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Wastewater and Excreta Management Evaluation in the Bukavu City, Democratic Republic of the Congo

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Abstract

The increasing production of wastewater and excreta presents a significant management challenge in the city of Bukavu, in Democratic Republic of the Congo (DRC). The objective of this study was to evaluate the causes and consequences of poor wastewater and excreta management and their associated environmental risks in Bukavu. This study was conducted from October 15 to November 18, 2023, and encompassed 1210 households across the three municipalities of Bukavu. The research was carried out through field surveys, interviews, observations, and documentary analysis. The findings revealed that the majority of households (66%) are owner-occupied, compared to 21% by tenants. In the Bagira municipality, most households utilize manually flushed latrines (47%), whereas the use of modern toilets and pit latrines predominates in the Ibanda (67%) and Kadutu (70%) municipalities, respectively. Common disposal sites for fecal sludge include designated pits (65%), nearby canals (20%), and rivers and lakes (15%). Furthermore, over 60% of households in Bagira and more than 80% in Kadutu discharge their wastewater into open drainage channels, while over 65% of households in Ibanda discharge it into soak pits. Wastewater serves as a breeding ground for mosquitoes, which are

vectors of malaria, the most prevalent disease in Bukavu. The results indicate that wastewater and excreta are predominantly managed in an unsanitary manner and are discharged into the environment. Pearson's Chi-square test indicated a statistically significant difference ($p < 0.05$) in wastewater discharge locations across the municipalities of Bukavu. It is imperative to intensify public awareness campaigns about the detrimental consequences of improper wastewater and excreta disposal.

Keywords

Wastewater, Fecal Sludge, Management, Bukavu City, DRC

1. Introduction

The current world is undergoing rapid urbanization. The global population is projected to reach 13 billion by 2030, and urban water demands are expected to double by 2050, leading to an increase in domestic wastewater production over time (Hasan et al., 2021). Approximately 2.8 billion people in low- and middle-income countries still rely on on-site sanitation systems for wastewater disposal, with nearly half of these systems failing to adequately treat human excreta (Jakariya et al., 2023). Sanitation management in this context poses significant challenges for most cities, particularly in the management of fecal sludge in urban areas where many individuals rely on individual sanitation facilities (Ya Lubo Shabantu et al., 2021).

Indeed, 580 million people shared sanitation facilities with other households, and 616 million used unimproved facilities (Ya Lubo Shabantu et al., 2021). Two-thirds of individuals without any sanitation services lived in rural areas, with about half residing in sub-Saharan Africa (Kwiringira et al., 2021). The discharge of wastewater and fecal sludge into open environments and rivers is common in developing countries such as Bangladesh, India, and sub-Saharan Africa (Singh et al., 2020; Foster et al., 2021; Chandana & Rao, 2022).

Studies conducted in African and Asian countries have highlighted gaps in fecal sludge management practices. For example, in Togo, a study in the city of Vogan revealed that nearly nine out of ten households (89.43%) had latrines. Among those without latrines, 66.67% practiced open defecation, 14.28% used neighbors' facilities, and 19.05% used public toilets (Nyakpo, 2022; Gbekley et al., 2023). A similar study in Thailand found that only 30% of the fecal sludge generated by on-site sanitation systems is managed safely, while the remaining 70% is handled unsafely (Alemu et al., 2023; Sisay et al., 2024). Additionally, research conducted in the city of Bukavu, in the Kadutu municipality, showed that most households along the "Kahuwa" river lacked septic tanks, with their toilets discharging directly into the river (Isidore et al., 2022).

Bukavu faces its own sanitation challenges. With an on-site sanitation system primarily comprising latrines and septic tanks (Bagalwa Nyamugara et al., 2024), poor sizing of sanitation infrastructure and mismanagement of accumulated wa-

ter inevitably lead to soil and water pollution, affecting both surface and groundwater (Baltazar et al., 2021; Conaway et al., 2023). In Bukavu, few studies have addressed the issue of poor wastewater and excreta management. The works of Isidore et al. (2022) and Bagalwa Nyamugara et al. (2024) focused on analyzing fecal sludge management practices in certain neighborhoods of Bukavu. To build upon previous research, this study aims to evaluate the broader issue of poor wastewater and excreta management and its environmental risks throughout the city of Bukavu.

Specifically, the study seeks to 1) identify the types of facilities households use to collect and store wastewater and excreta in Bukavu, 2) analyze the practices households employ to dispose of wastewater and excreta, and 3) identify the causes and consequences of poor wastewater and excreta management in Bukavu.

2. Material and Methods

2.1. Study Area Description

Bukavu is a city located in the eastern part of the Democratic Republic of the Congo (DRC), situated on the southwestern shore of Lake Kivu (**Figure 1**). Positioned at an altitude ranging from 1460 meters (lake level) to 1900 meters (Kadutu summit), it serves as the administrative center of the South Kivu province. The city shares a border with Rwanda, demarcated by the Ruzizi River and Lake Kivu (Lina, 2016).

Administratively, Bukavu is divided into three municipalities: Ibanda, Kadutu, and Bagira. These municipalities cover a total area of 63 km^2, of which 20 km^2 is water surface on the lake (Kalikone et al., 2017). Kadutu was the first of the three municipalities established in Bukavu. It hosts the largest market in Bukavu, numerous schools, a university, and the city's largest hospital. Overall, the city contains a total of 11 markets (Kalikone et al., 2017).

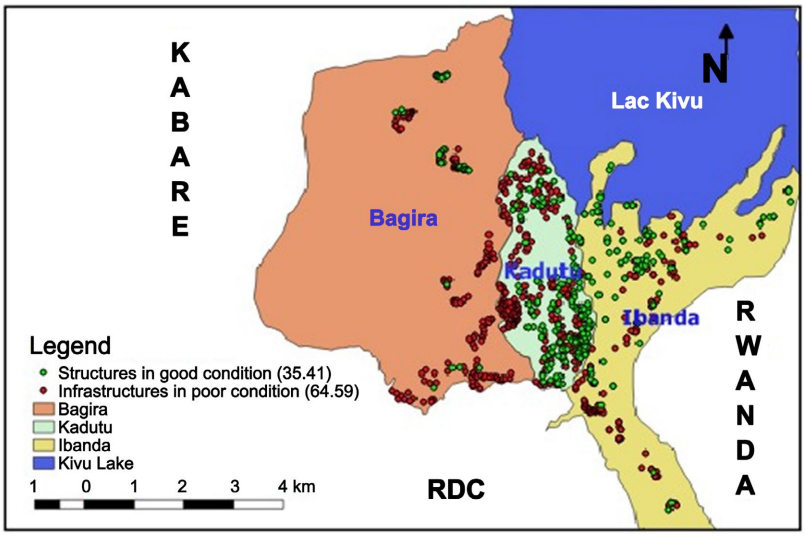

Figure 1. Study area: Bukavu city (DRC).

In 2020, the city of Bukavu had an estimated population of approximately 1.3 million, resulting in a population density of about 30,000 inhabitants per square

kilometer. Based on projections with a growth rate of 4.1%, the population is expected to reach 1,942,901 by 2030 and 2,375,222 by 2035 (Lina, 2016).

2.2. Methodology

The study was based on the hypothesis that in the city of Bukavu, there is a significant correlation between the use of non-collective sanitation and hygiene-related diseases. To test this hypothesis, we employed two data collection techniques: documentary research and field data collection (observations and questionnaire surveys conducted with household heads). The questionnaire survey gathered information on the geolocation and characteristics of sanitation types, household attributes, perceptions, challenges, and health issues among the population of Bukavu. A total of 1210 household heads were surveyed between October 15 and November 18, 2023, across 17 neighborhoods, taking into account the specific characteristics and geographical locations of the neighborhoods.

2.2.1. Household Survey

For data collection, the tablets were configured by installing the Kobo Collect application. The city of Bukavu is estimated to comprise 216,327 households, and for each surveyed household, only one individual was considered. Regarding household selection, a random targeting approach was employed to ensure comprehensive coverage of the sampling frame. The distribution of households to be surveyed within each neighborhood was proportional to the total number of households in that area. The sample size was calculated based on the formula provided by Rea and Parker (2014):

$$n = \left(t_p^2 * P(1-P) * N\right) \Big/ \left(t_p^2 * P(1-P) + (N-1) * y^2\right) \quad (1)$$

where n = sample size; N = target population size (number of households); P = expected proportion of responses from the population; t_p = sampling confidence interval; and y = sampling margin of error. Accordingly, with n representing the sample size and N the total number of households, the sampling interval t_p was determined for each neighborhood using the formula $t_p = N/n$. The first household was randomly selected within the interval [1, t_p], while the remaining households were chosen following the predetermined sampling step, as calculated above (systematic sampling). In other words, the sampling fraction was iteratively added to the randomly selected starting point. In cases where a building had multiple apartments on different floors, only one household per building was included in the sample.

Given the possibility of errors or incomplete forms during the survey, we increased the sample size by 5%. The total number of households surveyed was 1210. Based on the percentage distribution of households in each commune of Bukavu, we surveyed 290 households (24%) in the Bagira commune, 520 households (43%) in the Ibanda commune, and 400 households (33%) in the Kadutu commune.

2.2.2. Analysis and Data Treatment

The data collected from survey forms and interviews were entered into an SPSS

version 16 database. The analysis initially involved interpreting respondents' opinions, with proportions determined by calculating percentages. Subsequently, cross-tabulations of different variables were conducted using SPSS version 16 to identify potential dependencies between two variables. Pearson's Chi-square test was applied to assess deviations from independence.

3. Findings

3.1. Characteristics of Surveyed Households

3.1.1. The Surveys According to the Social Categories of Households

According to the distribution of household living standards in the city of Bukavu, Bagira primarily hosts middle-income households, accounting for 82.3%, while 17.7% belong to the low-income category (Figure 2). The Ibanda municipality is predominantly characterized by high-income households, comprising 74.1%, with middle-income households making up 25.9%. In contrast, the Kadutu municipality is mainly populated by low-income households, which represent 89.5%, while middle-income households account for 10.5%.

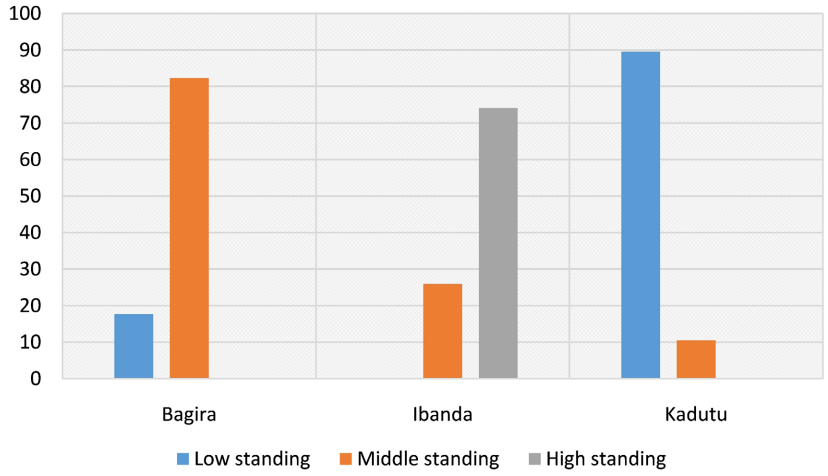

Figure 2. Households categories.

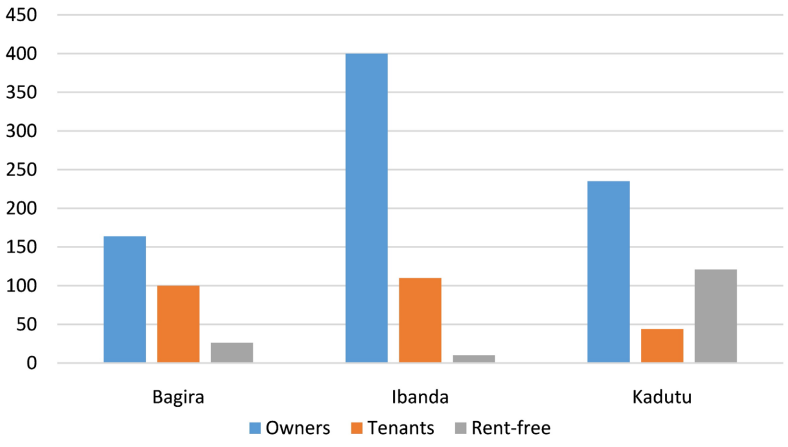

Figure 3. Household occupation status.

3.1.2. Housing Occupancy Status

The majority of housing units (66%) are occupied by owners, 21% by tenants, and 13% are provided without charge (Figure 3).

3.1.3. Types of Toilets Used by Households

The majority of households in the Bagira commune predominantly use manually flushed latrines (47%), whereas the use of modern toilets and pit latrines is significantly more prevalent in the Ibanda (67%) and Kadutu (70%) communes, respectively (Figure 4).

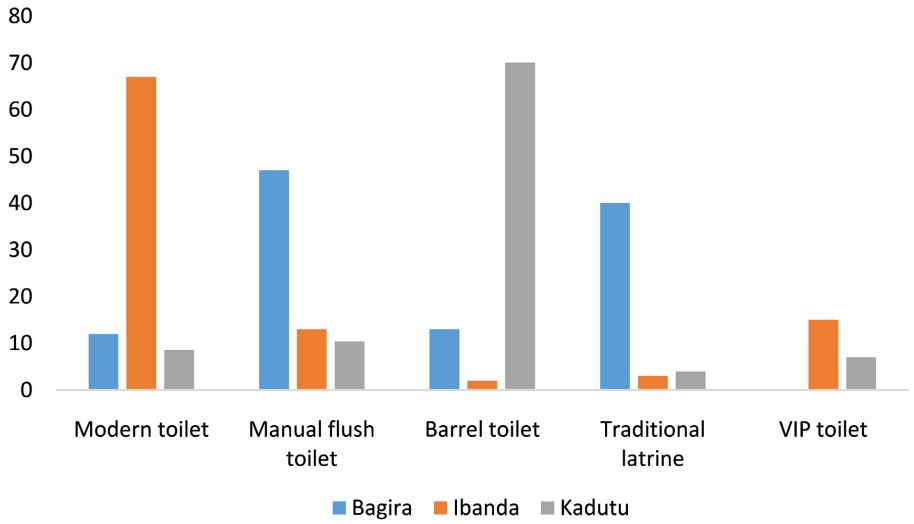

Figure 4. Types of toilets used by households.

3.2. Wastewater Disposal Sites and Sludge Dumping Locations

In the city of Bukavu, 61.4% of households in Bagira and 35.8% of households in Kadutu discharge their wastewater into drainage ditches, whereas over 69.8% of households in Ibanda discharge into seepage wells (Table 1).

Table 1. Cross-referencing the origin and location of wastewater discharges.

			Waste water discharge					Total
			Gutter	Courtyard	street	Sinkhole	River	
Municipality	Bagira	Number	178	21	15	1	75	290
		%	61.4	7.2	5.2	0.3	25.9	100
	Ibanda	Number	87	12	22	363	36	520
		%	16.7	2.3	4.2	69.8	6.9	100
	Kadutu	Number	143	51	33	140	33	400
		%	35.8	12.8	8.3	35	8.3	100
Total		Number	408	84	70	504	144	1210
		%	33.7	6.9	5.8	41.7	12	100

Chi-square tests of Pearson: 164.524[a], Likelihood ratio 195, 729; ddl: 8, $p < 0.05$.

The survey conducted in the three municipalities reveals that the common disposal sites for emptied materials are as follows: constructed pits (65%), nearby canals (20%), and various other locations such as rivers and lakes (15%) (Figure 5).

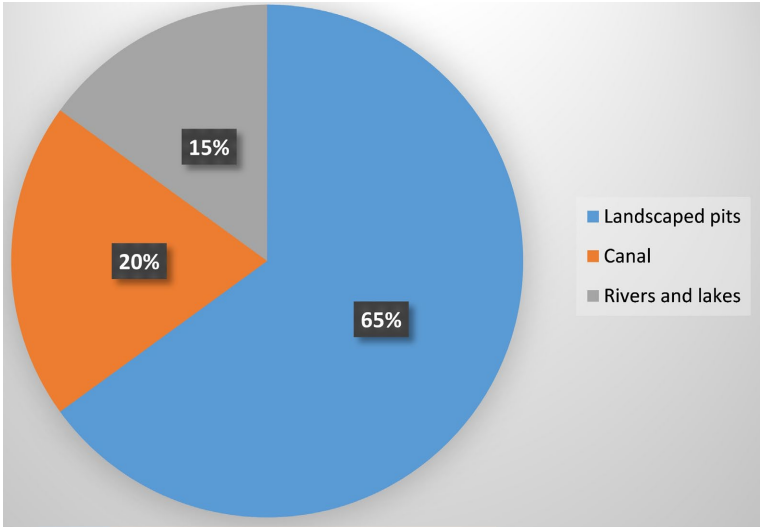

Figure 5. Dumping sites for sludge.

3.3. Causes and Consequences of Poor Wastewater and Excreta Management

The results obtained from our respondents indicate that 47% of our sample assert that the incivility of the population is the primary cause of the inadequate management of waste in the city of Bukavu. This is followed by unregulated construction and the lack of state involvement, each representing 18% of the sample size (Figure 6).

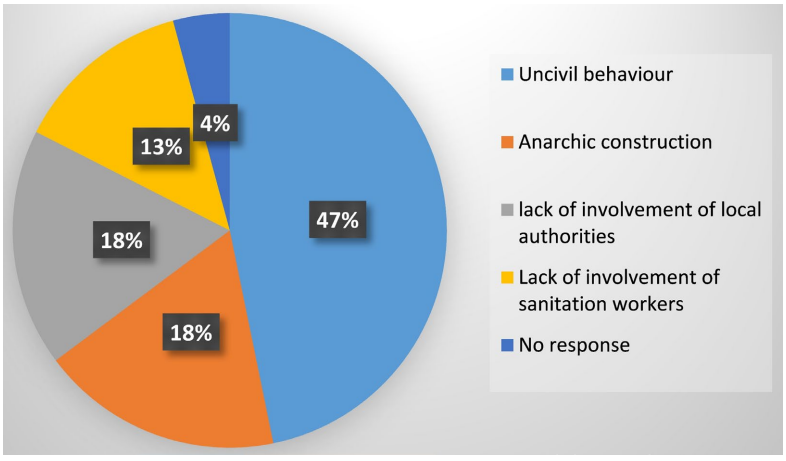

Figure 6. Causes of poor management of wastewater sludge and excreta.

The findings obtained (Figure 7) from our survey indicate that 56% of the respondents recognize that inadequate management of wastewater and excreta con-

tributes to the proliferation of diseases in the city of Bukavu. This highlights a significant level of awareness among the population regarding the public health risks associated with poor sanitation practices

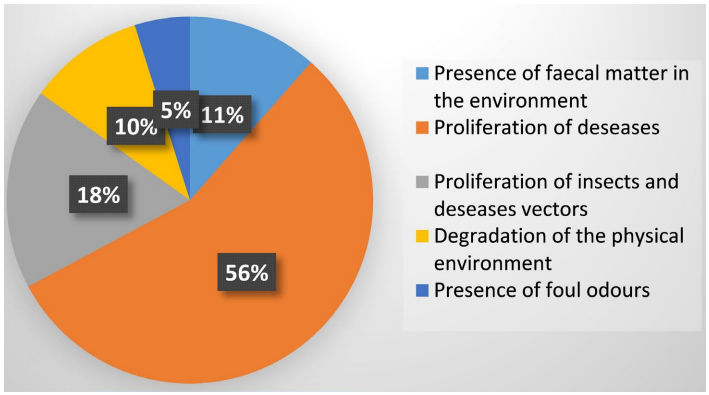

Figure 7. Consequences of poor wastewater and excreta management.

4. Findings Discussion

4.1. Characteristics of Surveyed Households

The results obtained in the city of Bukavu indicate that over 60% of households are owner-occupied, while less than 15% are tenant-occupied (**Figure 3**). This parameter is significant as it provides insights into the sanitary conditions of their homes, given their relatively long-term residence. Additionally, it would be relatively easier to encourage these homeowners to invest in improving their wastewater and excreta treatment facilities (Lina, 2016).

The findings of this study are consistent with those of Nyakpo (2022) in the city of Vogan, where 53.42% of households were owner-occupied, 16.44% were occupied by family members of the owner, and 30.14% were tenant-occupied.

For social categories (**Figure 2**), the Bagira commune predominantly hosts middle-class households (82.3%), Ibanda is mainly occupied by high-income households (74.1%), and Kadutu by low-income households (89.5%). The majority of households in Bagira commune use manual flush latrines (47%), while modern toilets and pit latrines dominate in the Ibanda (67%) and Kadutu (70%) communes, respectively (**Figure 4**).

This indicates that household income influences the type of toilet facilities installed in homes. High-income households tend to install septic tanks, while low-income households rely on traditional or pit latrines. The latter pose significant health and environmental risks and should be replaced with facilities that are more health- and environmentally-friendly (Aissi et al., 2023).

Traditional latrines do not provide a barrier between the user and excreta. Populations using such facilities are not considered to have access to adequate sanitation as per the Sustainable Development Goals (SDGs). It is therefore crucial to support these populations in acquiring sanitation facilities that ensure reliable health and environmental protection. Otherwise, the situation risks becoming

more chaotic by the SDG deadline (Nguea, 2024).

These findings align with those of Bagalwa Nyamugara (2024), who reported that 69.3% and 47.3% of high- and middle-income social categories, respectively, used modern toilets with septic tanks. In contrast, low-income households predominantly used traditional latrines (41.3%) or pit latrines (36%).

4.2. Wastewater Disposal Sites and Sludge Dumping Locations

Regarding the common sites for the disposal of wastewater and septic sludge, survey results (**Figure 5**) indicate that septic sludge is primarily discharged into designated pits (65%), nearby drainage channels (20%), and rivers and lakes (15%). As for wastewater (**Figure 1**), over 60% of households in Bagira and more than 80% of households in Kadutu discharge their wastewater into drains, while over 65% of households in Ibanda release their wastewater into leach pits.

The cross-tabulation percentages represent the occurrences where each municipality discharges its wastewater (**Table 1**). The data reveal that all municipalities discharge wastewater into drainage channels, with Bagira (middle-income) leading, followed by Kadutu (low-income). Notably, in Kadutu, soak pits are also used for wastewater management, whereas in Ibanda (high-income), wastewater is predominantly discharged into rivers. Pearson's Chi-square test yielded a high coefficient of 164.524, with a Likelihood Ratio of 195.729 for 1210 valid observations. These results indicate a statistically significant difference ($p < 0.05$) in wastewater discharge locations across the municipalities of Bukavu.

The current wastewater and septic sludge management practices in the city of Bukavu have significant public health and environmental consequences. They notably contribute to the pollution of water bodies that could potentially be used for drinking. The high prevalence of malaria could be attributed to the development of mosquito larvae in stagnant wastewater pools (Kawata et al., 2024). Diarrheal diseases and intestinal parasitoses are likely caused by the ingestion of pathogens due to poor sanitation conditions (Ya Lubo Shabantu et al., 2021). Ensuring better management of wastewater and excreta would help improve the health of the population in the city of Bukavu (Aissi et al., 2023).

These findings reinforce those already reported by Isidore et al. (2022) in the Kadutu commune, which indicate that the so-called "other" practice involves discharging the contents of septic tanks into rivers or drains, both of which rely on manual emptying. It is important to note that these practices have harmful health and environmental consequences. The city of Bukavu lacks a sludge treatment facility. The majority of households are unaware of the existence of a sludge treatment station, which results in a situation where sludge emptiers discharge the waste anywhere, disregarding any protective measures for the surrounding population and the receiving environment.

4.3. Causes and Consequences of Poor Wastewater and Excreta Management

The survey results presented on **Figure 6** indicate that 47% of our sample identify

public incivility as the primary cause of poor excreta management in the city of Bukavu. These findings align with those of Isidore et al. (2022) in the Kadutu municipality. Other cited causes include anarchic construction and the lack of state involvement, each accounting for 18% of the responses.

Despite this, 56% of respondents acknowledge that poor wastewater and excreta management leads to the proliferation of diseases in Bukavu, a result consistent with the findings of Lina (2016) in the same city. It is important to note that untreated wastewater contains various excreted organisms, including pathogenic agents. To address this issue, it would be essential to implement public information, awareness, and environmental education programs, while also enforcing legal regulations when necessary (Singh et al., 2021).

Studies have also supported the conclusion that proper wastewater management practices effectively reduce diarrheal diseases (Shukla et al., 2023). In several countries, wastewater and excreta treatment and valorization are now mandatory to improve sanitary conditions. Various reuse options are available depending on the treatment processes, including agricultural irrigation, recreational and municipal reuse, groundwater recharge, aquaculture, and land application. However, these applications require water quality standards appropriate for each specific use (Nasim et al., 2022).

5. Conclusion

At the end of the study, it was noted that people's wastewater and excreta management practices present health and environmental risks. The aim of this study was to assess the causes and consequences of the poor management of wastewater and excreta and the environmental risks involved in the city of Bukavu.

We found that the population of Bukavu has poor access to wastewater and excreta management. The population's lack of civic responsibility is the main cause, and the proliferation of disease is the consequence of poor wastewater and excreta management in Bukavu. The absence of robust public policies and of the necessary sanitation skills within the government departments responsible for sanitation, the lack of a sanitation culture among citizens and the lack of adequate financial, technical and human resources are just some of the factors that are exacerbating the situation of access to basic sanitation in the city of Bukavu. To this end, the population needs to be educated about environmental sanitation, and human, financial and technological resources need to be mobilized with a view to achieving Sustainable Development Goal 6. Semi-collective sanitation systems need to be set up and will concern to develop shared sanitation facilities that serve multiple households, particularly in densely populated urban areas where individual sanitation systems are impractical on one hand, and to build decentralized wastewater treatment units at the neighborhood level to prevent direct discharge into the environment on other hand. Finally, improved sanitation facilities need to be built for low-income households; laws and regulations need to be enforced and the development plan for the city of Bukavu needs to be reviewed.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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