. Unfortunately, due to inadequate funding and a lack of mobilization among key stakeholders in the sector, the challenge of addressing sanitation issues persists. Sanitation plays a crucial role in safeguarding both human health and the environment, as well as contributing significantly to the achievement of the Sustainable Development Goals (SDGs). Nevertheless, over a billion people still lack access to drinking water, and 2.6 billion lack basic sanitation. Poor sanitation rates, especially in developing countries, contributes to a rise in environmental pollution, disease prevalence and public health issues (Katukiza et al., 2012).

A United Nations report stated that only 10% of wastewater is currently treated before returning to the natural environment in Africa, 14% in Latin America, 25% in Asia, and 66% in Europe (pS-Eau, 2006). Developing countries predominantly rely on individual sanitation services, leading to environmental pollution through dumping in natural habitats. In urban development policies in southern countries, where funding prioritizes drinking water over sanitation, the UN reported that the number of people lacking sanitation access is nearly double those without drinking water (UN, 2005). The Economic Commission for Africa (ECA) states that Africa faces a constant challenge in improving access to sanitation facilities. The sanitation issues can be attributed to several factors such as a non-compliance with existing legislative and institutional frameworks, a rise in poverty level, the challenge for governments to deliver consistent urban management service, an inadequate sanitation facility, disparities in budget allocations, an absence of wastewater treatment, a low health coverage rate for sanitation workers, and an inadequate urbanization policy.

In Cameroon for instance, liquid sanitation situation is escalating into a critical concern due to rural migration, leading to the establishment of settlements in areas without basic services (Ngnikam et al., 1997). This lack of basic services exacerbates fecal-oral diseases, viewed as a direct outcome of the lack of sanitary facilities, promoting a rapid spread of intestinal parasites. (Mills et al., 2018). In addition, the inadequate disposal of waste (both solid and liquid) in streets and watercourses fosters the proliferation of disease vectors, including mosquitoes, cockroaches, and mice, along with emitting foul odors (Mwaguni, 2002). Furthermore, it's reported that waste collection points also serve as breeding grounds for resistant parasites (Nkengazong et al., 2021). All these issues are noticeable in Yaoundé, posing flood risks, and leading the country's decision-makers to initiate the Yaoundé Sanitation Program (PADY).

Yaoundé Sanitation Program, currently in its third phase, was initiated to tackle the sanitation challenges in the city. The primary goal of this program is to establish effective rainwater drainage for Yaoundé and mitigate the risk of flooding. In the initial phase of the program, funding facilitated the drainage of 3.5 km out of the total 9.4 km of the main Mfoundi River, while the second phase addressed the remaining section of the river (MINEE, 2011).

2.2 Waste Management in Yaoundé

In developing countries, waste production continues to rise with urbanization and economic development. Daily waste production per individual worldwide is estimated between 0.4 and 1.1 kg (Chalmin and Gaillochet, 2009; Proparco, 2012;). Sanitation and waste disposal levels in developing countries are critical. In Cameroon, particularly in Yaoundé city, the challenges of waste management are exacerbated by the rapid population growth. With nearly 4 million inhabitants, it has been reported that Yaoundé contributes to the 12.6 million annual deaths caused by unsanitary conditions (WHO, 2002). Equally, inadequate financial resources, low levels of enforcement of regulations and poor governance often lead to poor solid waste management services (Manga et al., 2008)

Several authors (Tini, 2003; Ndam et al., 2023) argued that waste management in Yaoundé contradicts sustainable development principles. Waste can be found everywhere throughout the city, which highlights the difficulties of its management (Ngnikam and Tanawa, 2006). However, in Cameroon, waste management framework is closely linked to sanitation and aligns with international standards. The National Waste Management Strategy oversees waste management in Cameroon, and like other countries, Cameroon has ratified various waste management conventions. From the Vienna Convention for the Protection of the Ozone Layer ratified on August 30, 1989, to the Kyoto Protocol ratified on August 28, 2002, and additional laws, decrees, and orders are signed by the state of Cameroon. Various institutions, including government agencies and private stakeholders are in charge of waste management in the country. The legislative framework and institutional structure in Cameroon are designed to facilitate effective waste management and enhance sanitation conditions for the protection of populations. HYSACAM, the main private company in charge for collecting, transporting, and management of household solid waste in Cameroon. Situated in both Douala and Yaoundé, it also oversees waste management for an additional 12 towns. (Parrot et al., 2009 ; Kam Yogo & Ruppel, 2018).

3. Materials and Methods

3.1 Study area

Located around 250 km from the coastal area, Yaoundé city is situated between 3˚ 52'' latitude and 16˚ 04'' longitude. Founded in 1889 by Germans, Yaoundé is located in the Central region of Cameroon. Known as the city of seven hills, because it is surrounded by seven mountains, with the highest of which are located on the west and north-west sides: Mount Mbankolo (1,200 m), Mount Fébé (1,073 m) and Mount Akokndoué (967 m). The city lies within the catchment area of the Mfoundi river and is influenced by equatorial climate with 2 distinct seasons (two dry and two rainy seasons). Yaoundé city has more than a million inhabitants spread across the various catchment areas, who engage in a variety of activities that can sometimes damage the ecological integrity of the river or even cause the destruction of some tributaries. Following various surveys carried out in the vicinity of the city of Yaoundé, four districts out seven were chosen for this study. These included Etoudi and Essos in the north, and Biyem-Assi, Mendong and Nsimeyong in the west.

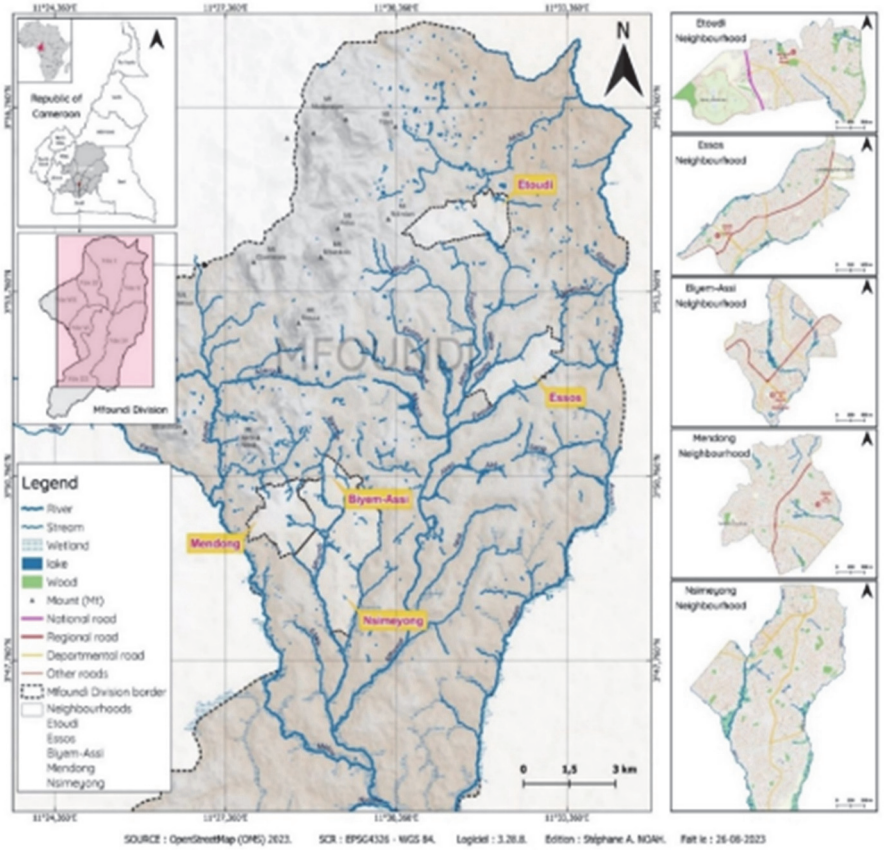

Figure 1. Map of the study area

3.2 Data collection and processing protocol

The aim of this study is to access people's behaviour towards household waste management and to highlight the related environmental and health impacts. Literature review, direct observations, and interviews with households living near watercourses were performed. A total of 250 households selected from four districts were interviewed (Etoudi in the Yaoundé I district, Nsimeyong in the Yaoundé III, Essos in the Yaoundé V, Biyem-Assi and Mendong in the Yaoundé VI). Districts surveyed in the framework of this study were selected based on the presence of watercourse, high population and housing density, the prevalence of unregulated waste dumps, and the socio-economic status of households. The questionnaire used was designed to collect the following information: identification of the head of household, management of both solid and liquid waste, waste management behaviour of the household, liquid and solid waste disposal method, health issues faced living near watercourses and strategies for improving and managing waste dumped in watercourses. The household survey data were processed using SPSS version 20.0, and the graphs and tables were produced using the Excel spreadsheet. Chi-square tests were performed to compare the dependence of the variables using SPSS software.

4. Results

4.1 Degradation of the living environment and pollution of surface water

Throughout the study period, numerous piles of household waste and small reservoirs of wastewater (figure 2) were consistently observed within the catchment areas of the watercourses, where they are mainly discharged. Most of the waste consists of paper, empty plastic bottles and various food scraps. In Étoudi, dumps along the Ako'o watercourse collect effluent from both the Étoudi industrial abattoir and households. In Biyem-Assi and Nsimeyong, the Biyémé watercourse serves as a dumping site for household waste. Similarly, in Essos, the Ebogo watercourse receives domestic effluent from nearby households, while in Mendong, the Mefou watercourse fulfils similar role.

Figure 2: A and B: Plastic waste and wastewater reservoir in the Biyémé watercourse (Biyem-Assi and Nsimeyong area), C and D: Household waste in the Ako'o stream (Etoudi area), E: Household waste dumped in the Essos area, and F: Empty plastic bottles along the Mefou stream (Mendong area).

4.2 Household waste behaviour

4.2.1 Socio-economic characteristics of households and their influence

The study shows that women are the main actors in household waste management, accounting for 80% of the waste management chain, followed by children (aged between 7 and 12) who are responsible for emptying the bins at locations specified by the parents. Regarding the level of education of household heads, the findings revealed that 26.4% have attended primary school, 52.4% secondary school and 21.2% higher education. The average household size is between five (5) and eight (8) people.

Most of households live in areas, facing challenges in accessing waste collection services, particularly in the Étoudi and Biyem-Assi, both located in flood-prone or low-lying areas. Among

these households, 38.4% have an income ranging from 0 to 50,000 XAF, 42% between 50,000 to 100,000 XAF, and 19.6% earn between 150,000 and 300,000 XAF. Additionally, most households are involved in commercial activities.

4.3 Households' behaviour regarding waste management

4.3.1 Presence of bins in households

The survey conducted across different sites (Table 1) reveal various household waste management practices. Specifically, in the Étoudi, Essos, Nsimeyong, Biyem-Assi, and Mendong areas, 84%, 100%, 100%, 78%, and 96% of households, respectively, possess bins in their house, indicating good waste management practice. However, it's worth noting that these bins consist of small plastic bags, small baskets, old buckets, or basins made of broken raffia, indicating limitations in their capacity to accommodate large quantities of waste.

Table 1: Distribution of bins in the different sites

	Etoudi		Essos		Nsimeyong		Biyem Assi		Mendong		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Yes	42	84%	50	100%	50	100%	39	78%	48	96%	229	92%
No	8	12%	0	0%	0	0	11	22%	2	4%	21	8,4

4.3.2 Waste disposal site

The results show that in the Étoudi and Mendong sites, 90% and 60% of households respectively dump their waste in the watercourses (table 2). Because, most of these households are settled in areas with difficult access to collection services and do not have refuse bins. Overall, 12% of households dump their waste in gullies, 46.4% in watercourses, 14% in refuse bins, 7.2% in crop fields, 8.8% in HYSACAM collection vehicles, 5.6% by incineration and 6% in watercourses or gullies.

Table 2: Distribution of waste disposal sites at the different locations

	Etoudi		Essos		Nsimeyong		Biyem Assi		Mendong		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Gullies	0	0	9	18	8	16	3	6	10	20	30	12
Watercourses	45	90	15	30	15	30	19	22	30	60	116	46.40
Refuse bins	0	0	13	26	9	18	3	26	0	0	35	14
Crop fields	3	6	2	4	0	0	12	16	5	10	18	7.20
HYSACAM vehicles	0	0	5	10	15	30	0	0	0	0	22	8.80
Watercourses or gullies	2	4	5	10	1	2	5	10	2	10	15	6
Incineration	0	0	1	2	2	4	8	16	3	6	14	5.60

4.3.3 Relationship between level of education and location of waste disposal

Households with primary education mainly dispose of their waste in watercourses and refuse bins (Figure 3). While households with secondary education dispose of their waste in watercourses and gullies. Households with higher education dispose of their waste in HYSACAM collection vehicles or incinerate it. The chi-2 test shows that the level of education has an influence on where waste is disposed of (p=0.000). Cramer's Phi (0.945) and V (0.668) values show that these two parameters are strongly correlated (df = 12).

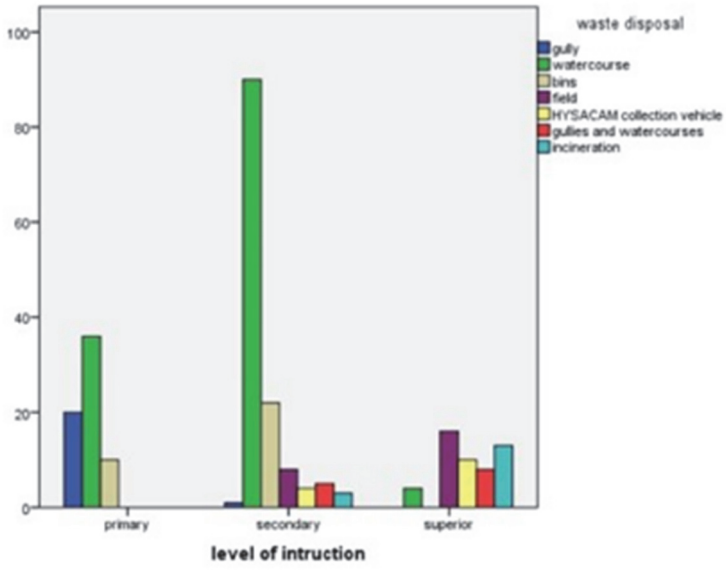

Figure 3: Relationship between level of education and location of waste disposal.

4.3.4 Distance of refuse bins from households

In the Étoudi and Mendong areas, 100% of households stated that there were no refuse bins near their area, while in the Essos area, 20%, 28% and 42% respectively stated that refuse bins were located at 100, 300 and more than 500 metres from their households (Table 3). In the Biyem-Assi area, 6% stated that the refuse bins were at 500 meters away and 94% said that there were no bins in their area. In the Nsimeyong area, 10%, 30% and 46% reported that the refuse bins were located 100, 300 and more than 500 metres away respectively, while 14% mentioned that there were no bins in their area. Overall, in regard to household location, only 6% of households had refuse bins located within less than 100 meters, while 11.6% had them within 300 meters, and 20.6% had bins situated more than 500 meters away. A significant majority, constituting 61.6% of households, had no refuse bins in close proximity.

Table 3: Distance to refuse bins by household location

	Etoudi		Essos		Biyem-Assi		Mendong		Nsimeyong		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Less than 100m	0	0	10	20%	0	0	0	0	5	10%	15	6%
300m	0	0	14	28%	0	0	0	0	15	30%	29	11,60%
More than 500m	0	0	26	52%	3	6%	0	0	23	46%	52	20,60%
No bin	50	100%	0	0%	47	94%	50	100%	7	14%	154	61,60%

4.3.5 Relationship between distance of households from waste disposal site

Table 4 indicates that the usage of refuse bins as waste disposal place diminishes as households are located further away from them.

Table 4: Distance of refuse bins from place of residence and place of refuse disposal

Cross-tabulated distance of refuse bins from place of residence * place of refuse disposal										
			Waste disposal site						Total	
			Gutter	Watercourses	Refuse bins	Field	HYSACAM collection vehicle	Rills and watercourses	Incineration	
Distance of refuse bins from place of residence	Less than 100m	Workforce	5	0	20	0	0	0	0	25
		% included in waste disposal site	23.8	0.0	62.5	0.0	0.0	0.0	0.0	10.0
	300m	Workforce	3	26	0	0	0	0	0	29
		% included in waste disposal site	14.3	20.0	0.0	0.0	0.0	0.0	0.0	11.6
	More than 500m	Workforce	3	5	12	0	14	5	1	40
		% included in waste disposal site	14.3	3.8	37.5	0.0	100.0	38.5	6.3	16.0
	No bins	Workforce	10	99	0	24	0	8	15	156
		% included in waste disposal site	47.6	76.2	0.0	100.0	0.0	61.5	93.8	62.4

The chi-square test shows that distance of households from refuse bins significantly influences the disposal location of waste (Phi value = 1.029; V= 0.594; p=0.000).

4.4 Wastewater disposal

In the Étoudi, Essos, and Mendong areas, 44%, 40%, and 54% of households, respectively, release wastewater in their yard (Table 5). Conversely, in Nsimeyong, 40% of households discharge wastewater into gullies, while in the Biyem-Assi area, 50% release it into watercourses. Respondents who directly discharge wastewater into gullies and watercourses mention doing so when the wastewater contain particles and is likely to block the drainage of their house. Overall, 36.8% of households discharge wastewater onto their yards and streets, 27.2% into watercourses, 20% into gullies, and 16% into house drainage.

Table 5: Distribution of wastewater discharging sites

	Etoudi		Essos		Nsimeyong		Biyem Assi		Mendong		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Yard and street	22	44%	20	40%	5	10%	18	36%	27	54%	92	36,8%
Watercourse	15	30%	8	16%	15	30%	25	50%	5	10%	68	27,2%
Gullies	8	16%	12	24%	20	40%	2	4%	8	16%	50	20%
House drainage	5	10%	10	20%	10	20%	5	10%	10	20%	40	16%

4.4.1 Presence of latrines in households and method of excreta disposal

Households situated upstream from the watercourse have constructed latrines in the river banks equipped with septic tanks, fitted pipes to directly discharge black water into the watercourse and have made a hole for the overflow of faeces. Among the identified latrine types, 64% were traditional, while 36% were modern.

Figure 4: A, B and D: Latrines constructed in the watercourses with a hole for the overflow of faeces at Biyem-Assi and Etoudi; C: Black water evacuation pipe at Etoudi.

4.5 Waste collection service

4.5.1 Existence of pre-collection services

Households in Étoudi, Biyem-Assi and Mendong are not aware of any waste pre-collection services, whereas in Essos and Nsimeyong, some households reported to be aware of pre-collection services but do not use them (table 6). According to these households, there is a fee for the services, and they lack the financial means to cover the costs.

Table 6: Level of awareness of pre-collection services in different sites

	Etoudi		Essos		Nsimeyong		Biyem Assi		Mendong		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Yes	0	0	5	10	37	74	0	0	0	0	42	16.8
No	50	100%	45	40	13	26	50	100	50	100	208	83.2

4.6 Indicators and causes of environmental degradation

The most frequently cited indicators of environmental degradation are: air pollution, insalubrity, house pests and water pollution. In the Étoudi area, the main indicators reported were air pollution, house pests, insalubrity and pollution of the river Ako'o, all linked to urbanisation, high population growth, poverty and poor waste management. The presence of the industrial abattoir, which discharge directly its waste into the Ako'o stream, is one of the main causes of environmental degradation in this area. In the Essos area, the most frequently cited indicators are insalubrity due to the household waste dumping practice (68.50%) and water pollution in the Ebogo river (75%), leading to an increase in mosquito breeding grounds. In the Biyem-Assi, the main indicators of environmental degradation perceived by households were insalubrity and water pollution in the Biyémé watercourse (82% and 92% respectively). In the Mendong, the main indicators of

environmental degradation are water pollution (98.6%) and insalubrity (75.15%), caused by the dumping of household waste in the Mefou River. In the Nsimeyong area, the indicators are insalubrity and water pollution. Field observations reveal that watercourses along the catchment areas are littered with household waste, resulting in the stagnation of black water a potential breeding ground for harmful insects. Additionally, the vegetation in these areas is overwhelmed with waste, and buildings are directly constructed on the banks of the watercourses (Figure 5).

Figure 5 : Images of urban environment in the Etoudi area

4.7 Consequences of environmental degradation on people's health

Inadequate waste management, lack of sanitation facilities, poor sanitation practices, and the inaccessibility of waste collection and latrine emptying services are the main factors contributing to various diseases, such as malaria, typhoid fever, diarrheal diseases, respiratory infections, and skin diseases. The population is notably vulnerable to malaria, accounting for 85.6% of the overall rate, followed by diarrheal diseases (67.2%), typhoid fever (60%), and cholera (12.8%) (Table 7). These diseases are more frequent especially in the Biyem-Assi and Étoudi areas, due to the insalubrity conditions prevailing there.

Table 7: Disease prevalence rates in Yaoundé households

	Malaria		**Typhoid fever**		**Diarrhoeal diseases**		**Respiratory infections**		**Dermatoses**		**Cholera**	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Nsimeyong	41	9	29	21	33	17	20	30	5	45	3	47
%	82	18	58	42	66	34	40	60	10	90	6	94
Essos	48	2	33	17	39	11	15	35	10	40	0	50
%	96	4	66	34	78	22	30	70	20	80	0	100
Mendong	25	25	17	33	10	40	3	47	2	48	0	50
%	50	50	34	66	20	80	6	94	4	96	0	100
Biyem-Assi	50	0	36	14	48	12	29	21	16	34	18	32
%	100	0	72	28	96	24	58	41	32	68	36	64
Etoudi	50	0	35	15	38	12	39	11	15	35	11	39
%	100	0	70	30	76	78	22	30	30	70	22	78

In addition to the aforementioned challenges, flooding poses a significant risk to people living in various area (Figure 6). Unregulated waste dumping along watercourses, the connection of pipes to facilitate black water drainage systems into the watercourses, and construction along the river banks

contribute to the flooding risk of these areas during heavy rainfall. Direct field observations confirm that these floods have resulted in the loss of numerous properties and houses, particularly in the Biyem-Assi area, where many households have had to abandon their residences.

Figure 6: Abandoned residences due to flooding (A, B) at Biyem-Assi

5. Discussion

Household responses indicate that a higher level of education serves as a determinant factor for effective waste management. The level of insalubrity observed in the study area can be explained by a combination of factors, including the relatively low level of education and the average household income of the household. The presence or absence of refuse bins, their distant location from households and lack of information about the pre-collection services would appear to be at the root causes of the behaviour of people who, in order to dispose their waste, opt for unregulated places and methods such as watercourse, gullies, crop fields and incineration. In this regard, Sotamenou (2005) states that the situation is notably critical in African cities due to the high population density, often characterized by low levels of education and awareness. Consequently, a significant amount of waste is dumped in watercourses and on streets. Similarly, Ngnikam and Tanawa (2006) highlighted that, due to the distant location of refuse bins in the collection circuits, a substantial proportion of the population (60%) resorts to dumping their waste in shallows and watercourses. This issue is particularly marked in the Nsimeyong and Essos areas, where despite the presence of refuse bins, people continue to dump their waste in the surrounding watercourses and crop fields. Our findings are similar to those obtained by Kuitcha et al. (2008) in the Yaoundé where rivers were the major waste disposal site in Nkoleton (60.5%) and Etoa-meki (50%). Indeed, there is a lack of interest and uncivil behaviour of households the refuse bins and waste collection services even if they are in close proximity to people. Furthermore, in addition to households' behaviour, the role played by the urban community, particularly through HYSACAM, is also insufficient. In fact, the densely populated informal settlements remain underserved by the waste collection company. Regrettably, the company has not undertaken any initiatives to assist the people living in these areas, many of which are situated in the shallows, in improving their waste management practices. Consequently, residents in informal settlements feel neglected and have developed their own methods of disposing of waste openly, leading to insalubrity with piles of waste and degraded living conditions as an immediate and primary effect. Tchuikoua (2010) also made similar observations regarding the inadequacy of HYSACAM's collection services for household waste management in isolated areas of Douala. As noted by Ntoban and Fogwe (2019), Yaoundé, like many cities in Cameroon, collects only 20% of its waste daily, despite established policies and responsibilities assigned to municipal and city council

authorities in accordance with the provisions of decentralisation laws in Cameroon. Consequently, huge mounds of waste can be observed throughout the city. The evacuation method for wastewater and the type of latrine present in various households are important factors that highlight the shortcomings in the sanitation system within the study area. Wastewater management in these so-called low-lying areas is individual due to the lack of equipment, basic services and adequate framework. In this study, 36.8% of households discharged wastewater into their yards and on the street, 27.2% into watercourses when they contain particles. According to Kambiré & Assi (2021) wastewater management remains individual due to the absence or scarcity of sanitation facilities. In the same line, Nguendo et al. (2008) showed that, apart from the collective sewerage system at planned popular sites, individual sanitation is still the main method of disposing of faecal matter in the city of Yaoundé. The presence of watercourses in the various neighbourhoods means that they become drainage points and the final receptacle for black water from the surrounding households. This results into the contamination and pollution of the rivers, with harmful impacts for the environment and the health in the surrounding communities. Tcheunteu et al. (2013). In the absence of a waste collection system, watercourses become the preferred disposal site for a significant portion of the population to discard solid household waste or empty cesspits. The dumping of household waste and black water along watercourses leads to stagnant water, which is a factor in the proliferation of various disease vectors, particularly mosquitoes that carry malaria, rats and cockroaches. As a result, Taweesan et al., (2015); Djourdebbé, (2019) ; Nzouebet et al., (2019) and stated Poor sanitation conditions constitute environmental risks that create breeding grounds for disease vectors. Similarly, Wethé *et al.,* (2003) revealed in the study conducted in Yaoundé highlighted that the health challenges faced by the population stem from the proliferation of disease vector breeding grounds, accompanied by unpleasant odors and the presence of wastewater, ultimately resulting in the contamination of water, soil, and food. Hence, the existing condition of the surveyed areas in the city of Yaoundé, characterized by the coexistence of waste and the population, implies potential repercussions on the health of the residents. Household surveys unveiled instances of potential exposure to malaria (85.6%), diarrhea (67.2%), typhoid fever (60%), respiratory infections (42.4%), dermatoses (19.2%), and cholera (15.2%). These occurrences are likely attributed to the prevailing insalubrity conditions in the various areas. Based on these surveys, the areas of Étoudi and Biyem-Assi appear to face a higher susceptibility to potential risks of these diseases due to their living environment. The prevalence of these diseases is a consequence of the biological pollution of water, presenting significant public health concerns (Kebiche et al., 1999). Similar findings were noted by Ndjama et al. (2008) in the city of Douala where populations faces related challenges. Thus, the surge in diseases within urban settings is attributed to human activities, particularly the inadequate management of household waste, causing adverse environmental effects (Ménard, 2011). It has been demonstrated that insufficient waste management can impact the quality of both subsoil waters (John and Rose, 2005) and surface waters (Djuikom et al., 2006). According to Coulibaly et al. (2018) the hygiene of the living environment significantly influences the occurrence of environmental diseases. The author underscores that the proximity of household waste to homes and the accumulation of run-off and domestic wastewater in neighborhood streets, exacerbated by the absence of sanitation infrastructure like gutters and septic tanks, create breeding grounds for mosquitoes and other pathogens. These environmental conditions are known to contribute to the spread of diseases such as malaria, diarrhea, and typhoid fever. The lack of adequate sanitation therefore has a direct impact on the health of the surrounding population. water-borne diseases in tropical countries are essentially due to poor living conditions and hygiene (Sy et al. 2011). The WHO states that the domestic environment in underdeveloped countries leads to the spread of malaria and numerous water-borne diseases through the stagnation of domestic waste water and rainwater. These health risks are linked to insalubrity conditions resulting from poor waste management in urban areas (Curtis and Cairncross, 2003). According to Bemmo et al. (1998) Households on the banks of watercourses are more exposed to health risks. Insufficient waste management in diverse areas is believed to be the cause of flooding, especially during the rainy season, leading some residents to

permanently leave their homes. The build-up of waste along watercourses in this timeframe obstructs the regular flow, resulting in overflow. Djatcheu, (2018) asserts that the blockage of low-lying areas, resulting from the deposition of solid waste such as household rubbish, bottles, plastics, and vehicle carcasses in existing rivers, stands as a significant contributor to flooding in areas with vulnerable housing. Poor waste management contributed to flood, water pollution and degradation of urban landscape (Henry et al., 2006). Douglas et al. (2008) have shown that the flooding observed in African cities is due to the obstruction of drainage channels by urban waste and, in particular, the construction of houses closes to drainage networks.

6. Conclusion

The people living in the various areas are the main cause of the deterioration of their living environment as a result of insalubrity. In the absence of an adequate sanitation system, people dump their waste in places that are easily accessible to them, and more specifically in the watercourses that run through their localities. The compromised sanitation conditions in the areas of the city of Yaoundé are rendering the populations of these areas vulnerable, resulting in the emergence of various diseases. Consequently, there is an urgent need to initiate awareness programs focusing on hygiene, sanitation practices, and solid waste collection, particularly in areas inaccessible to regular collection services. The goal is to mitigate insalubrity conditions in neighborhoods and foster a circular economy through waste processing. The proposed actions encompass heightening public awareness about hygiene and sanitation practices, along with establishing pre-collection and waste collection services in vulnerable housing areas.

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References

Bemmo, N., Njine, T., Nola, M., & Ngamga, G. (1998). Impact des différents dispositifs d'évacuation des eaux de vidange, des eaux usées, des excrétas humains et des déchets solides sur les ressources en eau, la santé et l'environnement : Cas des quartiers denses à habitats spontanés et des zones périurbaines de Yaoundé-Cameroun. *Proposition de systèmes appropriés tenant compte des contraintes locales. Rapport de recherche*, 160.

CHALMIN, P., & GAILLOCHET, C. N. (2009). *Du rare à l'infini—Panorama mondial des déchets* (Lavoisier). https://www.lavoisier.fr/livre/environnement/du-rare-a-l-infini-panorama-mondial-des-dechets-2009/chalmin/descriptif_2098947

Coulibaly, M., Tuo, P., & Aké-Awomon, D. F. (2018). Insalubrité et maladies infectieuses dans les quartiers précaires de Yopougon Gesco-Attié : Cas de Judé, Mondon et Ayakro (Abidjan, Côte d'Ivoire). *Revue Espace, Territoires, Sociétés et Santé*, *1*, 46-65.

Curtis, V., & Cairncross, S. (2003). Effect of washing hands with soap on diarrhoea risk in the community: A systematic review. *The Lancet infectious diseases*, *3*(5), 275-281.

CUY. (2023). Géographie de la Ville. *Communauté Urbaine de Yaoundé*. https://yaounde.cm/?page_id=1901

Djatcheu. (2022). Citadins pauvres et habitat précaire à yaoundé : De l'auto-construction à l'auto-viabilisation poor townmen and precarious habitat in yaounde: from self-construction to self-viabilization. *Revue de la ville et de l'environnement de l'UC3*, *vol.02*(02), 15.

Djatcheu Martin Luther. (2018). Fabriquer la ville avec les moyens du bord : L'habitat précaire à Yaoundé (Cameroun). *Géoconfluence*, 1-13.

Djourdebbé, F. B. (2019). Santé Environnementale dans les Villes en Afrique Subsaharienne : Problèmes Conceptuels et Méthodologiques. *European Scientific Journal ESJ*, *15*(9). https://doi.org/10.19044/esj.2019.v15n9p192

Djuikom, E., Njine, T., Nola, M., Sikati, V., & Jugnia, L. B. (2006). Microbiological water quality of the Mfoundi River watershed at Yaoundé, Cameroon, as inferred from indicator bacteria of fecal contamination. *Environmental Monitoring and assessment*, *122*, 171-183.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., McLean, L., & Campbell, J. (2008). Unjust waters: Climate change, flooding and the urban poor in Africa. *Environment and urbanization*, *20*(1), 187-205.

Doumont, D., & Libion, F. (2006). *Impact sur la santé des différents polluants : Quels effets à court, moyen et long terme ?*

Henry, R. K., Yongsheng, Z., & Jun, D. (2006). Municipal solid waste management challenges in developing countries – Kenyan case study. *Waste Management*, *26*(1), 92-100. https://doi.org/10.1016/j.wasman.2005.03.007

Hiligsmann, S., Lardinois, M., COPIN, A., THONART, P., RODRIGUEZ, C., & MHIRI, F. (2002). Impact environnemental des décharges de déchets ménagers sur la qualité des eaux. *Gestion intégrée de l'eau en Haïti (Port au Prince, 26-28 juin 2002)*, 192-204.

John, D. E., & Rose, J. B. (2005). Review of factors affecting microbial survival in groundwater. *Environmental science & technology*, *39*(19), 7345-7356.

Kam Yogo, E. D., & Ruppel, O. C. (2018). *Environmental law and policy in Cameroon—Towards making Africa the tree of life | Droit et politique de l'environnement au Cameroun—Afin de faire de l'Afrique l'arbre de vie*. Nomos Verlagsgesellschaft mbH & Co. KG. https://doi.org/10.5771/9783845294360

Kambiré, B., & Assi, Y. G. (2021). *Degradation du cadre de vie et risques sanitaires à bingerville (côte d'ivoire)*.

Katte, V. Y., Fonteh, M. F., & Guemuh, G. N. (2003). Domestic water quality in urban centres in Cameroon: A case study of Dschang in the West Province. *African Water Journal*, 43-54.

Katukiza, A. Y., Ronteltap, M., Niwagaba, C. B., Foppen, J. W. A., Kansiime, F., & Lens, P. N. L. (2012). Sustainable sanitation technology options for urban slums. *Biotechnology Advances*, *30*(5), 964-978. https://doi.org/10.1016/j.biotechadv.2012.02.007

Kebiche, M., Benabid, C., & Adjal, F. (1999). Pollution des eaux superficielles dans un climat semi-aride : La région de Sétif (Algérie). *Science et changements planétaires/Sécheresse*, *10*(2), 137-142.

Kuitcha, K., Kamgang, K. B. V., Sigha, N. I., Lienou, G., & Ekodeck, G. E. (2008). Water supply, sanitation and health risks in Yaoundé, Cameroon. *African Journal of Environmental Science and Technology*, *2*(11), 379-386.

Manga, V., Forton, O., & Read, A. (2008). Waste management in Cameroon: A new policy perspective? *Resources, Conservation and Recycling*, *52*, 592-600. https://doi.org/10.1016/j.resconrec.2007.07.003

Ménard, B. (2011). Thaïlande : Résurgences infectieuses et transition épidémiologique. *Médecine tropicale*, *71*(5), 421-427.

Mills, F., Willetts, J., Petterson, S., Mitchell, C., & Norman, G. (2018). Faecal pathogen flows and their public health risks in urban environments: A proposed approach to inform sanitation planning. *International Journal of Environmental Research and Public Health*, *15*(2), 181.

MINEE. (2011). *Strategie_nationale_d_assainissement_liquide_2011.pdf*. https://www.pseau.org/outils/ouvrages/minee_strategie_nationale_d_assainissement_liquide_2011.pdf

Mwaguni, S. M. (2002). *Public health problems in Mombasa District: A case study on sewage management* [PhD Thesis]. http://erepository.uonbi.ac.ke/handle/11295/17239

Ndam, S., Touikoue, A. F., Chenal, J., Baraka Munyaka, J.-C., Kemajou, A., & Kouomoun, A. (2023). Urban Governance of Household Waste and Sustainable Development in Sub-Saharan Africa: A Study from Yaoundé (Cameroon). *Waste*, *1*(3), 612-630. https://www.mdpi.com/2813-0391/1/3/36

Ndjama, J., Kamgang, K. B. V., Sigha, N. L., Ekodeck, G., & Tita, M. A. (2008). Water supply, sanitation and health risks in Douala, Cameroon. *African Journal of Environmental Science and Technology*, *2*(12), 422-429.

Ngnikam, E., & Tanawa, E. (2006a). Les villes d'Afrique face à leurs déchets [How Cities Address the Problem of Solid Waste]. *Edition de l'UTBM (Université de Technologie de Belfort-Montbéliard), Belfort Cedex, France*.

Ngnikam, E., & Tanawa, E. (2006b). *Les villes d'Afrique face à leurs déchets*. Université de technologie de Belfort-Montbéliard Belfort.

Ngnikam, E., Vermande, P., Tanawa, M., & Wethe, J. (1997). Une démarche intégrée pour la maîtrise de la gestion des déchets solides urbains au Cameroun. *Environnement, Ingénierie & Développement*. https://eid.episciences.org/8267

Nguendo, Y. H., Salem, G., & Thouez, J.-P. (2008). Risques sanitaires liés aux modes d'assainissement des excreta à Yaoundé, Cameroun. *Natures Sciences Sociétés*, *16*(1), 3-12.

Nkengazong, L., Ousmanou, D., Irma, K. N. G., Efietngab, A.-N., Bosco, T. F. J., Monique, N., & Serge, Z. T. (2021). Impact of Hygiene and Sanitation in Cameroon (HYSACAM) refuse dumpsites on the propagation of resistant forms of parasites in the city of Yaoundé, Centre Region-Cameroon. *International Research Journal of Public and Environmental Health*. https://journalissues.org/irjpeh/abstract/impact-of-hygiene-and-sanitation-in-cameroon-hysacam-refuse-dumpsites-on-the-propagation-of-resistant-forms-of-parasites-in-the-city-of-yaounde-centre-region-cameroon/

Ntoban, V. K., & Fogwe, Z. N. (2019). The Garbage Disposal Challenges in Bamenda (Cameroon) : An Urbanisation and Public Welfare Policy Accountability. *Published in International Journal of Resource and Environment Management*, *4*(75-92).

Nzouebet, W. A. L., Kengne, E. S., Wafo, G. V. D., Wanda, C., Rechenburg, A., & Noumsi, I. M. K. (2019). Assessment of the faecal sludge management practices in households of a sub-Saharan Africa urban area and the health risks associated: The case study of Yaoundé, Cameroon. *International Journal of Biological and Chemical Sciences*, *13*(5), 1-23.

Parrot, L., Sotamenou, J., & Dia, B. K. (2009). Municipal solid waste management in Africa: Strategies and livelihoods in Yaoundé, Cameroon. *Waste management*, *29*(2), 986-995.

Proparco. (2012). *Les déchets : Quels enjeux pour les pays en développement ?* Revue PROPARCO. https://www.proparco.fr/fr/ressources/les-dechets-quels-enjeux-pour-les-pays-en-developpement

Prüss-Üstün, A., Bonjour, S., & Corvalán, C. (2008). The impact of the environment on health by country: A meta-synthesis. *Environmental Health*, *7*, 1-10.

pS-Eau. (2006). *Assainissement_pays_developpement.pdf*.

Rhouma, A., Mougou, I., & Rhouma, H. (2019). *Croissance urbaine et environnement : Déchets urbains (Tome I)*. Éditions universitaires européennes.

Sotamenou, J. (2005). Efficacité de la collecte des déchets ménagers et agriculture urbaine et périurbaine dans la ville de Yaoundé. *Mémoire de DEA, université de Yaoundé II*. https://www.memoireonline.com/05/07/456/efficacite-collecte-dechets-menagers-agriculture-urbaine-periurbaine-yaounde.html

Sy, I., Koita, M., Traoré, D., Keita, M., Lo, B., Tanner, M., & Cisse, G. (2011). Vulnérabilité sanitaire et environnementale dans les quartiers défavorisés de Nouakchott (Mauritanie) : Analyse des conditions d'émergence et de développement de maladies en milieu urbain sahélien. *VertigO*, *11*(2). https://www.erudit.org/en/journals/vertigo/1900-v1-n1-vertigo0119/1009364ar/abstract/

Sy, I., Piermay, J.-L., Wyss, K., Handschumacher, P., Tanner, M., & Cissé, G. (2011). Gestion de l'espace urbain et morbidité des pathologies liées à l'assainissement à Rufisque (Sénégal). *Espace géographique*, *40*(1), 47-61.

Taweesan, A., Koottatep, T., & Polprasert, C. (2015). Effective faecal sludge management measures for on-site sanitation systems. *Journal of Water, Sanitation and Hygiene for Development*, *5*(3), 483-492.

Tcheunteu, simplice, Magloire, O. O. J., Mavie, T. G., & Patience, T. N. R. (2013). Les déterminants physiques et humains de la pollution des eaux de surface dans les fonds de vallee du bassin versant du mbanya à douala (Cameroun). *Int. J. Adv. Stud. Res. Africa*, *4*(1). https://www.academia.edu/download/38197592/Tcheunteu__Olinga_et_Al.__-_Article_IJASRA_Vol4.pdf

Tchuikoua, L. B. (2010). Gestion des déchets solides ménagers à Douala au Cameroun : Opportunité ou menace pour l'environnement et la population ? *Carnets de géographes*, *1*.

Tini, A. (2003). *La gestion des déchets solides ménagers à Niamey au Niger : Essai pour une stratégie de gestion durable* [PhD Thesis, Lyon, INSA]. https://www.theses.fr/2003ISAL0084

Wethé, J., Radoux, M., & Tanawa, E. (2003). Assainissement des eaux usées et risques socio – sanitaires et environnementaux en zones d'habitat planifié de Yaoundé (Cameroun). *VertigO - la revue électronique en sciences de l'environnement*, *Volume 4 Numéro 1*, Article Volume 4 Numéro 1. https://doi.org/10.4000/vertigo.4741

WHO. (2013). *La Santé dans le programme de développement pour l'après-2015 Projet de document pour les comités régionaux de l'OMS 2013*.

WHO. (2016). *L'eau, l'assainissement et l'hygiène dans les établissements de soins de santé : État des lieux et perspectives dans les pays à revenu faible ou intermédiaire.* Organisation mondiale de la Santé. https://apps.who.int/iris/handle/10665/249610