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Impact of Dumping Faecal Sludge on the Microbiological Quality of Funa River Water in the City of Kinshasa, the Democratic Republic of Congo

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ABSTRACT
The Funa river in the city of Kinshasa Democratic Republic of Congo is transformed into a wild dump and in its downstream part, into a receptacle for septic tank sludge coming from the city's houses, buildings, hospitals etc. The aim of this study was to investigate Funa river water and determine its pathogenic pollutant load coming from dumped faecal sludge. A survey carried out from October 2018 to September 2019 during the dry and rainy season on the identification of pathogenic and non-pathogenic germs made it possible to highlight the microbiological quality of the water. Results obtained showed that on average 5197 m^3 of faecal sludge was dumped into this river. The germs identified were Escherichia coli (22,566.6-30.103 CFU/100 mL), *Enterococcus ssp* (18.333,3–18 333.3 UFC/100 mL) Salmonella (22.566,6–30103 UFC/100 mL) and Shigella (366,6 – 800 UFC/100 mL) in significant numbers. Thus, the dumping of faecal sludge into the Funa river represents a serious public health risk considering the number of pathogenic microorganisms identified in the water. The protection of this river is a necessity in order to preserve the health of the local population.

Keywords: Enterococci, Faecal sludge, Funa, Salmonella, Shigella, Water quality

INTRODUCTION

The capital of the Democratic Republic of Congo (DRC), the City Province of Kinshasa is the largest city in the country, with an estimated population of 13 million in 2019 over an area of 9,965 km^2. (INS, 2020). It is crossed by about twenty rivers including the Funa river which joins in its downstream part to two other rivers like river Yolo and river Kalamu.

Several enthropogenic activities take place in and around these rivers, including fishing, sand dredging by young people from the neighborhood, swimming by children, watering of gardens by market gardeners. The traffic on the port sometimes requires some people to come into direct contact with the water of these rivers.

Most of these rivers are turned into landfills by the people of Kinshasa and among all these, the Funa river is particularly victim of the dumping of sludge from septic tanks, transported by private companies invested in the emptying service of water systems. Individual sanitation of the various dwelling places (permanent and temporary) and places of daily activities in the city province of Kinshasa.

All the septic tank emptying companies in the city of Kinshasa discharge their sludge into this river, more precisely at the site commonly called "André Motors" in the municipality of Limete. This site, nicknamed "**Nyeterie**" (to mean "production of faecal matter"), is a place where septic tank sludge is dumped in a well-identified place, directly on the ground without prior treatment. This place is directly at a channel that directs all that slime to the Funa river. This practice has been done for a few years because there is no good faecal sludge treatment system in the city of Kinshasa, and it is a risk related to faecal peril.

However, faecal sludge can contain certain chemical substances, resulting from phytosanitary products and even pathogenic organisms excreted by humans (viruses, bacteria, protozoa and others). These organisms have the ability to survive outside the human body (Zénon *et al*, 2018; Florian *et al*., 2002). Thus, dispersed in the water, the pathogenic organisms easily come into contact with the human beings who live in the vicinity of the river and who practice various activities on this watercourse. All people in contact with water are particularly the most exposed insofar as water contaminated by faeces constitutes a mode of transmission of diseases and can prove to be a source of various epidemics at the base of loss of human lives. (Saab *et al.*, 2007).

The "Nyeterie" is a well-identified place in the city of Kinshasa, where various septic tank sludge emptying trucks come to unload this waste. However, this practice constitutes a public health risk while the State must ensure the health of the population as stipulated in the Constitution of the DRC of 2006 as amended in 2011, in its article 53, namely "Everyone has the right to a healthy environment conducive to their full development. She has a duty to defend him". The State ensures the protection of the environment and the health of the population. (Constitution of the DRC 2006 and 2011; Stéphane *et al*., 2017).

Every river is a dynamic system. An open system like that of the living, it lives in a certain balance. Pollution alters this ecological balance. (Edeline, 2001). The presence of organic matter such as faecal sludge in a river and in large quantities induces biological and chemical pollution. Faecal material contains pathogenic microorganisms which can be transported through this sludge from septic tanks. Indeed, water has been identified for a long time as a vehicle for pathogenic microorganisms and therefore a transmission route for so-called waterborne diseases.

Thus, a determination of the water quality of the Funa river at different points (before the discharge upstream and downstream of the discharge) proved important in order to assess the impact of this practice on this watercourse. In addition, the specificity of septic tank sludge can induce pathogenicity. This is how an identification of pathogenic microorganisms of faecal origin (*Escherichia coli*, *Shigella* and *Enterococcus ssp)* in the waters of the river as well as their count is carried out in order to determine the polluting load of these sludge on the waters of the Funa river.

Determining pollutant loads is an important step in remediation. This determination involves the characterization of the sludge, but also the determination of the parameters making it possible to calculate this polluting load of the residential or non-residential systems.

MATERIALS AND METHODS

Study Environment

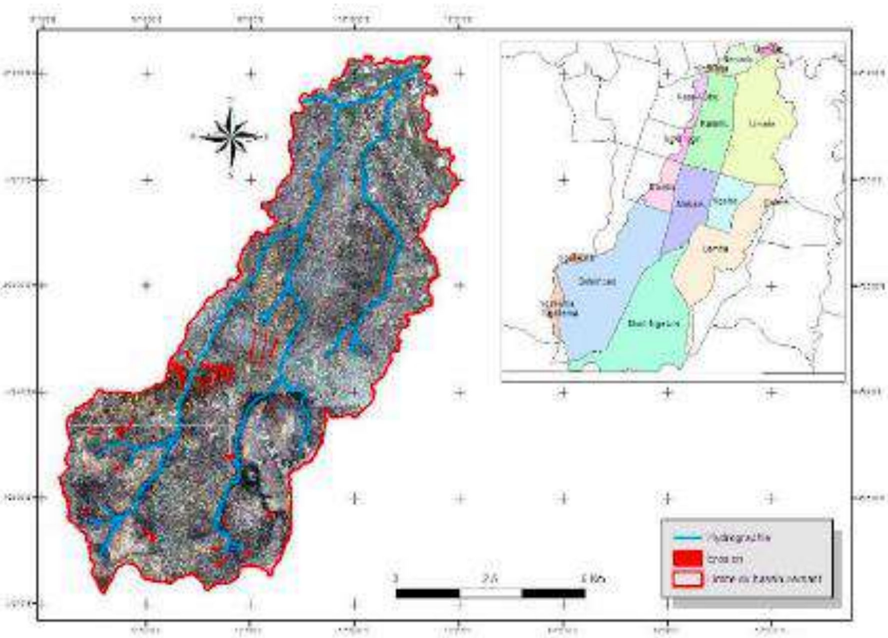

Figure 1: Funa river watershed

Nine (9) km long, the Funa river has its source in the commune of Mont-Ngafula in the Kindele district, crosses the commune of Makala, receives the waters of the Bumbu, Yolo and Kalamu rivers and flows into the Congo river via the avenue boatmen, in the Bribano district in the municipality of Limeté (Mukendi, 2022; Benteke, 2020). Most of the houses in this neighborhood are built along the river (Vuni, 2022). The Funa watershed is located on longitudes 15°17’51 East and latitudes 04°25’030 at an altitude of 329 meters as shown in Figure 1. The coordinates of the different sites were taken using the Garmin model edge 820 GPS.

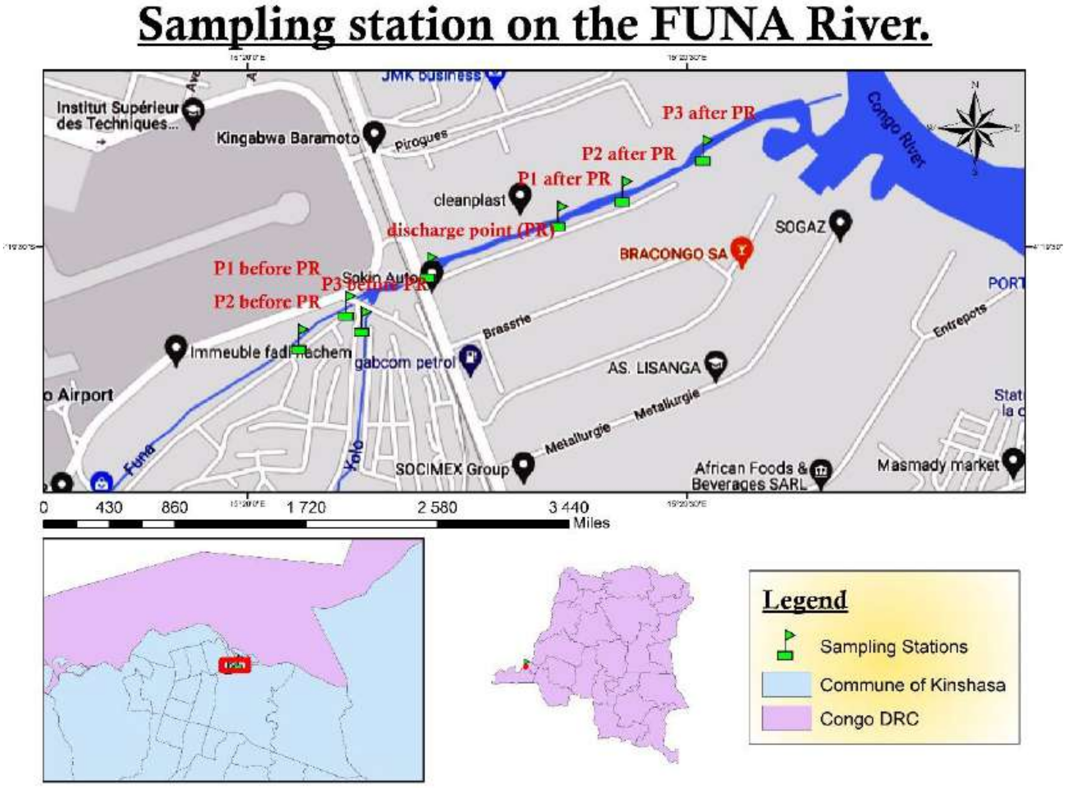

Figure 2: Water sampling stations on the Funa river

The Funa river has several sub-basins; Kemi sub-basin, Yolo River sub-basin and Bumbu river sub-basin. Covering an area of 4 km², the Funa watershed is located downstream of the sandy Bateke Plateau, and is delimited by a central basin of alluvial origin in the DRC (Sylave Tika Asakuau, 2013).

Materials

Culture medium

For the identification of microorganisms (*Escherichia coli, Shigella* and *enterococci*), water from the Funa river as well as culture media Trypticase Soy Agar, Tryptone Soy Agar (TSA), Tryptone Bile X Glucuronide Agar (TBX) and Slanetz Bartley Agar (SBA) were used for the identification of microorganisms.

Other materials

A Garmin model edge 820 GPS was used for the mapping of the site, illustrated in Figure 2. Test tubes, an incubator, Pasteur oven, an autoclave, a gas canister, Petri dishes, 100µl micropipettes, tips, Falcon tubes, analytical balance and a lamp, filter membranes, a filter ramp and pliers were used for this identification. The equipment used to measure the flow of the Funa river includes: wooden or cork float, four stakes, cane meter, tape measure, stopwatch and canoe.

Methods

The survey

It consisted of permanent and regular daytime surveillance of the "Nyeterie". This monitoring was carried out during the two seasons (rainy and dry) and made it possible to make a daily count by pointing of the trucks discharging sludge from septic tanks for twelve months.

Sampling

The first step is the collection of water samples. It was important to make sure that the sample is representative of the water quality we want to test. Samples were taken in sterile containers to avoid contamination.

The waters of the river from the 3 stations: upstream (Longitude: 015° 20' 0.6" and Latitude: 04° 19' 34.1") here coded AmRiF, at the point of impact with the faecal sludge coming from a PiRiF coded channel. (Longitude: 015° 20' 12.4" and Latitude: 04° 19' 31.4") and downstream, 200 meters from the PiRiF (Latitude: 015° 20' 21.3", Longitude 04° 19' 27.9") coded AvRiF were taken from a depth of 50 cm in sterile 500 mL glass vials, transported in a refrigerated chamber (4°C) and in the dark in the laboratory as quickly as possible.

Enumeration of microorganisms in the water sampled

Once in the laboratory, the water sample is filtered through sterile circular cellulose acetate grid membranes with 0.45 pm porosity and 47 mm diameter to concentrate bacteria and microorganisms. The bacteria and other microorganisms are then placed in a culture medium and incubated at a specific temperature to promote their growth.

After incubation, bacterial colonies and microorganisms were identified by the analytical method described by Khadija, C. and Omar (Khadija, C. and Omar, A. (2007).

Finally, the enumeration and isolation of bacteria was carried out by the filter membrane technique.

Calculation of the pollutant load

The polluting microorganism load is defined as the quantity of microorganism carried in the river in one day. It is determined by using equation (1):

$$CP = N \times F \times Q \quad (1)$$

Where,

CP = Pollutant Load

N = Number of microorganisms in (UFC/100 mL)

F = Dilution factor

Q = River flow (in m^3/d)

Sludge Pollutant Load

The fecal sludge pollution load is defined as the amount of fecal sludge discharged into the river in one day expressed in Ton/day. The dumping frequency and the density of the sludge (the Pollutant Load in sludge dumped per day) is deduced according to equation (2)

$$m = \rho \times V \times n \quad (2)$$

Where,

m = bou mass

ρ = density of the sludge

V = capacity of emptying vehicle tanks

n = spill frequency

The flow of the Funa river was measured by using the method of Hauet *et al.* (2013). The measurements were taken in two phases, during the rainy season (October, November and December) and during the dry season (June, July and August). The flow (in m^3/s) was calculated by multiplying the average water flow velocity (in m/s) by the width of the river (in m) and by the average depth (height) (in m).

D = Flow in m^3/s

H = the depth (height) in meter (m)

L = width of the river in meter (m)

V = the speed of water movement in m/s

$V = L/t$

L = Length between points AA' and BB" in meters (m)

t = flow time in seconds (s).

The average flow of the Funa river is 4.40 m^3/s during the dry season and 14.25 m^3/s during the rainy season.

RESULTS AND DISCUSSION

Survey

Faecal sludge dumping monitoring was conducted for 12 months (October 2018 to September 2019). The volume of faecal sludge was estimated at 62,363 m^3 per year (Figure 3).

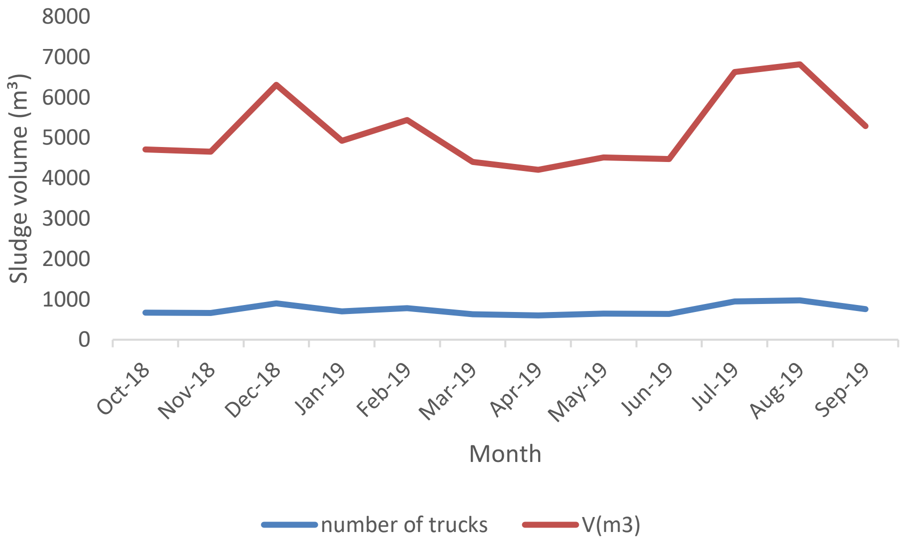

Figure 3: Volume of faecal sludge discharged into the Funa river over 12 months

The volume of 62,363m^3 of faecal sludge per year discharged into the Funa river sufficiently proves that the river is loaded regularly and daily (on average 173.23 m^3 of pit sludge/day).

Figure 3 shows a spill peak between July and August 2019 corresponding to a volume of sludge of 6,629 m^3 for the month of July and 6,818 m^3 for the month of August of the year 2019 and during the month of December of the year 2018. These peaks correspond to school vacation periods, a period during which there is an increase in the number of permanent people in the houses and which could eventually lead to the rapid filling of septic tanks. This survey also made it possible to note a permanent coloring of the water of the river in poor green color, observed throughout the year and a characteristic smell of faeces felt around the "Nyeterie" and the point of impact between the channel that conducts the discharged sludge and the Funa river. The average of monthly frequency of discharge of faecal sludge into the river was determined by emptying vehicles, which is equal to 676 and the capacity of the tanks of these vehicles which varied between $5m^3$ to 12 m^3 (volume of sludge drained daily).

Identification of microorganisms in water containing fecal sludge from the Funa river

Microorganisms of faecal origin have been identified in the waters of this river, both upstream and downstream, during both seasons (dry and rainy). An estimate of their number was also made in this study. (Tables 1 and 2). The data in Tables 1 and 2 were obtained after dilution of the crude sample (7 times at the rate of one time equal to 10/100 mL). When no colonies appear in the agar inoculated with the test volume of the undiluted sample, the result is expressed as "not detected in 1 mL" (Basic Laboratory Procedures in Clinical Bacteriology, World Health Organization. Geneva.1991. 1st edition).

In the presence of more than 300 colonies on the dishes inoculated with the highest dilution inoculated, the results are expressed only approximately (CWEA, 2014).

Table 1: Count of microorganisms in the rainy season on a diluted sample.

Stations	*Escherichia coli* (UFC/100mL)	*Shigella spp* (UFC/100mL)	*Salmonella* (UFC/100mL)	*Enterococus* (UFC/100mL)
AmRiF	11933.30	500.00	330.00	14533.30
PIRiF	16200.00	1000.00	500.00	4000.00
AvRiF	13566.60	500.00	100.00	9833.30

Table 2: Count of microorganisms in the dry season on a diluted sample.

Stations	*Escherichia coli* (UFC/100mL)	*Shigella spp* (UFC/100mL)	*Salmonella* (UFC/100mL)	*Enterococcus ssp* (UFC/100mL)
AmRiF	22567.00	367.00	233.00	18333.00
PIRiF	30000.00	800.00	1400.00	10000.00
AvRiF	23533.00	400.00	300.00	11667.00

The results show that despite the dilution of the samples, the number of colonies of *Escherichia coli* and *Enterococcus ssp* is still high. This means that the dilution does not have a significant impact on the microbial concentration regardless of the season. *Salmonella* and *Shigella* microorganisms are also present, although in reduced numbers compared to the others (*E. coli* and *Enterococcus ssp*). These results are similar to those obtained by Eric B. e*t al.* (2021) *and* Innocent *D. et al*. (2018) in the irrigation water in northern Benin.

E. coli is part of the group of fecal coliforms and is a more specific indicator of fecal pollution than other fecal coliforms. It is present in human faeces.

The presence of *E. coli* in the waters of the Funa river indicates that the bacterial contamination of the waters is recent, while that of *Enterococcus ssp* indicates that it is old. (Stephen T. et al 2013). The presence of large numbers of *Escherichia coli* could be justified by the direct discharge of faeces from local residents, via Chlorinated PolyVinyl (PVC) tubes coming out of latrines or plots located on the minor bed of the river, along the banks as observed and identified along the Funa river. This practice, called "Munduki" – which means "gun" in the local language Lingala – is found in all urban rivers in the city of Kinshasa (Sikulisimwa, 2021).

It should be noted that the organisms responsible for waterborne diseases cannot live in pure water but can survive for several days. Vegetative cells die rapidly while pores, and cysts persist over an extended period. *Salmonella typhosa*, *Shigella dysenteriae* and *Vibrio comma* are included in the range of pathogenic bacteria commonly encountered in water (Ross E. McKinney, 2007). However, their pathogenicity is associated with their origin. This means that it is essential to identify the presence of indicator coliform bacteria of faecal origin, in particular *Enterobacteriaceae* (*Escherichia* and Aerobacteria). *E. coli* is essentially of faecal origin.

This proves that the presence of these microorganisms in these waters represents a permanent risk of contamination by pathogenic agents (*Salmonella, E coli* and *Shigella spp*). *Salmonella* is responsible for typhoid and paratyphoid. The presence of *Shigella* poses a risk of transmitting shigellosis. This bacterium causes an infection that is transmitted by the faecal-oral route, through dirty hands or water contaminated with faeces in poor hygienic conditions and lack of sanitation.

The discharge of faecal sludge into the environment without any prior treatment constitutes exposure to faecal peril, which is a set of infectious diseases due to pathogens deposited in the external environment by excrement from unhygienic toilets or open defecation. Diseases due to faecal peril (diarrhoea) kill each year, according to the WHO, 4.3 million people, including 17% of children with 90% of children under 5 years old are attacked by the parasites, verminoses (Muhubao and Ali, 2021).

Among the declared waterborne diseases, there is *typhoid fever* (44%) and *cholera* (47%) in areas where hygiene is precarious. Indeed, studies conducted in Kinshasa revealed that Kinshasa had experienced an epidemic of typhoid fever caused by the multi-resistant strain of *Salmonella typhi* between October 2004 and January 2005 with a fatality rate of 53% associated with ideal perforations. (Kumul *et al.*, 2022). Contamination of water by faecal germs could represent threats to the health of users, particularly the elderly, vulnerable people and children, exposing the population to water-borne diseases. The same would be true in the case of the Funa river. (Andry *et al., 2023) ;* Wognin A *et al, 2014*).

Calculation of the microorganism load

To. Pollutant Load (CP) in faecal sludge discharged into the Funa river

Knowing the capacity of the tanks of the sewage vehicles, which varies between 5m^3 to 12m^3 and the frequency of discharge of faecal sludge and considering an average volume of 8,5m^3 of the vehicles which discharge the sewage sludge into the Funa river, the monthly load or daily sludge dumped is calculated for the 12 months as observed and presented in Table 3.

Table 3: Statistical data of daily and monthly fecal sludge pollution load.

Statistics parameters	Daily pollution load (Tons/day)	Monthly pollutant load (Tons/month)
Minimum	173.69	5210.67
Maximum	272.41	8444.58
Average	211.64	6436.75
Standard deviation	36.43	1131.64

During the rainy season the average flow of the Funa river was 14.25 m^3/s.

Taking into account the dilution of the raw sample, the polluting load of microorganisms is given in the Table 4.

Table 4: Pollutant load of microorganisms during the rainy season.

Station	*Escherichia coli (UFC.m^3/100ml.j)*	*Shigella spp (UFC.m^3/100ml.j)*	*Salmonella (UFC.m^3/100ml.j)*	*Enterococcus ssp (UFC.m^3/100ml.j)*
AmRiF	170 049 525.10^4	7 125 000.10^4	4 702 500.10^4	207 099 525.10^4
PIRiF	230 850 000.10^4	14 250 000.10^4	7 125 000.10^4	57 000 000.10^4
AvRiF	193 324 050.10^4	7 125 000.10^4	1 425 000.10^4	140 120 250.10^4

The average flow of the Funa river during the dry season is 4.40 m^3/s. Taking into account the dilution of the raw sample, the polluting load of microorganisms is calculated and presented in Table 5.

Table 5: Pollutant load of microorganisms during the dry season

Station	*Escherichia coli (UFC.m^3/100ml.j)*	*Shigella spp (UFC.m^3/100ml.j)*	*Salmonella (UFC.m^3/100ml.j)*	*Enterococcus ssp. (UFC.m^3/100ml.j)*
AmRiF	99 294 800.10^4	1 614 800.10^4	1 025 200.10^4	80 665 200.10^4
PIRiF	132 000 000.10^4	3 520 000.10^4	6 160 000.10^4	44 000 000.10^4
AvRiF	103 545 200.10^4	1 760 000.10^4	1 320 000.10^4	51 334 800.10^4

Septic tanks are pre-treatment systems for faeces. The sludge is well mineralized when the system is working properly and does not generate odours. The presence of faecal odors is an indication of incomplete mineralization of faeces. *Escherichia coli* is an indicator of fresh feces. This confirms the non-mineralization of the sludge or either a malfunction of the pits or early emptying. (Sikulisimwa, 2011).

The presence in the environment of these microorganisms in large quantities, in waterways, sufficiently demonstrates the danger to which the population is exposed. This sludge from septic tanks still contains pathogenic microorganisms and cannot be discharged into the environment without systematic treatment. Microorganisms constitute pollution, the load of which is determined.

CONCLUSION

Contaminated water and lack of sanitation lead to the transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid fever and polio. Lack of sanitation services or poor management exposes affected people to avoidable health risks (Mohamed D. *et al*., 2023). The results of this study reveal that the waters of the Funa river is loaded with pathogens and can constitute reservoirs of *Shigella spp*, *Salmonella* and *Escherichia coli*. In a river whose water is used for several activities, the presence of pathogenic bacteria is a significant risk. This study made it possible to identify some pathogenic microorganisms responsible for certain common diseases in Kinshasa and to reveal the presence of reservoirs of pathogenic agents responsible for these diseases, which constitute a public health problem. Preventive measures should be taken as soon as possible by the local authorities to avoid future proliferation of infectious diseases such as typhoid fever, bacillary dysentery and cholera among the population in contact with this river. As water is one of the essential resources for life on our planet, each person has the obligation to ensure the preservation of the quality of this resource and to be informed about the problems of its contamination. Raising awareness can be considered to explain how local residents can participate in improving their living conditions and those of future generations. Monitoring water quality plays an important role in public health because it can prevent catastrophic damage to the soil, the human body and the health of the population in general. During the practice of aquatic activities, infectious diseases developed by ingestion of contaminated water could cause gastroenteritis, dermatitis, otitis externa and conjunctivitis (Souleymane D. et al., 2022). The success of faecal sludge management in the city of Kinshasa requires the support and participation of all layers of society. This can be achieved through awareness, sensitization and educating the populations. The systematic control of hygiene and sanitation conditions should be revitalized. Improving the current situation requires both the strengthening of institutional and technical capacities, with reference to technological and scientific innovations, without leaving aside the training and awareness of the population.

COMPETING INTERESTS

The authors declare that they have no competing interests

AUTHORS' CONTRIBUTIONS

The corresponding author MN was responsible for the design of the present work and the writing of the manuscript, OK contributed to the sampling, BR contributed to the correction of the manuscript, KO and WL contributed to the interpretation of the results and the correction of the manuscript. In addition to supervision, the CS author supervised the work as a whole and corrected the manuscript.

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