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Assessment of drinking-water quality in the Dibamba watershed (Douala-Cameroon)

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Abstract

Background: Residents of Douala including Dibamba watershed collect water from various points to fulfill their freshwater needs. However, it is known that many microorganisms, including parasites, bacteria, viruses, and even alga, are present in water where they form a complex ecosystem. These microorganisms are held responsible for most of the contamination in drinking water and related diseases that threaten health of many individuals.

Objectives: This study aims to determine the bacteriological and physicochemical quality of drinking water used by city dwellers in the Dibamba watershed.

Methods: A cross-sectional study was conducted in different communities living in the watershed. A total of 58 drinking water samples were randomly collected from a variety of water resources. The analyses were performed for temperature, Ph, and conductivity; and for bacterial parameters, namely, to trace the presence of organisms and opportunistic pathogens indicative of fecal contamination.

Results: Water used for consumption purposes have an acidic pH, low dissolved oxygen content, and shows high levels of microorganisms, testifying water pollution due to domestic wastewater discharged without any prior treatment, and coming from domestic, livestock and agricultural activities carried out in the watershed. These contaminated waters contain pathogenic species (*Shigella, Salmonella, E.Coli*, etc.) suspected of being the cause of waterborne infectious diseases in the watershed..

Conclusion: The results of our study show that 95% of tested drinking water samples are of low microbiological quality. They neither fulfill requirements of World Health Organization standards, nor fit for human consumption. Therefore, Decision-makers and Stake holders should implement practical actions to facilitate access to safe and sufficient drinking water in the watershed.

Keywords: Bacteriological quality; Physicochemical parameters; Opportunistic pathogens; Drinking water; Watershed; Dibamba; Cameroon

1 Introduction

It is the responsibility of governments through national water companies to deliver water which is adequate in quantity and acceptable in terms of safety. A significant proportion of the world's population use water for drinking, cooking and personal and home hygiene (UN-Water 2016). Thus, water is essential to sustain life and a satisfactory supply must be made available to consumers. However, in the past decade there has been a growing concern among the general public with respect to the safety (free of microorganisms) and aesthetic qualities (taste and odor) of drinking water supplies (Czajkowski *et al*. 2021). In fact, drinking water released into the distribution system becomes altered during its passage

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through pipes, open reservoirs, standpipes and storage tanks. Yet, bacteria may enter the distribution system through the failure to disinfect water or maintain a proper disinfection residual, low pipeline water pressure, intermittent service, excessive network leakages, corrosion of parts and inadequate sewage disposal (Khan *et al* 2021). That is why efforts should be made to achieve a drinking water quality with acceptable levels of chemical elements, but free of microbial risk. Failure to do so may expose the general population to water-related microorganisms and the potential health consequences are such that its control must always be of paramount importance and must never be compromised (Oluwadara et al 2021). In spite of the promises made during these two last decades and owing to the fact that the right to drinkable water is nowadays part of human rights, one-sixth of the world population still does not have access to safe drinking water (UN, 2021). According to WHO, in 2022, 6 billion people used safely managed drinking-water services – that is, they used improved water sources located on premises, available when needed, and free from contamination. The remaining 2.2 billion people without safely managed services in 2022 included: 1.5 billion people with basic services, meaning an improved water source located within a round trip of 30 minutes; 292 million people with limited services, or an improved water source requiring more than 30 minutes to collect water; 296 million people taking water from unprotected wells and springs; and 115 million people collecting untreated surface water from lakes, ponds, rivers and streams. Besides, sharp geographic and economic inequalities persist, not only between rural and urban areas but also in towns and cities where people living in low-income, informal or illegal settlements usually have less access to improved sources of drinking-water than other residents (WHO, 2023). In Douala for example, out of the estimated 4,063,200 inhabitants, only about 20% have access to drinkable water provided by Cameroon Water Utilities Corporation (Camwater), the national drinking water company. Thus, Douala dwellers do suffer a severe and permanent drinking water supply crisis (Priso and Nguendo-Yongsi 2024). The growing imbalance between supply and demand has led to continuing shortages and to the use of waters collected from springs, wells and even rivers and rainwater. Apart from quantitative shortages, the quality of drinking water is becoming a serious public health issue for the past few years. Information on the water quality status in many countries in Africa is not readily available, but it is assumed that, in Douala metropolis, the quality of water for drinking has deteriorated because of inefficient management of the piped water distribution system and because of direct discharge of untreated sewage into the Dibamba River, where raw water is collected. The contamination of natural water with fecal material, domestic and industrial waste may result in an increased risk of disease transmission to individuals who use those waters. Human pathogenic microorganisms that are transmitted by water include bacteria, viruses, and protozoa. Most of them usually grow in the human intestinal tract and reach out through the feces. Thus and ideally, drinking water should not contain any microorganisms known to be pathogenic or any bacteria indicative of faecal pollution. Since the presence of these microorganisms has been traditionally seen as an indicator of fecal contamination, tests are useful for monitoring the microbial quality or water used for consumption. Therefore, the present work focuses on physicochemical parameters and on bacterial agents with the most common indicators such as total coliforms, fecal coliforms and *Esherichia coli*. Thus, the purpose of this study is to use in one hand taste, turbidity and inorganic minerals, and in another bacterial counts to evaluate the microbial quality of water samples from sources and points of consumption.

2 Materials and methods

2.1 Study area and sampling sites

The study was conducted in the Dibamba watershed, located on the north-eastern outskirts of the city of Douala, the largest city in Cameroon and its economic capital. Located 3°45'19" North and 9°56'41" East, Douala features a tropical monsoon climate, typically features warm and humid conditions with an average annual temperature of 27.0 °C and an average humidity of 83%. With a growth rate of 4.7%, the population of the city was estimated to be 4,063,200 inhabitants in 2023. Even though Douala is the economic center of Cameroon, a large percentage of its inhabitants live below the poverty line. Recent data shows that about 30% of the population lives in poverty (INS 2019 ; MacroTends 2023). The total area of the city is about 41,000 ha, comprising 11 watersheds among which the Dibamba watershed (Figure 1). 40 to 60 of the metropolitan area is occupied by slums, and only 50% of housing in Douala can be considered as accessible by a paved road. 86% of the population uses onsite sanitation systems, with only 2% of the residents connected to offsite systems. As well, more than 80% are not connected to the drinking water supply network.

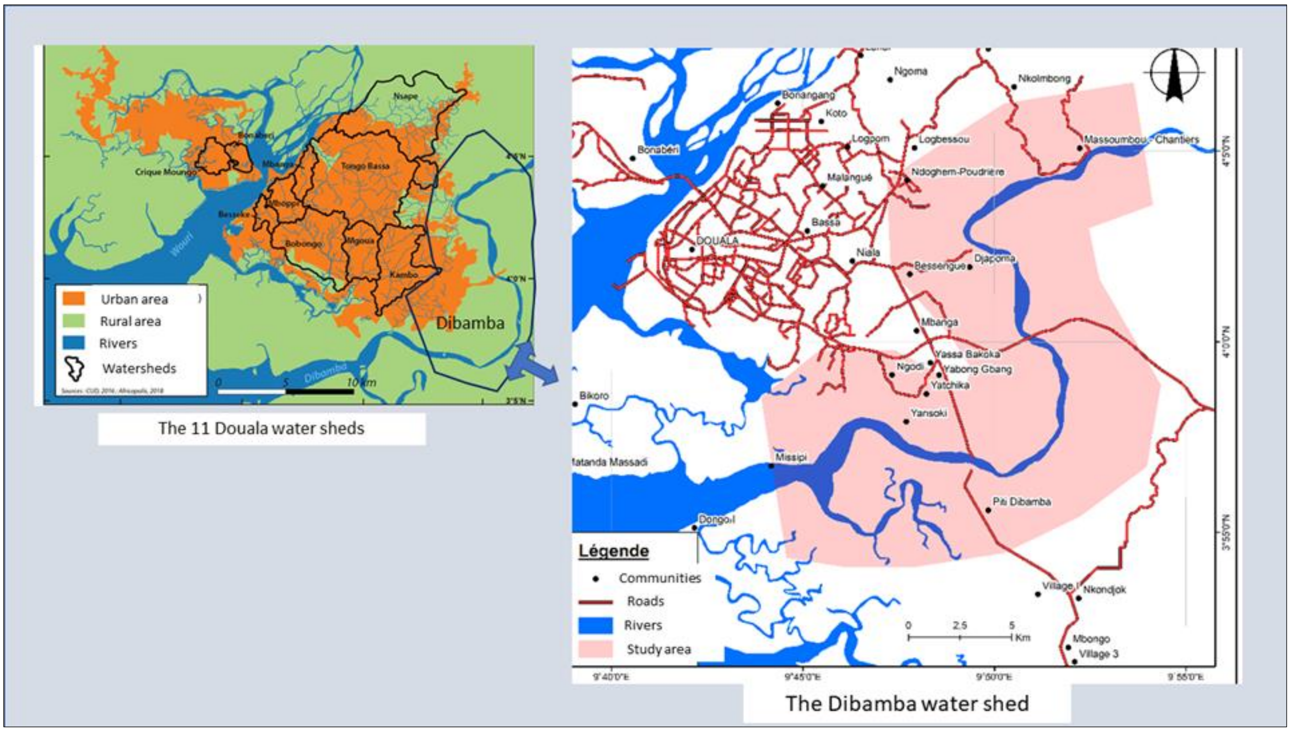

Figure 1 Location of the study area

2.2 Period of study and sampling sites

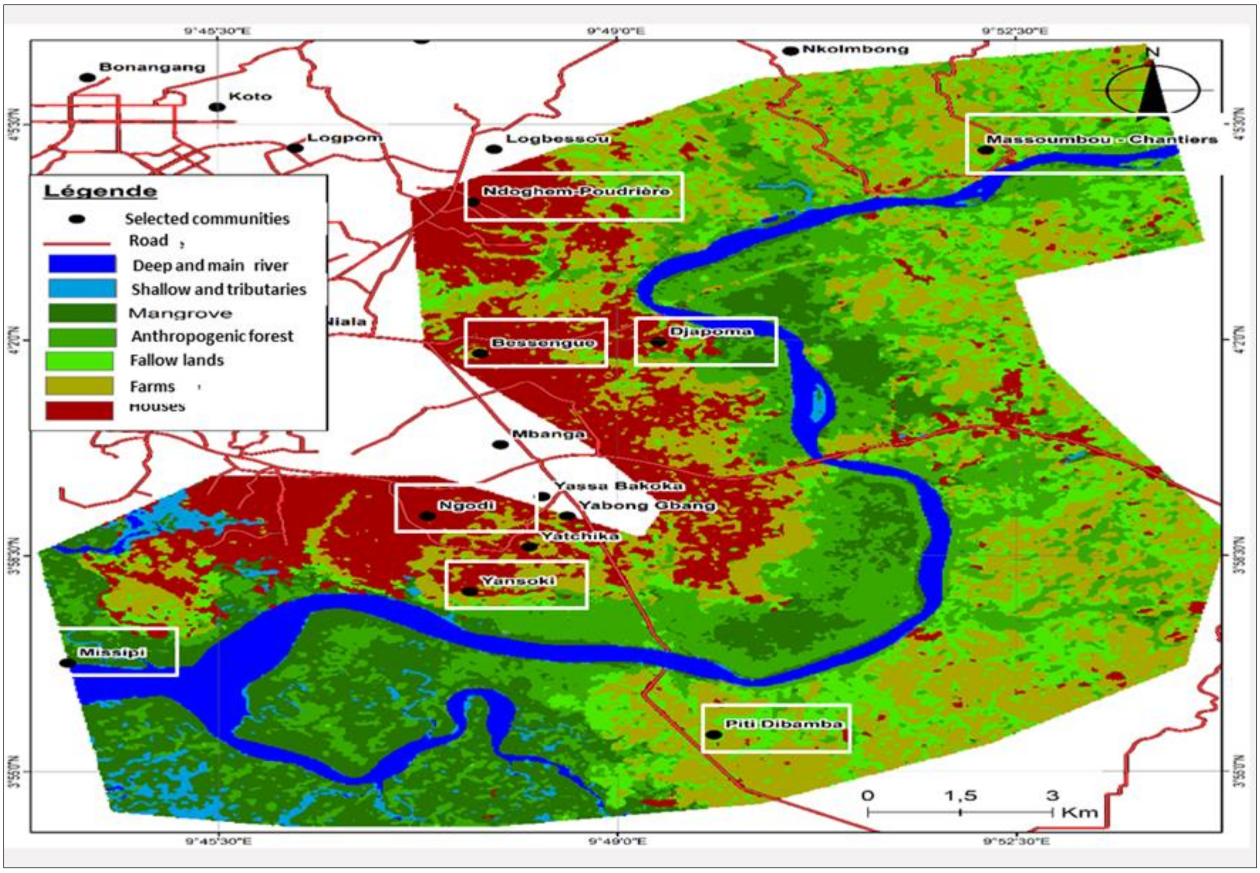

Figure 2 Surveyed communities

Field surveys and samples were carried out in May and June, which corresponds to the transition period between the dry season and the rainy season. Our sampling sites involved 8 of the 10 communities that make up the Dibamba water shed. Water was collected from wells, springs, and rivers within Our selection of these 8 areas for our research was based on three criteria: Firstly, the areas have a diversity of water supplies, representative of those found in the metropolitan area of Douala; secondly, they are all located within the newly urban extension displaying both urban and rural characteristics; lastly, enough demographic information was available to allow for adequate statistical design of the study, particularly the sample size determination. Those 8 selected communities are : Massoumbou-Chantier, Ngoghem-Poudrière, Bessengue, Djapoma, Ngodi, Yansoki, Missipi, Piti-Dibamba (Figure 2).

2.3 Samples collection

In each selected site, 500 ml of water was sampled in the form usually collected and consumed by inhabitants. For pipe borne water, taps were allowed to run for one minute before water was aseptically collected into sterile widemouthed glass bottles. Water from wells and springs was collected in pre-sterilized devices and then poured into sterile autoclaved polypropylene bottles. All collected samples were labeled with different codes for analysis. The same alphabet in the code represented water collected from the same source and the numbering that follows differentiates the geographical location (community) and the physical aspects of the water source (well managed, roughly developed, poorly managed). All samples were placed in an ice-cooler (4 °C), then transported to the laboratory where they were processed within four hours of collection. The designated investigation laboratory was Laboratory of the Institute of Geological and Mining Research in Yaoundé.

2.3.1 Microbiological examination of water samples

The microbiological analyses performed on the samples were total viable count. The total plate count was conducted by pour plate technique on plate count agar (PCA) and counting the colonies developed after the incubation at 37°C for 24 hours (APHA, 2012). The total coliforms were enumerated by the membrane filtration (MF) technique as described by APHA (2012). Detection of *Salmonella* and *Shigella* species were done by the enrichment of water samples on Selenite F broth, followed by isolation of the typical organism on selective medium, Xylose Lysine Deoxycholate Agar (XLD) (Awang *et al*. 2021). All colonies with different characteristics on M-Endo agar, Xylose Lysine Deoxycholate Agar (XLD) agar and Thiosulphate Citrate Bile salt sucrose Agar (TCBS) were subcultured onto Nutrient agar (NA) for purification. The detection of *Pseudomonas* was done by placing filtered cellulose nitrate membrane filters onto basic *Pseudomonas* Agar. The media was incubated at 42 °C for 40-44 hours. Later the agar was checked under ultraviolet light to detect pigment thought to be *Pseudomonas aeruginosa* or *Pseudomonas* ssp. To detect *E. coli*, all colonies of coliforms which showed characteristic occurrence on endo agar and mFC agar were subcultured on eosin methylene blue (EMB) agar, incubated over-night at 37 °C, and subjected to biochemical tests to identify *E. coli* (Bing-Mu Hsu et al. 2010; Thakur et al. 2018).Other enteric bacteria isolated on respective selective or differential media were identified on the basis of their colonial, morphological and Biochemical properties following Bergey's Manual of Determinative Bacteriology (Hensyl, 1994).

2.3.2 Determination of Water Quality Parameters

The samples were also evaluated on the physicochemical aspects to determine turbidity, total suspended solid (TSS) and pH: Turbidity in Nephelometric Turbidity Units (NTU) was measured using a HACH ratio turbidometer (Model 2100 AN, Co., USA). A total of 15mL sample was placed in a special container and inserted into the turbidometer for reading; as for pH, WTW pH 420 meters were used; The Total Suspended Solid (TSS) was assessed according to Mazlin et al. (2003), that is, a filter paper was weighed and later wet with sterile distilled water. The sample was stirred homogenously to ensure no precipitation. The sample was measured accurately and poured through the filter paper. The filtering was done using a suction pump. Next the filter paper was transfer into the oven for drying at 103 °C for 24 hours. The filter paper was left to cool before being weighed. The TSS was counted according to the formula: *mg of total suspended particles/ L = (A-B) x 1000 mL sample*. Besides, volumetry (assay method) was applied to the quantitative analysis of calcium, magnesium, chlorides and bicarbonates. Indeed, the calcium and magnesium contents of the samples are determined by complexometry, by titration with Ethylene Diamine Tetra Acetic Acid (EDTA). The chloride content of the samples was determined by argentometry (Mohr's principle by titration with silver nitrate). Finally, the bicarbonate content was determined by acid-base assay, by titration with sulfuric acid. Spectrophotometry was used for the quantitative analysis of nitrates, nitrites, ammonium, fluorides, total iron and sulfates by colorimetric assay.

2.4 Samples analyses

WHO has established guidelines for drinking water quality, which set maximum limits for different contaminants such as bacteria, viruses, chemicals, heavy metals, etc. These guidelines are regularly updated based on scientific advances and new knowledge on health risks. In this study, water quality was determined according to WHO standards set out in chapters 7 and 8 of the drinking water recommendations manual (WHO 2017). Regarding those recommendations, results were expressed in number of Colony Forming Units (CFU) per 100 ml of water. And given the high number of total coliforms, samples were classified into three levels: Good (0-20 total coliforms per 100 ml), Poor (21-100 total coliforms per 100 ml) and Poor (more than 100 total coliforms per 100 ml). For fecal coliforms, the levels used were: Good (0-5 fecal coliforms per 100 ml), Poor (6-20 fecal coliforms per 100 ml) and very poor (more than 20 fecal coliforms per 100 ml). Statistical techniques such as frequency distribution and Student's t test were used to analyze the data. Analyses of variance (ANOVA) at 95% confidence level were used to determine the significance difference. The data yield was analysed by Statistical Package Social Science (SPSS) programme version 17.0.

3 Results

A total of 58 drinking water samples were collected from different communities. Their distribution according to water sources is given in Table 1.

Table 1 Sampling collection according to water sources

		Communities						
Water sources	**Massoumbou-Chantier**	**Ngoghem-Poudrière**	**Bessengue**	**Djapoma**	**Ngodi**	**Yansoki**	**Missipi**	**Piti-Dibamba**
Taps	0	9	5	0	3	0	0	0
Wells	4	2	2	3	1	2	4	3
Springs	0	2	1	1	0	1	2	2
Rivers	2	1	1	1	1	1	2	2
Aggregate	6	14	9	5	5	4	8	7

3.1 Quantitative bacteriological analysis

Total Plate Count: Total plate count for total bacterial count performed for all water samples showed only 03 samples, i.e. 5.2% were within the WHO guideline value (<10 cfu/ml). Table 2 shows that 100% of wells and springs samples exceeded the guideline value.

Table 2 Source wise quality of total bacterial count

Water sources	**Percentage of samples compared with the WHO guideline value**		**Sampled water sources**
	Guideline value (< 10 cfu/ml)	**Excess to Guideline value (>10 cfu/ml)**	
Community Taps	03.4%	96.6%	17
Wells	01.0%	99%	21
Springs	0%	100%	9
Rivers	0%	100%	11

Coliforms count: Source wise distribution of coliforms count has shown that the 47.0 % of community taps and 100% of wells, springs, and rivers crossed the WHO guideline value i.e 0 cfu/100 ml (Fig. 3).

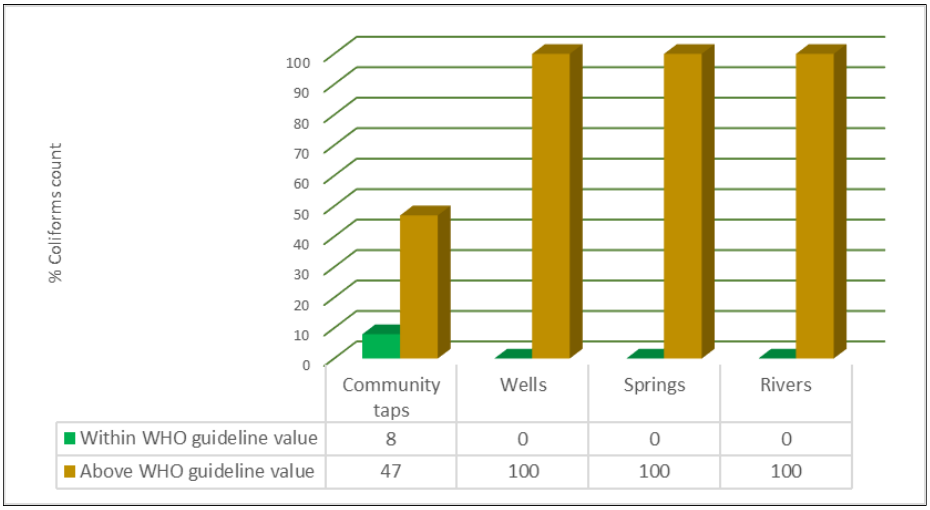

Figure 3 Source wise quality of Coliform count

3.2 Qualitative bacteriological analysis

Table 3 Distribution of bacterial isolates according to the source of drinking water

	Water sources							
	Communities taps		**Wells**		**Rivers**		**Springs**	
	frequency	**percentage**	**frequency**	**percentage**	**frequency**	**percentage**	**frequency**	**percentage**
¤ ***Enteric bacteria (Enterobacteriaceae)***								
Citrobacter freundii	2	06.6	13	13.5	...	...	8	07.3
Eschérichia coli	2	06.6	19	19.8	1	14.3	7	06.4
Klebsiella levinea	3	10.0	7	07.3	...	...	12	11.0
Shigella	1	03.33	1	01.0	1	14.3	1	00.9
Campylobacter	2	06.6	6	06.2	2	28.6	10	09.2
Klebsiella pneumoniae	12	40.0	14	14.6	2	28.6	13	11.9
Klebsiella oxytoca	...	...	...	...	1	14.3	...	...
Serratia	2	06.6	4	04.2	...	...	8	07.3
Clostridium Difficile	1	03.33	2	02.1	...	...	14	12.8
Proteus mirabilis	1	03.33	7	07.3	...	...	13	11.9
Proteus vulgaris	1	03.33	3	03.1	...	...	3	02.7
Providencia	...	...	2	02.1	...	...	8	07.3
Salmonella spp	3	10.0	13	13.5	...	...	10	09.2
Enterobacter aerogenes	...	...	2	02.1	...	...	1	00.9
Enterobacter asburiae	...	...	3	03.1	...	...	1	00.9
¤ ***Strict aerobic bacteria***								
Acinetobacter baumannii	3	42.8	5	17.2	1	25.0	2	09.5
Pseudomonas aeroginosa	2	28.6	10	34.5	2	50.0	16	76.2
Pseudomonas ssp,	2	28.6	14	48.3	1	25.0	3	14.3

From the microbiological analyses performed on the 58 samples, 242 isolates of enteric bacteria (Enterobactericeae) and 61 isolates of strict aerobic bacteria were obtained and identified. Of the 242 isolates of enteric bacteria, 19.5% was *Shigella*, 32.7% was *Salmonella*, 47.1% were *Escherichia coli* (Table 3). And of the 61 aerobic bacteria, 23.60% were Acinetobacter and 76.40% were *Pseudomonas*.

As presence of coliforms or fecal coliforms bacteria do not mention whether a sample will make someone unpleasant, we had to determine levels of contamination. The breakdowns for the four sources of water are illustrated in Figure 4. Let's mention that there were significant differences in total coliform counts, fecal coliform counts, fecal streptococcus and strict aerobic bacteria counts among the four sources ($p < 0.001$).

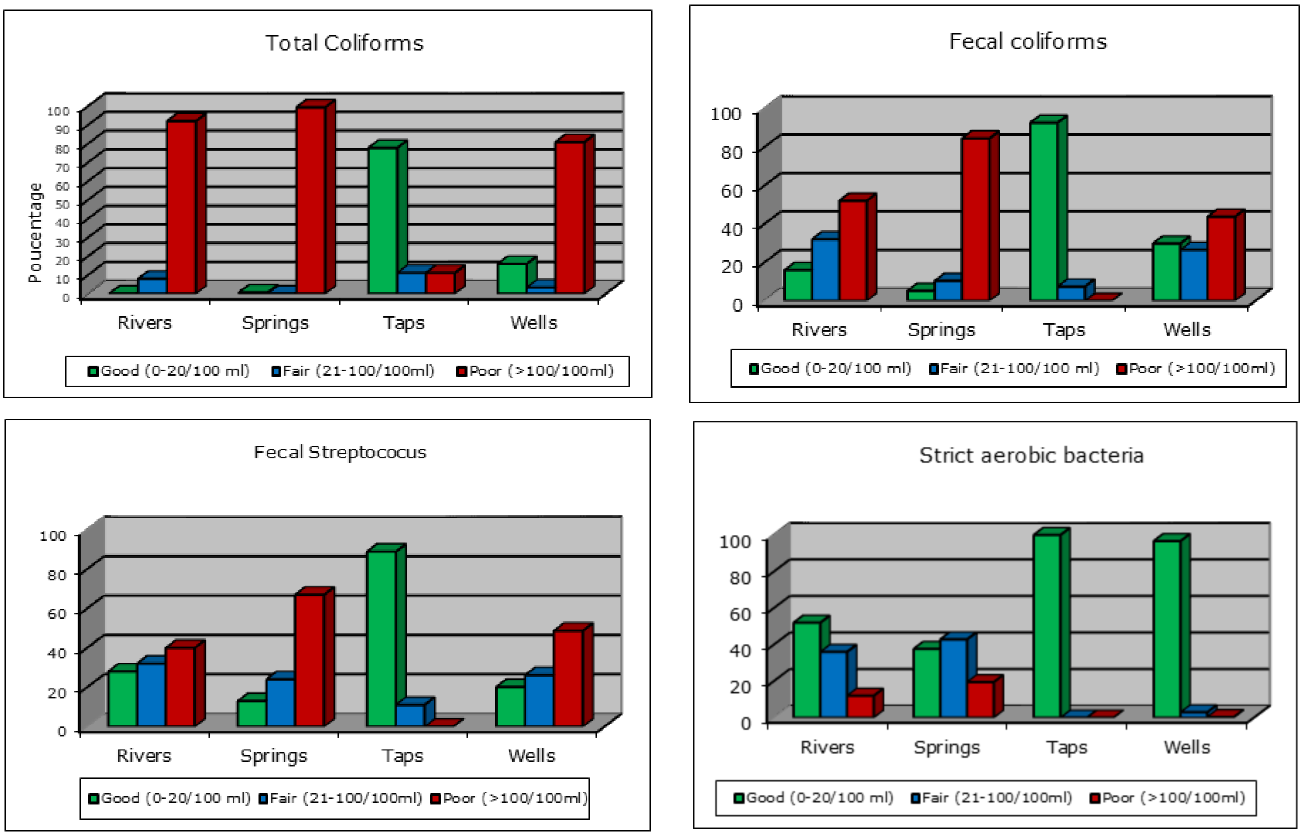

Figure 4 levels of drinking water quality in Dibamba, in terms of four bacteriologic variables counts

Drinking water or potable water being water that is safe and readily available for public health, whether it is used for drinking, domestic use, food production or recreational purposes, we wanted to determine the potability of each water resource in the Dibamba watershed. Figure 5 shows that water from springs and rivers are not drinkable at all. And for wells resource, only about 5% were drinkable versus 12% for taps.

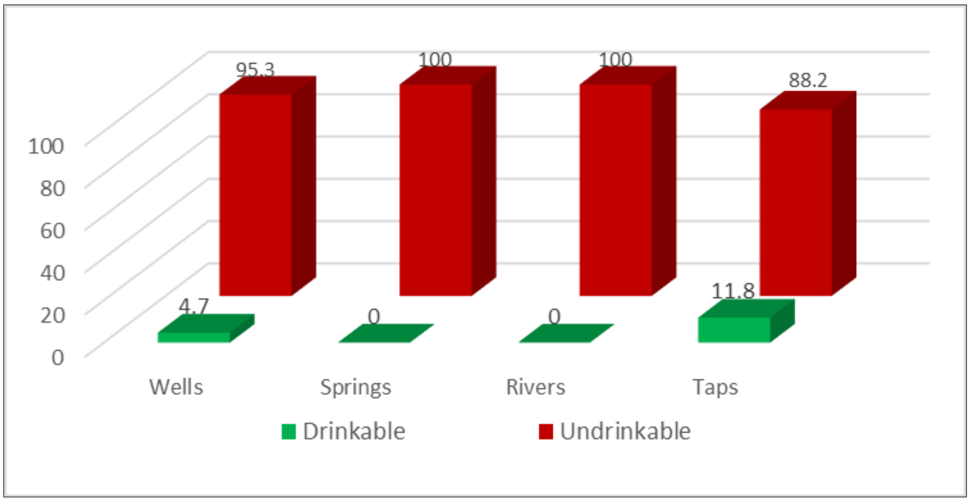

Figure 5 Distribution of drinking water resources in the Dibamba watershed according to their level of potability

3.3 Physicochemical analysis

The physical and chemical parameters exhibited considerable variations from sample to sample. All the measurements were carried out in the vicinity of temperature 30 °C. The observations are summarized in table 4.

Table 4 Physico-chemical parameters of water samples

Parameters	Standard value	Massoumbou	Ngoghem	Bessengue	Djapo ma	Ngodi	Yansoki	Missipi	Piti-Dibamba
Temperature (°C)	25	28.1	29.0	27.5	30.0	28.0	31.0	26.8	27.4
Conductivity (µS/cm)	200-800	460	375	850	300	830	370	700	940
Turbidity (NTU)	1-5	6	3	7	7	9	8	2	4
pH (pH unit)	6.5-8.5	8.7	8.8	7.4	8.3	8.6	6.8	7.9	8.7
TDS (mg/L)	150-250	280	310	179	280	248	317	390	277
Ca	100	110	113	115	200	78	129	171	83
Mg (mg/L)	50	55	43	48	120	89	42	60	52
Chloride (mg/L)	250	202	222	267	187	310	240	325	240
Phosphate (mg/L)	250	180	260	255	185	253	175	257	129
Nitrits (mg/L)	3.0	2.6	3.1	3.5	4.0	3.0	2.4	3.3	4.2
Nitrates (mg/L)	45	48	51	49	42	47	44	36	37
D.O. (mg/L)	5.7	7.2	5.9	6.5	5.9	7.1	5.7	6.1	6.4
C.O.D. (mg/L)	10.0	10.2	9.0	11.0	13.3	---	---	9.7	---
TDS: Total dissolved solids ; DO : dissolved oxygen ; COD.: Chemical oxygen demand									

4 Discussion

Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Therefore, the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water. This study highlights the presence of coliforms, fecal coliforms and *Escherichia coli*. Most coliforms are present in large numbers among intestinal flora of humans and other warm-blooded animals and are thus found in fecal wastes (Gonçalves et al 2021). Thus, they are used as an index of the potential presence of entero-pathogens in water environments. All samples showed positive results for the presence of *Streptococcus* and *P. aeruginosa*. This indicates that the water was not free from faecal contamination as *Streptococcus* is one of the indicators for faecal contamination in drinking water (Holcomb and Stewart 2020). Though *Pseudomonas* does not harm a healthy individual but only cause problem in individual with weak immune system (Weyand and Goronzy 2016), it is more reliable and safe if the drinking water does not show their presence. According to guideline values for bacteriological parameters, the total and fecal coliform bacteria should at least be absent, if not less than 10/100 ml water intended for drinking. Results clearly indicated that most of the natural water sources are highly contaminated. It might be due either to the failure of the disinfections of the raw water at the treatment plant or to the infiltration of contaminated water (sewage) through cross connection, leakage points and back siphonage. However, some studies have associated the occurrence of coliform bacteria in drinking water system with rainfall events (Manini et al 2022). According to these authors, rainfall is a complex variable and may have many different impacts on drinking water quality, as rainfall can be a mechanism that introduces coliform bacteria into the system through leaks and cross-connections and that it can wash dissolved nutrients into the watershed and increase organic carbon levels. Our data indicated that about 95% water resources qualities were not fit for drinking purposes. These findings are considerably higher than that of Sahelian region of Burkina Faso (30.2%) as reported by Guillemin *et al*. (1991). As the location of water resources can potentially be viewed as a modulating factor for microbiological quality, we assessed relationship between the physical aspects i.e. the environmental conditions and the quality of the water.

Physical characteristics of water were assessed. In this study, ***temperatures*** were in most cases above the WHO standard value, whereas we know that the best temperature for drinking water is room temperature (20°C) for maximum flavour, or chilled cold (6°C) for maximum refreshment. ***Electrical conductivity*** is a vital parameter when determining water quality. As salinity and temperature increase, conductivity also increases, which can have a negative effect on the quality of water. This is because the higher the conductivity, the higher amount of impurities (dissolved substances, chemicals, and minerals) are in the water (Egbueri et al 2023). The conductivity recorded here ranges between 300 and 940 µS/cm. This conductance range is not recommended for drinking water supplies, but up to 800 µS/cm is still considered safe. The high value of conductivity was recorded during the dry season whereas low value was recorded during rainy season. The relative high conductivity recorded during study may be attributed to the predominance of non leached substratum and the large size of the catchments area. A high level of conductivity reflects the pollution status as well as tropic levels of the aquatic body. ***Turbidity*** of water is the expression of optical property in which the light is scattered by the particles present in the water. Clay, slit, organic matter, phytoplankton and other microscopic organisms cause turbidity in lake water (Zimoch and Paciej 2020). High turbidity shows presence of large number of suspended solids. Turbidity in the Dibamba rivers recorded ranges between 2 NTU to 9 NTU. The high turbidity during summer season may be due to addition of large amount of sewage waste and pollutant from the surrounding neighborhoods. The increase in turbidity might also be due to the growing of aquatic vegetation and also by lowering the volume of water. What ever it is, turbidity itself is not a major health concern, however, high turbidity can interfere with disinfection and water treatment processes and provide a medium for microbial growth and contamination. Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The amount of total dissolve solid in our study ranges between 179 ± 6.48 ppm to 390 ± 32.1 ppm. Due to contamination of domestic wastewater, garbage, fertilizer… in the natural surface water body the value of TDS was reported to be high. Though an elevated TDS level can affect the taste of water, it is not usually harmful to human health. However, readings above 500 ppm require further investigation for toxic particles and heavy metals, and readings above 1000 ppm are considered unsafe for human consumption (Wang 2021). The ***pH*** of water is a measure of its acidity or alkalinity. Water with a pH below 7 is considered acidic, while water with a pH above 7 is considered alkaline. Ideal drinking water for human consumption has a pH between 6.5 and 8.5. Water pH that is too low can be corrosive and damage pipes and appliances, while water pH that is too high can taste soapy and can lead to limescale deposits. When it comes to human health, it is important to drink water with a balanced pH to maintain the body's acid-base balance.

Regarding chemical parameters, ***Calcium*** was one of the sought elements as it is most abundant ions in freshwater and is important in bone building. The amount of calcium in the sampled waters in Dibamba ranges between 78 ± 1.83 to 200 ± 2.8. The amount of calcium increases during dry season due to rapid oxidation /decomposition of organic matter.

The amount of ***magnesium*** recorded in the waters ranges between 42 ± 1.29 ppm to 120 ± 1.58 mg/L. Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium. The considerable amount of magnesium influence water quality. What ever it is, their presence in acceptable values is quite interesting because there is some evidence that calcium and magnesium in drinking water help protect against gastric, colon, rectal cancer, and pancreatic cancer, and that magnesium may help protect against esophageal and ovarian cancer (WHO 2009). Hard water may also serve a protective role against atherosclerosis in children and teens (Weaver, 2014; Al Alawi et al 2018). ***Nitrates*** are contributed to freshwater through discharge of sewage and industrial wastes and run off from agricultural fields. In our study, most samples crossed the standard values, which is worrying as we know that a growing body of literature indicates potential associations between nitrate/nitrite exposure and other health effects such as increased heart rate, nausea, headaches, and abdominal cramps (Bryan and Hans van Grinsven 2013; Ward et al 2018). The amount of phosphate recorded here ranges between 129 ± 0.02 mg/L to 260 ± 0.06 mg/l. The washing of large amount of clothes by laundry worker, as well as continuous entry of domestic sewage in some areas are responsible for increase in amount of phosphate in the watershed. Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate, leading to Hyperphosphatemia (Jereb et al 2017).

5 Conclusion

Drinking water is indispensable for human existence. The growing imbalance between water supply and water demand has led to chronic shortages and competition that have resulted in pollution and environmental degradation. The present study investigated water quality at sources and points of consumption of semi-urban communities. Most people of such areas use water directly from available sources, without any treatment and therefore are exposed to a variety of water related diseases since drinking water is contaminated with pathogenic bacteria. Apart from quantitative shortages, the quality of drinking water in the Dibamba watershed is becoming a serious public health issue. The major conclusion that emerges from our investigations is that the quality of water samples subjected to study was not acceptable from majority of physicochemical parameters while as per the bacteriological standards, the water needs to be treated before being used for domestic purposes. Thus, the potential risk of getting infected by water borne diseases is present. Based on these findings, it seems logical to suggest that current regulations be revised to include water quality testing both before and during the period of settlement, not only in our sampling sites, but in all the neighborhoods in which dwellers use water from underground sources. Indeed, the control of drinking water quality in distribution networks remains a major challenge in sub-Saharan urban areas, however comprehensive planning should be made for continuous monitoring of water resources, especially the contaminated ones. Further study is needed to determine factors that are responsible for the presence of coliforms in drinking water so that effective intervention can be initiated.

Compliance with ethical standards

Acknowledgments

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Data availability statement

All relevant data are included in the paper.

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