

Physico-Chemical and Microbiological Evaluation of Drinking Water Points in the Manianga District, Commune of Djiri (Brazzaville-North) and the Commune of Kintélé (Pool Department), Republic of Congo

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Abstract : This present paper aims to assess the physico-chemical and microbiological quality of drinking water points in the Manianga districts, commune of Djiri and Kintélé in the Pool Department. Ten (10) water samples (three (03) and seven (07) sources) were collected in December 2022 during the long rainy season, which would correspond to the groundwater recharge period, for physico-chemical and microbiological analyzes according to standard methods in the laboratory of the Institute for Research in Exact and Natural Sciences (IRSEN). The results obtained were compared to the drinking water quality standards recommended by the World Health Organization (WHO). It appears that from laboratory results all the elements analyzed are compliant, except the pH which presents values lower than the WHO standard for drinking water. It varies between 5.79 and 6.02. This would reflect the acidic nature of the water in the study area. Microbiologically, except for two (2) water points, eight (8) water points are loaded with total coliforms (78 CFU/100ml), fecal coliforms (68 CFU/100ml) and fecal streptococci (14 CFU/100ml). Therefore, these eight (08) waters points do not comply with WHO regulations on the microbiological quality of drinking water (0 CFU/100ml). This contamination is perhaps attributed to the effluent's infiltration from traditional toilets near contaminated water points into the groundwater. They are of poor quality and unsuitable for human consumption without prior treatment.

Keywords: *physico-chemical, microbiological, commune of Djiri, commune of Kintélé, hydrochemistry*

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1. Introduction

Groundwater resources are essential to human health and the socio-economic development of populations. they guarantee life, good health and offer the means to improve the living conditions of populations [1]. The water problem is acute, both globally and in countries with low water resources. The challenges are enormous, particularly from the point of view of supply, distribution of drinking water and in certain cases inherent treatments [2].

Studies carried out by Matini [3], Eblin [4], Traoré [5]

and Ouattara [1] on water resources in several African countries have reported numerous pollution sources of surface and groundwater waters. These sources of pollution are essentially due to strong population growth associated with uncontrolled urbanization and uncontrollable socio-economic conditions in African cities. As a result, it is observed an increased water needs, waste production and the discharge of a large volume of wastewater into receiving environments. The water purification envisioned for human consumption must receive particular attention. Indeed, water envisioned for consumption must not contain dangerous chemical substances or harmful pathogenic germs likely in the more

or less long term to damage the human health [6]. Thus, monitoring environmental quality becomes a major public health issue in these cities [4].

In Brazzaville, capital of the Republic of Congo, the drinking water distribution is ensured by “La Congolaise Des Eaux (LCDE)”. It is a public company which the goal is to treat, distribute and market drinking water to satisfy the population needs. Unfortunately, it struggles to serve the ever-growing Congolese population with drinking water. Indeed, certain neighborhoods in Brazzaville city are not supplied with drinking water due to lack of distribution network. This is the case of the Manianga and Kintélé districts in the commune of Djiri and in the department of Pool respectively. Some residents of these neighborhoods obtain water from wells, springs and surface water sources. This water is used for domestic practices and as drinking water. In addition, the lack of an adequate sanitation system leads to the presence of human and animal waste, commercial and industrial residues in certain areas of these neighborhoods. Far ahead, it could potentially contribute to reduce the water points quality

and cause the proliferation of water-related diseases. Therefore, the present work is focused to assess the physicochemical and microbial quality of the drinking water. An approach integrating classical hydrochemical methods was used to analyze and understand the results obtained by using the WHO drinking water guidelines.

2. Material and Methods

Study area

The districts of Manianga and Kintélé are located on the second northern exit from Brazzaville (Figure 1). Manianga extends from the Djiri river to the water tower in the Ngamakosso district on the right bank of the Djiri. While, Kintélé extends from the Djiri river to the viaduct (Figure 1) on the left bank side. The boundary between the two districts is marked by the Djiri river. Manianga belongs to the district 9 (Djiri), however Kintélé is located in the Pool-Nord department [7].

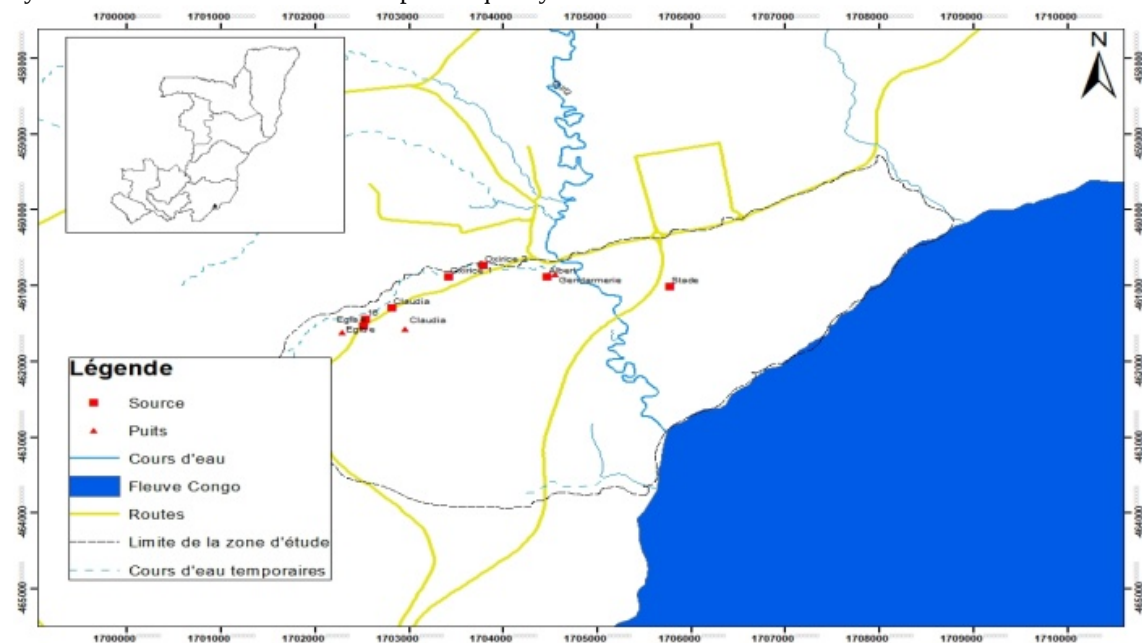


Figure 1. Geographic map of the location of the study area

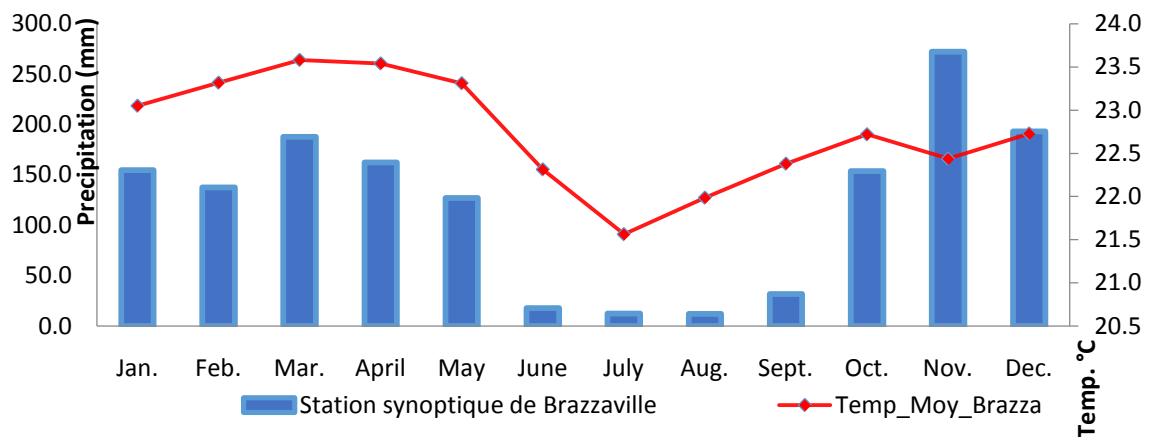


Figure 2. Monthly average precipitation at the Brazzaville station for the period (1987-2022) [10]

Geomorphology, the study area is linked to the physical state of the relief of a land. The relief of the districts of Manianga and Kintélé is essentially made up of hills covered by grassy savannahs with sandy soils [8].

The climate prevailing in the study area is that of the Brazzaville city (Figure 2). It is a humid tropical climate characterized essentially by two main seasons, where it is observed a long rainy season from October to May, marked by a period of rainfall break from January to February and a long dry season from June to September [9].

Precipitation is moderate between 1100 and 1800 mm of rain per year. The yearly average temperature is around 25°C and humidity is always above 70% [10].

Geologically, the study area is mainly made up of sandy sedimentary series called the Batéké sands [11]. The Batékés sands are ocher sands made up of hematite (Fe_2O_3) and quartz (SiO_2). They are sandy-clayey, weakly clayey, poor in organic matter and with high permeability [12]. Batéké sands are made up of hydromorphic soils, ferrallitic soils, ferruginous soils and podzolized soils. Then, the most representative types of soils are ferrallitic soils and podzolized soils [12].

On the hydrogeological point of view, the study area is made up of the aquifer of the Batékés sand series. This aquifer is of alluvial type. The waters of the aquifers are weakly mineralized, and their pH varies between 5.3 and 6 [13].

Sampling methodology

Sampling water points is an important process that must be carried out well to guarantee the reliability of the analysis results [14]. This was done after the survey of the study area and the selection of water points in relation to the population's attending, so as to cover all the water points used (Figure 3).

A sampling campaign was carried out during the long rainy season in December 2022 (Figure 3). These samples were then analyzed according to the standards in force of the French Standardization Agency (AFNOR) [15] at the IRSEN laboratory. A GPS (Garmin eTrex 32X) was used to determine the geographic coordinates of each structure. we used polyethylene bottles of 1.5 liter which were prepared and washed carefully, then rinsed with distilled water. The samples taken were labeled then stored in a cooler containing ice at 4°C during their transportation to the IRSEN laboratory with an information sheet for each sample.

Physicochemical analyzes

For each sample, the temperature, electrical conductivity and pH were recorded in situ while the other parameters were measured in the laboratory according to the analyzes methods recommended by AFNOR [15]. This made it possible to collect 20 water samples from three (03) wells and seven (07) sources. The results of chemical analysis are expressed in mg/l.

In order to properly identify the hydrochemical facies and to have an indication of the qualitative aspect of the waters studied, the graphic representation of the analyzes results was an essential tool. To achieve this goal, we used the Piper diagram. This type of diagram makes it possible to represent several water samples simultaneously and to characterize the hydrochemical facies of the water. It is

composed of two triangles, representing the cationic facies (Ca^{2+} , Mg^{2+} , K^+ , Na^+) and the anionic facies (Cl^- , NO_3^- , SO_4^{2-} , HCO_3^-) and a diamond summarizing the overall facies on which is plotted the intersection of the two lines coming from the points identified on each triangle [2].



Figure 3. Some sampling points

Bacteriological analyzes

The importance of this bacteriological analysis of water is not to carry out an inventory of all the species present, but to search either for those which are likely to be pathogenic or, which is often easier, for those which accompany and which are in greater numbers often present in the intestine of mammals and are by their presence indicative of fecal contamination [15]. This analysis is important because the bacteriological quality of water requires permanent controls and represents the most frequent cause of unpotable water [15].

The germs sought in the waters of the ten (10) water points studied are total coliforms, fecal coliforms (*E. Coli*) and fecal streptococci (ST) by the limb filtration method. For the essential water sampling for the bacteriological analysis, we used 1.5 liter polyethylene bottles. At the time of sampling, we open the bottle and introduce it into the 30 cm deep of the well, taking care not to contaminate the sample. Then, we remove the bottle filled with water. The cord is detached, and the bottle is closed under the required aseptic conditions until analysis. For the case of sources, the bottle is filled after rinsing three (03) times with the sample. The method used to detect bacteria in the water was based on the so-called filter membrane method, according to "AFNOR" standards [15].

Data processing

Hydrochemical and microbiological results were compared to WHO water quality standards [16] to assess the suitability of water points for drinking and domestic use. Hydrochemical facies indicating the dominant cations and anions in the waters were obtained using the Piper diagram. The quality of the physicochemical analyzes was controlled using the ionic balance for the reliability of the results. The analyzes results are reliable for ion balance values between -10 and +10%.

3. Results and Discussion

Physico-chemical characteristics

The results of the measured physicochemical parameters of the water are presented in Table 1. The values of these parameters are the results of sampling from the December 2022 campaign. The descriptive statistics are presented in Table 2. The temperature varies between 25.4°C and 28.5°C with an average of $26.9 \pm 1.1^\circ\text{C}$. The temperatures of the study area are similar to those of Rodier [26] for an average water temperature of 30°C in the humid tropics. Water temperature is an ecological factor with a significant environmental impact [17]. The growth and development of aquatic organisms, particularly microbial growth and development, chemical and biochemical reactions, density, viscosity, solubility of gases in water and dissociation of dissolved salts are all dependent on temperature [18]. Temperatures above

25°C obtained in our study do not present a risk for consumers. These temperature changes are strongly influenced by environmental conditions linked to the local geographical situation, the geology of the area, the hydrology of the ecosystem and especially the climate [19]. The pH varies between 4.9 and 6 with an average of 5.4 ± 0.3 (Table 2) indicating that the water points of Manianga and Kintélé are predominantly acidic.

The values of electrical conductivity and TDS vary between 8.0 and 20.0 $\mu\text{S}/\text{cm}$ and 4.0 and 16.0 mg/L with average values of $11.8 \pm 3.7 \mu\text{S}/\text{cm}$ and 8.0 mg/L respectively (Table 2). These waters are very weakly mineralized. The low salinity of groundwater is probably due to the too short flow path in the aquifers and to dilution effects during rainfall events. Wells and springs are the water points considered in this study. The low mineral content can also be explained by the fact that the waters come from poorly soluble mineral geological structures.

Table 1. The results of the physicochemical parameters (All concentrations are mg/L except T (°C), EC ($\mu\text{S}/\text{cm}$) and THT (mg CaCO_3/L)

Samples	pH	T	EC	TDS	Ca^{2+}	Mg^{2+}	THT	K^+	Na^+	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^-	Fe^{2+}	Mn^{2+}	PO_4^{3-}	Al	Pb
Source 16	4.9	25.5	16.8	8.2	0.4	0.6	2.4	0.3	2.1	1.8	1.3	6.8	0.6	0.2	0.1	0.02	0.0	<0.01
Source Church	5.6	28.5	10.3	4.0	1.3	0.3	4.7	0.2	0.6	1.1	0.8	4.1	0.5	0.1	0.01	0.02	0.0	<0.01
Well Church	5.0	27	9.5	4.6	2.5	0.9	9.0	1.2	2.3	8.5	2.6	6.4	0.03	0.1	0.02	0.03	0.0	<0.01
Source Claudia	5.3	26	9.0	7.1	1.9	0.4	6.5	0.2	0.8	1.5	1.2	5.9	0.6	0.1	0.02	0.1	0.0	<0.01
Source Albert	5.2	27	10.3	5.0	1.4	0.3	4.5	0.2	0.6	1.1	0.8	4.2	0.4	0.1	0.01	0.02	0.0	<0.01
Gendarmerie well	6.0	27.5	20.0	16.0	5.0	1.6	17.2	2.0	6.2	6.9	2.5	24.4	13.6	0.1	0.4	1.2	0.0	<0.01
Claudia Well	5.4	28	8.0	9.0	1.3	0.3	4.2	0.1	0.5	1.0	0.8	3.8	0.02	0.1	0.01	0.1	0.0	<0.01
Source Stadium	5.2	25.4	11.9	12.2	3.0	0.6	9.9	0.3	0.3	2.3	1.8	9.1	0.9	0.02	0.01	0.1	0.0	<0.01
SOx1	5.4	26.5	10.9	7.8	2.2	0.3	7.0	2.5	0.4	1.2	2.8	5.5	0.01	0.1	0.01	0.6	0.0	<0.01
SOx2	5.6	27.8	11.6	5.7	1.5	0.3	5.1	0.2	0.7	1.2	0.9	4.7	0.5	0.1	0.01	0.4	0.0	<0.01

Table 2. Descriptive statistics of physicochemical results

Settings	Min	Max	Avg	SD	WHO standards
pH	4.9	6.0	5.4	0.3	6.5-8.5
T (°C)	25.4	28.5	26.9	1.1	25
EC ($\mu\text{S}/\text{cm}$)	8.0	20.0	11.8	3.7	<350
TDS (mg/L)	4.0	16.0	8.0	3.7	<200
Ca 2+ (mg/L)	0.4	5.0	2.0	1.3	<70
Mg 2+ (mg/L)	0.3	1.6	0.6	0.4	<50
THT (mg CaCO_3/L)	2.4	17.2	7.0	4.2	<150
K + (mg/L)	0.1	2.5	0.7	0.9	<12
Na + (mg/L)	0.3	6.2	1.5	1.8	<150
Cl- (mg/L)	1.0	8.5	2.7	2.7	<200
SO4 2- (mg/L)	0.8	2.8	1.5	0.8	<250
HCO3- (mg/L)	3.8	24.4	7.5	6.2	<200
NO3 - (mg/L)	0.0	13.6	1.7	4.2	<50
Fe 2+ (mg/L)	0.0	0.2	0.1	0.0	<5
Mn 2+ (mg/L)	0.0	0.4	0.1	0.1	<1
PO43- (mg/L)	0.0	1.2	0.2	0.4	<5
Al (mg/L)	0.0	0.0	0.0	0.0	<0.3
Pb (mg/L)	<LD	<LD	-	-	0.01

The total hardness (TH), measuring the contributions of calcium and magnesium to the mineralization of water points, was determined, and is expressed in quantity of

CaCO_3 . In the context of this study, the hardness values vary between 2.4 and 17.2 mg CaCO_3/L with an average of 7.0 mg CaCO_3/L (Table 2). Water with a hardness less than 60 mg/L is considered soft. Waters with a hardness between 60 and 150 mg/L are moderately hard and those with a hardness greater than 150 mg/L are considered hard. The waters of the study area are fresh.

The concentrations of major cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) are below the WHO guideline values (WHO, 2017). The order of cation abundance is $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ with concentrations equal to 0.1 meq/L, 0.06 meq/L, 0.05 meq/L and 0.02 meq/L respectively. The anion concentrations are 0.12 meq/L, 0.03 meq/L, 0.07 meq/L and 0.03 meq/L for HCO_3^- , SO_4^{2-} , Cl^- and NO_3^- respectively. The order of abundance of major anions is $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^-$. Just like major cations, the contents of major anions are all lower than the WHO guideline values for drinking water (WHO, 2017). The Piper diagram was used to determine the hydrochemical types of water points in the study area (Figure 3).

Hydrochemical types of water points

The hydrochemical classification of the waters studied (Figure 3); It appears that the waters Source Stade, Puits Claudia, Source Claudia, Source Ox2, Source Eglise, and Source Albert are bi carbonated calcic and magnesium; the waters of Source Ox1, Puits Eglise, Source

Gendarmerie are chlorinated and calcium and magnesium sulfate; Source 16 is Bi carbonate sodium and potassium / Bi carbonate calcium and magnesium.

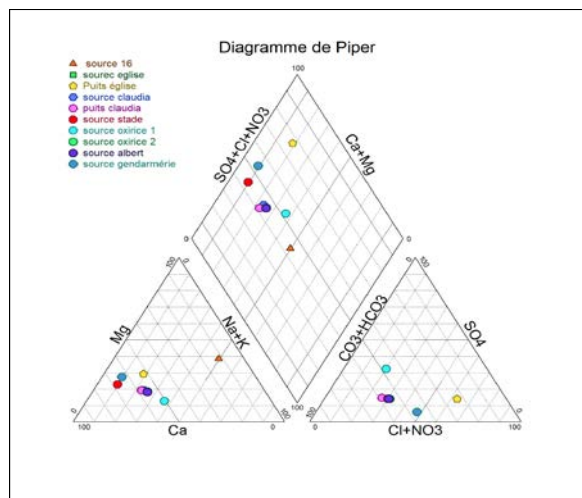


Figure 4. Hydrochemical facies of water points in the districts of Manianga and Kintélé

Microbiological quality of water points.

Total coliform count

Figure 4 shows the total coliform load in the ten water samples analyzed. The waters of springs and wells (Source 16, Source Albert, Puits Eglise, Puits Claudia, Source Eglise, Source Ox 2, Source Claudia and Puits Gendarmerie contain total coliforms at concentrations respectively of 37, 11, 10, 10, 6, 2, 1 and 1 CFU / 100 ml. However, the Ox 1 and stadium sources are free of contamination. Regarding the contaminated sources, the water from spring 16 was the most contaminated while the Claudia spring was. was the least polluted Concerning the Claudia and church wells being the most contaminated compared to the gendarmerie well.

Consequently, according to the WHO potability standard in relation to this parameter, only water from the Ox 1 and Stade sources can be consumed among the waters analyzed.

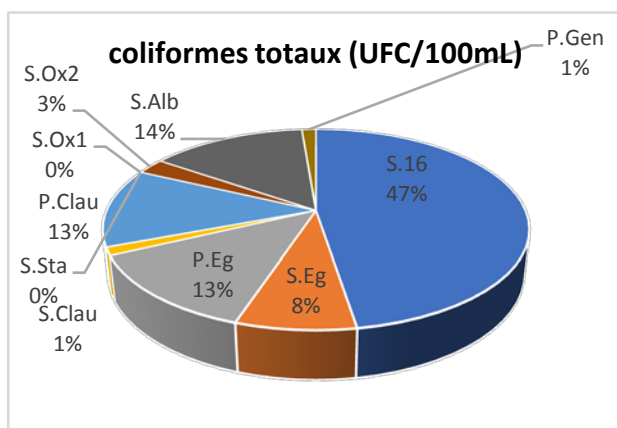


Figure 5. total coliform load in water samples

Fecal coliform (FC) enumeration

Fecal coliform concentrations in the ten water samples (Figure 5). The Source 16 spring water sample was the most contaminated with a load of 44 CFU/100 ml, followed by the Claudia well sample with a load of 13

CFU/100 ml. Then, the samples from church wells, church sources and Ox 2 were the least contaminated with respective loads of 8, 2 and 1 CFU/100 ml. On the other hand, the water samples from the Ox 1, Albert, Claudia, gendarmerie and Stade sources do not contain fecal coliforms. Thus, the waters from sources 16, Albert, Ox 2, gendarmerie, stadium and the Claudia well are unfit for human consumption if we apply the WHO potability standard in relation to this parameter.

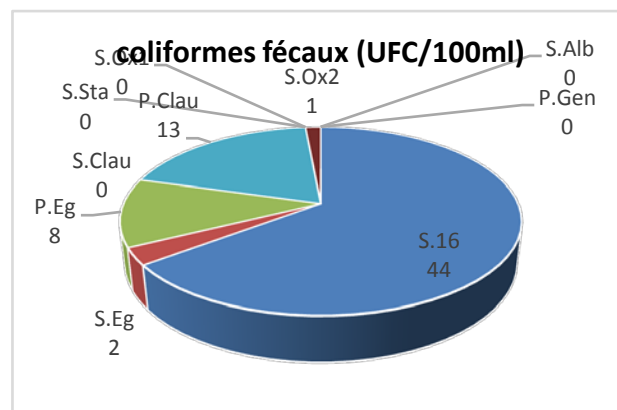


Figure 61. fecal coliform load in water samples

Enumeration of fecal streptococci (CF)

Figure 6 shows the concentration of fecal coliforms in the ten water samples. Water samples from the gendarmerie well, sources 16, Albert, Eglise, Ox 1, Ox 2, Claudia and Stade give 0 CFU/100 ml. These waters are not contaminated by fecal coliforms. As for the samples from the Claudia and Eglise wells, there were 13 and 1 CFU/100 ml respectively. Thus, if we apply the WHO potability standard in relation to this parameter, the water from the Church and Claudia wells is unfit for human consumption.

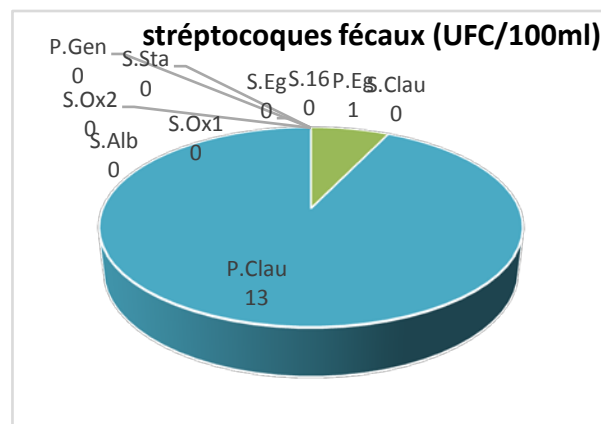


Figure 7. Load of fecal coliform colonies in water samples

Summary diagram of enumeration results

Figure 7 shows the variation in total coliform, fecal coliform, and fecal streptococcal loads in water samples. It appears that source 16 is the most polluted with a total germ load of 81 CFU/100ml. But the Claudia spring and the gendarmerie well are the least polluted with respectively total germ loads of 1 and 1 CFU/100 ml. However, the Claudia, church wells, the church, albert and oxirice 2 sources respectively have total germ loads of 36, 19, 8, 11, 3 CFU/100 ml.

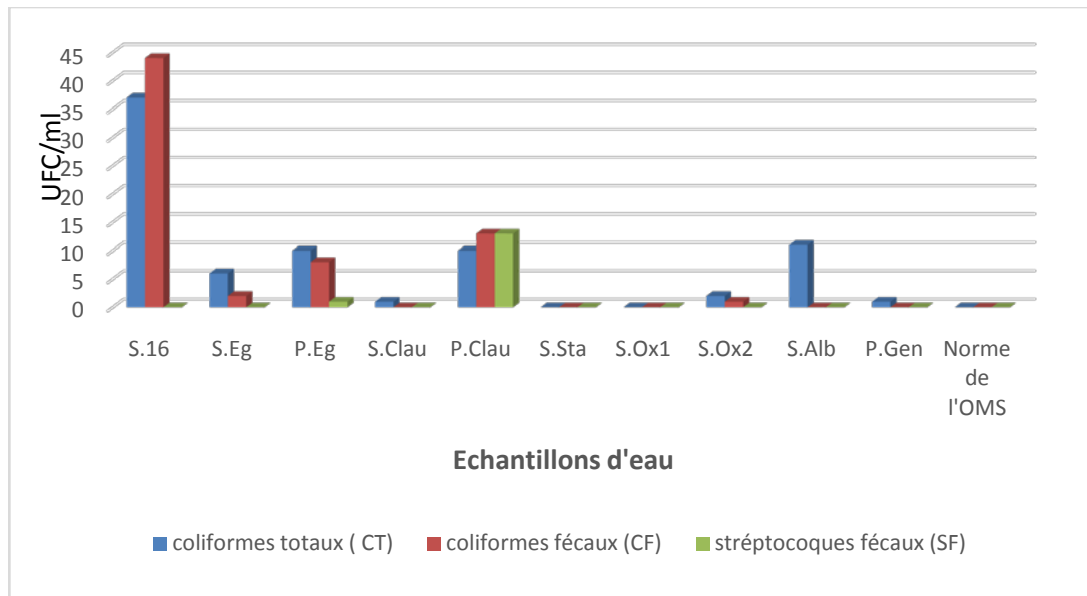


Figure 8. variation in microbial loads in water samples

4. Discussion

In recent years, the continued deterioration of groundwater around the world has made it necessary to protect aquifers. The quality and quantity of groundwater have deteriorated due to recent improvements in the industrial and agricultural sectors [17]. Many activities unintentionally or intentionally release pollutants into the environment, leading to degradation of groundwater quality and contamination of aquifers [18,19]. In terms of groundwater resources, the most important goal for developing countries like India is to provide safe drinking water by 2030, which has been accepted as a sustainable development goal by all states. members of the United Nations in 2015 to answer the question of the dangers associated with standard groundwater. Therefore, proper assessment of groundwater vulnerability by developing an optimal framework is an essential step to protect groundwater quality. Recently, many methods, including statistics, machine learning, and artificial intelligence, have been used in hydrology and groundwater vulnerability studies to measure and manage groundwater resources [20,21]. Analysis of the waters of Manianga and Kintélé showed that the water is acidic. The acidity of this water is in agreement with the results obtained by Obami [22] from the Mbé plateau. This aspect of groundwater has been reported in several studies, including Soro [23] in the Bendama basin of Tortia, where the average well water pH was 5 and Ahoussi [24] in Bondoukou. This change in acidity may be due on the one hand to the evaporation of well water, which is very pronounced in the dry season, and on the other hand to the concentration of H ions, particularly free CO₂ in the soil. Indeed, in the humid tropics, this acidity comes mainly from the decomposition of plant organic matter and the production of carbon dioxide in the first layer of the soil. The presence of soil CO₂ in water promotes the hydrolysis of silicate minerals and the formation of HCO₃ ions [25]. These waters are very weakly mineralized, with conductivity values below 400 μ S/cm.

Average conductivity values are between 8 μ S/cm and 16 μ S/cm. The low salinity of groundwater during the rainy season is due to the dilution effect of rainwater, as most water points are undeveloped and receive runoff directly. The average water temperature in the sampling area varies between 25.4°C and 28.5°C. Our results are similar to those of Rodier [26] for an average water temperature of 30°C in the humid tropics. Water temperature is an ecological factor with a significant ecological impact [27]. The growth and development of aquatic organisms, particularly microbial growth and development, chemical and biochemical reactions, density, viscosity, solubility of gases in water and dissociation of dissolved salts are all dependent on temperature. Temperatures above 25°C obtained in our study do not present a risk for consumers. These temperature changes are strongly influenced by environmental conditions linked to the local geographical situation, the geology of the terrain crossed, the hydrology of the ecosystem and especially the climate [27]. This study in the suburbs of Brazzaville allowed us to highlight fecal contamination of the water and to evaluate the contamination of the water from a bacteriological point of view. This is how we looked for pathogens that could be the basis of the feces of humans and warm-blooded animals which are more easily maintained in the external environment, these are: total pathogens, fecal pathogens, coliforms fecal (*E. coli*), total coliforms and enterococci. The waters studied are of good physicochemical quality when compared with the values of drinking water as set out in the guidelines of the World Health Organization [28,29]. This study showed that eight (08) water sources contain high numbers of pathogenic bacteria such as fecal coliforms (*E. coli*), total coliforms and enterococci, which are a common contamination of human sewage [30]. Fecal coliforms are of animal or human origin and their presence in water indicates recent fecal contamination [30]. Fecal coliforms or thermotolerant coliforms are a subgroup of total coliforms capable of fermenting lactose at a temperature of 44.5°C. The species most commonly associated with

this group of bacteria is *Escherichia coli*. *Escherichia coli* is used as an indicator of the microbiological quality of water because it contains mainly bacteria of fecal origin and, to a lesser extent, certain species of the genera *Citrobacter*, *Enterobacter* and *Klebsiella* (8, 9,35). Fecal coliforms and enterococci, originating primarily from animal or human fecal contamination, can cause gastrointestinal illness. Every 100 ml of drinking water should be free of pathogenic bacteria before drinking. The presence of fecal coliforms (*E. coli*) and/or enterococci tells us that it is fecal matter from feces, septic tanks or toilets. This contamination is more pronounced in water from wells and some springs, except oxirice 1 and stadium springs, and is believed to come from toilets, sewage, surface water and solid waste near wells and springs. Microbial contamination of these waters poses significant health risks to residents and makes these polluted waters unfit for human consumption. The high levels of total coliform bacteria in the water indicated that the water was polluted by domestic sewage, the proximity of wells and springs to toilets, and infiltration of surface water into wells. It should be noted that most wells and springs are built without borders or covers into which rainwater and runoff carrying all kinds of waste (manure) can easily flow. Collecting water using buckets or any rusty containers left on the ground will further cause contamination of well water. All these reasons were found in the work carried out by Kisanguka [31], which showed that 83% of well water was contaminated with microorganisms. These results corroborate those of Malangu [32] according to which the rivers and wells of Lubumbashi were 90% polluted, and of Mulongurungu [33]. Overall, all wells and water sources sampled appeared to show signs of fecal contamination and, with the exception of oxirice 1 and stadia sources, were not susceptible to water intended for human consumption. All samples analyzed had more or less significant concentrations of total coliforms, fecal coliforms (*E. coli*) and enterococci, which did not correspond to the guideline values issued by the World Health Organization [16] for drinking water. Undeveloped water points are numerous and often equipped with temporary covers. These uncontrolled well waters and springs expose people to various diseases. The results obtained fully confirm the degradation of the environment around these water points and their poor maintenance, which can be the cause of bacterial contamination. The topography of the adjacent area will constitute an aggravating circumstance due to the poor behavior of households regarding the disposal of domestic wastewater and solid waste. As a result, we see that these waters have high levels of pathogenic bacteria, which clearly presents a significant health risk in the short term.

5. Conclusion

The water points studied in the Manianga and Kintélé districts present physicochemical characteristics generally in compliance with WHO standards. The waters of the area have an acidic pH and are weakly mineralized.

The presence of fecal coliforms in the sampled area indicates that the use of this contaminated water as

drinking water as well as the watering of vegetables with this polluted water could represent a major risk for the health of local populations. Fecal coliforms are common indicators of fecal contamination and their presence in water can cause waterborne illnesses.

These waters are characterized by a predominance of calcic and magnesium bicarbonate facies over chloride ions and sulfates which are practically absent there.

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