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Water Quality on the Basement Areas in Kouba-Adougoul and Its Surroundings, Guera Province, Chad

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Abstract

Water is an essential element for all forms of life. The quantity and quality of water are a problem in places. In Kouba Adougoul and its surroundings in south guera, water-related health problems are reported. That is why this study focuses on the quality of water in the basement areas, of Kouba Adougoul. Our objective is to contribute to a better understanding of water of human consumption in these areas for this, we carried out a physicochemical and bacteriological control on a number water point. Ten water points were collected during May 2022 for analysis. To achieve this objective, we made the *in-situ* analysis of physical parameters such as pH, electrical conductivity, and temperature. These measurements were made using the multi-parameter kit. The result shows that, the water temperatures vary from 24.4˚C to 27.4˚C proving that the waters are from deep depths. For the use of these waters, it is necessary to take certain precautions. The pH values varied between 6.15 and 7.78, an average of 6.77 giving some waters an aggressive character. It was low mineralized, with electrical conductivity averages ranging from 182.1 to 2100 $\mu S/cm^{-1}$ an average of 586.36 $\mu S/cm^{-1}$. For the chemical parameters, it is by hydrometric titration that the content of the ions was determined. The determination of the various coliforms in these waters was carried out by its various methods which led to detecting that the waters of Kouba Adougoul are turbid, and present high proportions of nitrates, iron and ammonium. The presence of pathogenic germs, such as total coliforms and thermo-tolerant coliforms in these waters, has been demonstrated. For their consumption, these waters deserve treatment beforehand. In the study area, the anthropogenic activities are considered the most serious sources of groundwater.

Keywords

Environmental Pollution, Hydrochemistry, Aquifers, Crystalline Basement, Kouba-Adougoul (Guera-Chad)

1. Introduction

Worldwide, freshwater accounts for only 2.7%. They are found on the surface and in the basement. These fresh waters are unevenly distributed in Africa (Kasser, 1995). In Chad, surface waters are found in rivers, lakes and ponds to the south of the country and in the Ouadis to the north of the country. Groundwater occurs in sedimentary soils for continuous aquifers and in basement areas for discontinuous aquifers.

The biggest challenge facing human beings is its availability but also its quality (Bendra, Fetouani, Sbaa, Gharibi, El-halouani, & Rhomari, 2005). Located in the heart of Chad, the Guera region is one of the regions at risk of water-related threats. Central Chad is characterized by a Sahelian climate with rainfall in most cases more or less great. In this region, most of the boreholes that capture the baseplate yield flows not exceeding 1 m^3/h. The crystallophyllian rocks and Precambrian granitoids of Tibesti in the north, Ouaddai in the east, Guerra in the center, Mayo-Kebbi in the southwest, and Mbaibokoum in the south correspond to the basement (Kusnir, 1988).

The population of the Guera region was (553,795) in 2013 (INSEED, 2009). Kouba-Adougoul, one of the localities in the region, is the subject of this study. Groundwater is accessed through wells and boreholes. However, the development of the drinking water supply network by the Société Tchadienne des Eaux (STE) is not keeping pace with that of spontaneous habitats in peripheral areas.

Kouba Adougoul is related to rapid population growth accompanied by spontaneous settlement construction in peripheral areas. The city is thus exposed to water supply problems, both in terms of quantity and quality. The variety of domestic and economic activities (industry, agriculture, informal trade in lubricants in particular) with their corollary of discharges of solid waste (landfills) and liquids affect groundwater quality (SEURECA, 2014).

As a result, many diseases, mainly diarrhea, but also infectious dartres, can be blamed on inadequate sanitation and hygiene and on unsafe water. The main objective of this work is to contribute to a better knowledge of the water resource of KOUBA ADOUGOUL from a physicochemical point of view.

1.1. Location of Study Area

1.1.1. General and Demographic Framework

The Guera is located between the 18th and 13th degrees of north latitude and the 17th and 20th degrees of east longitude (INSEED, 2009). Kouba Adougoul is located 15 km south of Mongo, the capital of Guera as shown in (**Figure 1**).

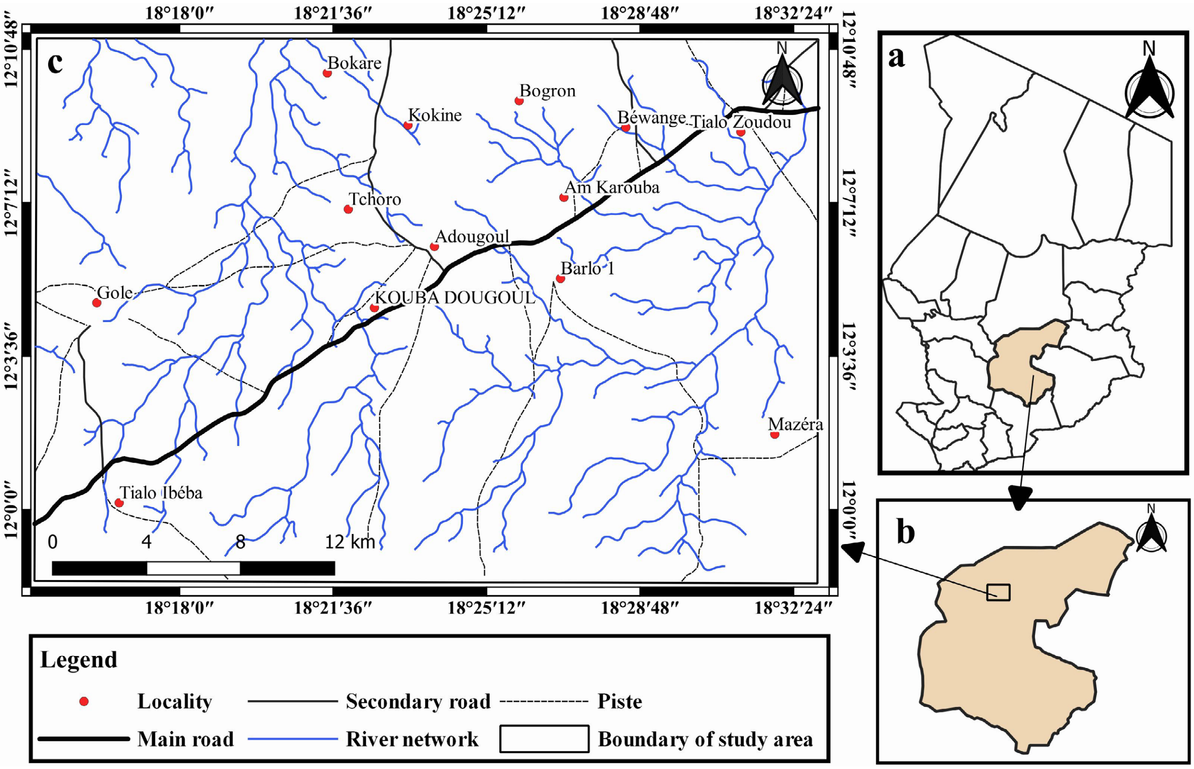

Figure 1. Map of the study area.

The study area is located in the Sahelo-Sudanese climatic zone with a dry tropical regime. The climatic variations are driven by the movements, during the year, of two air masses: the continental air of the North-East which gives birth to the harmattan, and the humid air of the South-West whose advance determines the rainy season (Valentin, 1997). There are two clearly differentiated seasons during the year: the rainy season which lasts 4 to 5 months (May-June to September), and the dry season which lasts 7 to 8 months (October to April-May). Other climatic parameters such as temperature, relative humidity, exposure time and evaporation also vary in time and space. Maximum average annual precipitation is 900 mm and a minimum of 300 mm. The presence of mountains promotes a microclimate in some localities that receive more precipitation (orographic rain) than others. The annual rainfall aggregations as illustrated in the figure show us the rainier and rainier years over a period of 2010-2020 at the level of the weather stations in Mongo, Figure 3. The soils of the Guera department are the result of the decomposition of the granites of the mountain massifs where until now rockfalls are frequent and visible. The nature of the soil is granite (clay-sandy). It's a very rich soil for the agriculture. The relief is characterized by a wide plain interspersed by the mountain ranges, To the east by the Mongo Mountain (Reine du Guera) and to the west by the mountain range of Abou Telfane (Mont Guedi, 1506 m) as well as by inselbergs to the south and north with altitudes varying from 200 to 300m away. The city of Mongo has a significant East-West difference in height of about 2052 m in length as shown in Figure 2.

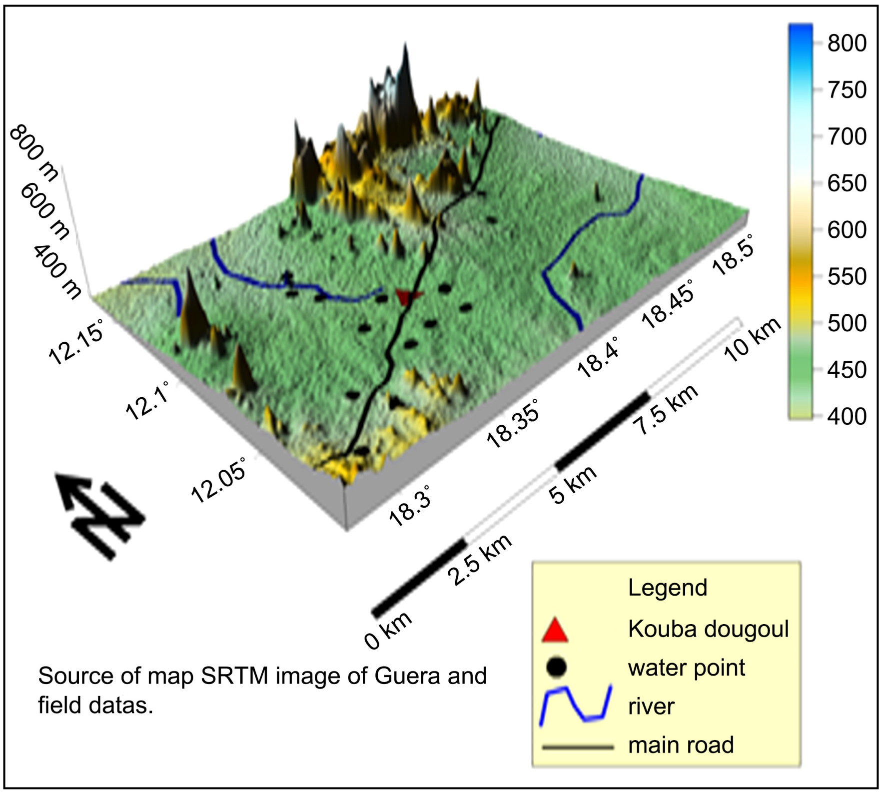

Figure 2. Map of geomorphology.

1.1.2. Geological, Hydrolgy, Hydrogeology Framework

The Guera Province is largely made up of the central massif. The latter is located in the heart of the Chadian basin and constitutes an orogenic unit grouping together three main massifs (Kusnir & Mountaye, 1997). Abu Telfan, Kenga and Melfi Massif (Isseni, 2011; Djerossem, 2020). It is based on a crystalline substratum, consisting essentially of plutonic and metamorphic rocks (Gentil, 1961; Kusnir, 1995; Schneider, 2001; Isseni, 2011) cut by basic filonian rocks (Nkouandou et al., 2017). Metamorphic formations consist of micaschists, quartzites, and gneisses. They often appear in restricted septa or enclaves within granite (Kusnir, 1995; Schneider, 2001). There are also many small secondary massifs and inselbergs separated by sandy arena areas. It peaks at 1613 m at the peak of the Guera while the average coast of the surrounding plain oscillates between 400 and 500 m. The city of Mongo, which constitutes our study area, contains two granite massifs (east and north-west of the city), clays, sands and silts formations as shown in (**Figure 3**).

The river system is not too developed. Permanent waterways are absent in the community. Only a few temporary outflow Ouadis are found in the locality as shown in **Figure 1**.

The hydrogeology of the area is characterized by two types of groundwater in this province (Schneider & Wolf, 1992): subriver groundwater and basement groundwater.

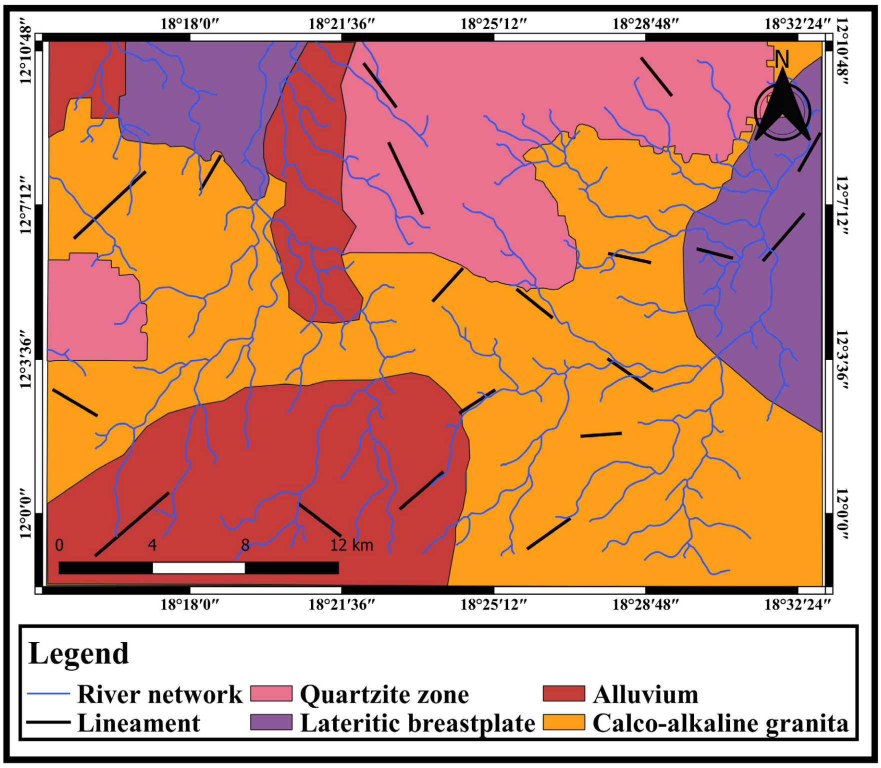

Figure 3. Geological Map in Schneider, 2001.

Subriver water tables consist mainly of alluvium, consisting of coarse and highly permeable debris, as the majority of Guera water points capture water tables from alluvium in the main valleys (Schneider, 2001). The installation of alluvium can reach 10 to 30 meters. They are usually coarse at depth (Upper Holocene) and therefore permeable. The depth of the water table increases upstream to downstream or the junction with the general water table is not demonstrated. Subriver water tables should be found in Darangué, Dabourg, Abouregue and Gire (on the Mangalmé cut) and in Melmelé, BangBang and Mbourmo wadis (Schneider, 2001). The recharge of these water tables depends on the floods and therefore on the precipitation on the catchment areas (Kabo, 2023).

The base-forming sheets are located in the fractured or altered zones of the crystalline mass. In these areas, the depth of the well is generally 10 to 15 meters but can be much greater (26 m at the massif located west of Melfi, 30 m at the northern part of Aboutelfan). It should be pointed out that these water tables are fed by rainwater that runs along the rocky walls. With respects to groundwater chemistry, it should be noted that the Guera groundwater dry residue is low (<250 mg/l) (Schneider, 2001).

Recent hydrogeological studies show that aquifers in the study area are discontinuous with limited storage capacity. The waters that contribute to the recharge of the water tables go through a complex infiltration (Ngounou Ngatcha et al., 2011). According to Non-Assem (2020), in this area, the majority of current water points (boreholes, wells) capture infrared, subriver, floodplain, and fractured/cracked media.

Several wells are dug in the altered part of the basement, either in cracks around the crystalline massifs, fed by the rains that flow on the rocky walls (layers of inselberg sides), or in the alteration fringe. A tablecloth of the latter type feeds Mongo. The depth of these wells is generally from 10 to 15 m, but it can be much greater (26 m in the massif located west of Melfi, 30 m in the northern part of AbuTelfan (Abadie & Gagniere, 1966). As regards the chemical characteristics of the groundwater, it should be noted that the dry residue of the groundwater of the Guera is low (less than 250 mg/l). The facies of the water are Magnesian Calcium and sulfated. The chloride and sulfate contents are less than 20 mg/l.

Furthermore, sources have been recognized in the crystalline zone, but they are few in number and their flow rate is never high except for a few exceptions, including Mangalmé. Abadie and Gagniere (1966) cite the sources of the Djombo of Dappo and Mala clans the Abu Telfane massif. However, the groundwater resources of the region are very poorly known as studies have been limited to a few reconnaissance routes and rare reconnaissance surveys without systematic inventory.

The average alluvial thickness is 20 meters. They're coarse in depth. The static level in these layers is generally low. In the basement areas, the depth of the wells can reach 25 meters (Abadie & Gagniere, 1966) and that of the boreholes reaches an average of 70 meters. Erosion is greatly increased in the locality and this is one of the reasons for the decrease in groundwater recharge.

2. Material and Methods

2.1. Data Collection and Sample Analysis

For this study, ten samples of water from kouba adougoul in guera were collected on June 2022 for physicochemical and bacteriological analysis.

In the field, the garmin GPS Global position system that helped locate and record the coordinates of the structures as shown in (**Figure 4**). A multi-parameter kit for pH, electrical conductivity and temperature measurements. A bottle of distilled water to rinse the tube before and after analysis Polyethylene (PE) bottles of 150 and 500 ml for sampling. A mechanical wrench kit for disassembling drill heads A cooler for storing samples and the Indelible markers to label samples.

During the sampling campaign, *in situ* parameters such as electrical conductivity, hydrogen potential and temperature were measured.

These physicochemical parameters were measured using a multiparameter and the measurements were made directly on the unfiltered water. The WTW type portable micro-possessor waterproof multimeter is equipped with two electrodes, one measuring the pH and the other measuring the electrical conductivity. This kit is equipped with an automatic temperature compensation device that automatically raises the temperature.

Prior to *in situ* parameter measurements, the multi-parameter probes were first calibrated with buffer solutions.

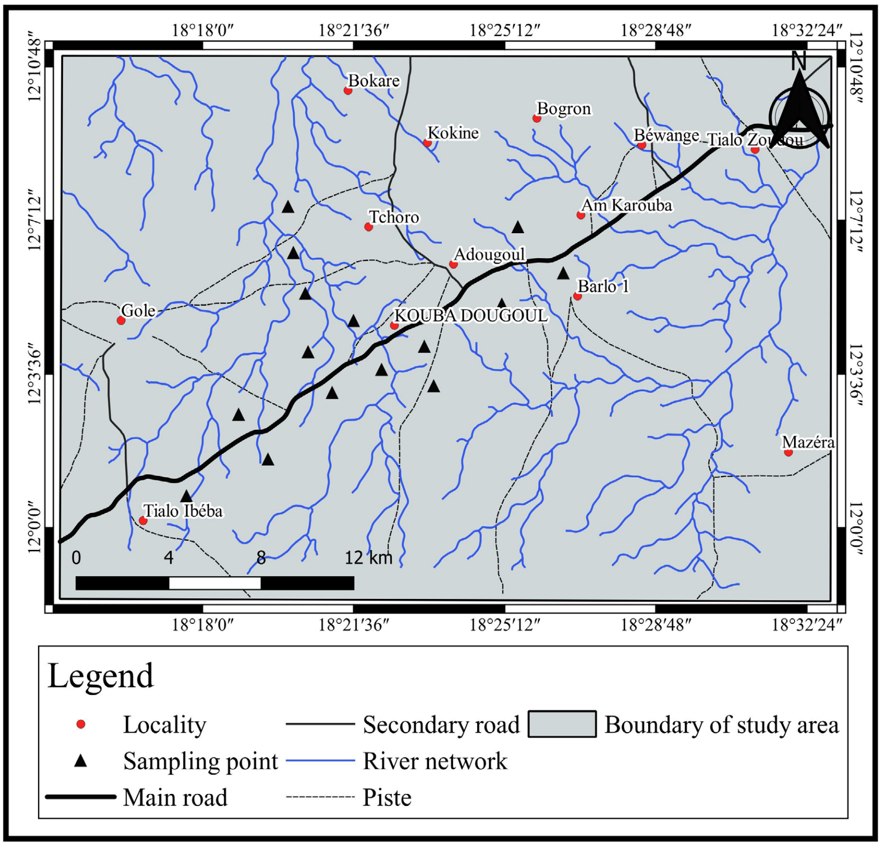

Figure 4. Map of sampling points.

For pH, the probe was first immersed in a basic pH buffer solution (10.7), then a neutral pH solution (7) and finally in an acidic pH buffer solution (4). After each plunge of the probe, the "calibrate" button of the multi-parameter shall be pressed, then the "measure" button and the pH value of the buffer solution used shall be displayed on the multi-parameter screen. The pH meter is thus calibrated. The calibration procedure is the same for the conductivity meter but only one 1413 µS/cm buffer solution is used; the measurements are as follows:

Rinse the probes with distilled water before and after each measurement.

Dip the probes directly into the stream (in the case of gutter water) or into the samples (in the case of groundwater).

After stabilization of the measurements, read rapidly the values of the hydrogen potential and of the electrical conductivity and the respective temperature.

2.2. Laboratory Analysis

All the groundwater samples as well as the stormwater were analyzed at the Laboratory of Mongo. The elements analyzed, the method of analysis and the apparatus used are:

Flame spectrometer and DR 890 spectrometer:

Principle: Five ions are determined simultaneously: Na, K, Ca, Li, Ba. The apparatus uses a low-temperature flame.

Reagents: Nitric acid, 100 ml potassium solution, 190.7 mg dehydrated potassium chloride, permuted water.

Photometer 7100:

By adding reagents (tablets) to the sample, the substance to be analysed is converted into a substance that absorbs light of a specific wavelength. Photometry involves measuring the absorption of this light, which is proportional to the concentration of the substance (Lambert-Beer law).

The photometer can be read directly. The chemical elements are determined as follows: The analysis of the chemical elements like HCO_3^-, CL^-, NO_3^-, SO_4^{2-}, Ca, Mg, F, was done with photometer and volumetric dosing method and photometer 71000 equipment. For the Fe^{3+}, Mn^{2+}, Cu, Zn, the spectromrter was using with Colimeter DR890 equiment. The last element like Na^+, K^+, was done ,by the spectromrter with the Flames pectrometer BWB - XP.

The sample is taken in two tubes: one of 10 ml and the other of 10 ml to 20 ml.

Switch on the instrument and select the parameter programme.

Enter the results data:

For all the samples, the photometric method is used to determine the levels of Ca^{2+}, Mg^{2+}, K^+, Na^+, NO_3^-, Cl^-, SO_4^{2-} ions and the titration method is used to determine the levels of bicarbonate ions (HCO_3^-).

3. Results and Discussion

3.1. Physico-Chemical Parameters of Water

These are easily measurable and useful parameters for determining the chemical status of pollutants in water.

The water temperature varies from 24.4˚C to 27.3˚C. The lowest temperature is observed at Koubo Puit and the highest is observed at Mabrouka Forage. The temperature is always important for chemical reaction as shown in (Figure 5).

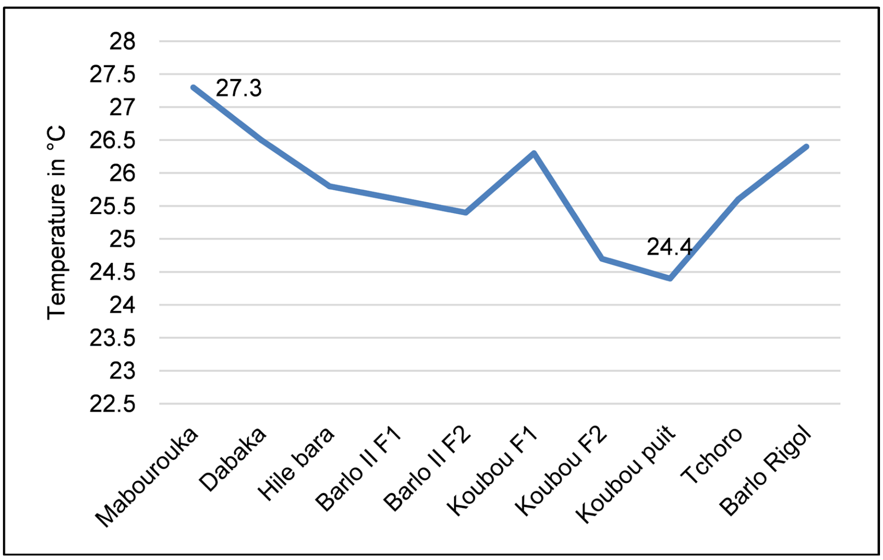

Figure 5. The water temperature.

The pH of the water measured varies between 6.15 (Barlo F2) and 7.78 (Koubou Adougoul F2). The average is 6.77 (**Figure 6**). According to the turbidity (NTU), the samples of Dabakal, Barlo II F2, Tchoro and Barlo rigole have high values. In Dabakal, the turbidity is 101 NTU and Tchoro and Barlo rigole the turbidity increases from 33.5 to 36.4 and in Barlo II F2 is 17.8, respectively. The others are weak as shown in (**Figure 7**).

The electrical conductivity (CE) of the groundwater in the study area is between 2100 (Barlo F2) and 182.1 (Koubou Adougoul F1), for an average of 586.36 as shown in (**Figure 8**).

The total dissolved solids (TDS) maximum concentration is at the Barlo1 drilling with 1200 mg/l and the minimum concentration at the Kouba drilling and other villages with 100 mg/l (**Figure 9**). We observe a minimum total hardness of 0.8 mg/l recorded at the Dabakal amar drilling and a maximum total hardness of 11.9 mg/l at the Barlo F2 drilling as shown in (**Figure 9**).

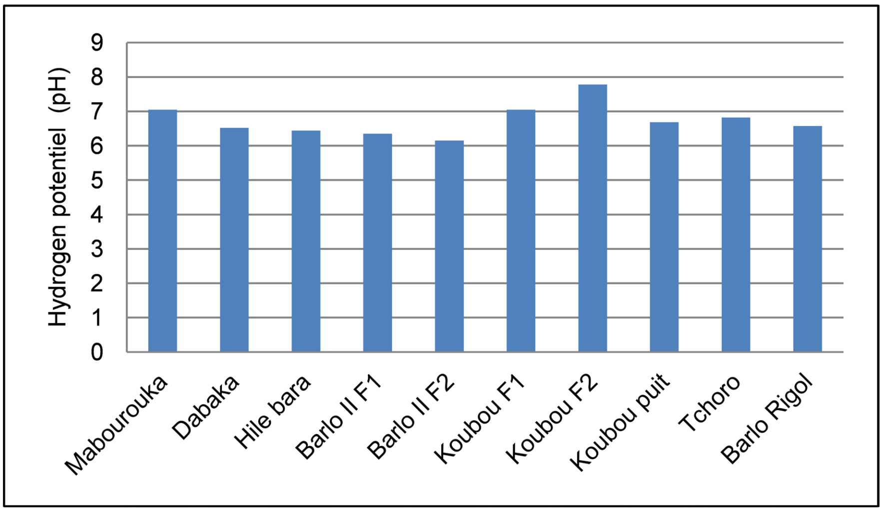

Figure 6. The pH of the studied water.

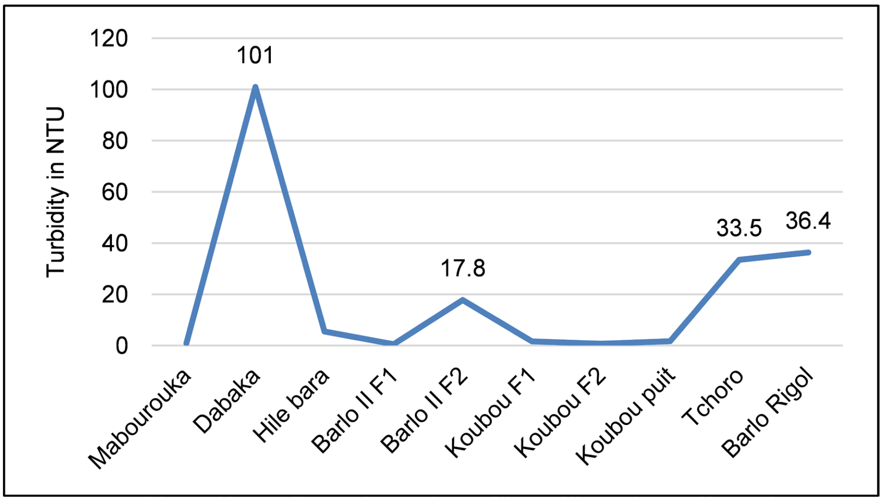

Figure 7. The turbidity (NTU) of the groundwater.

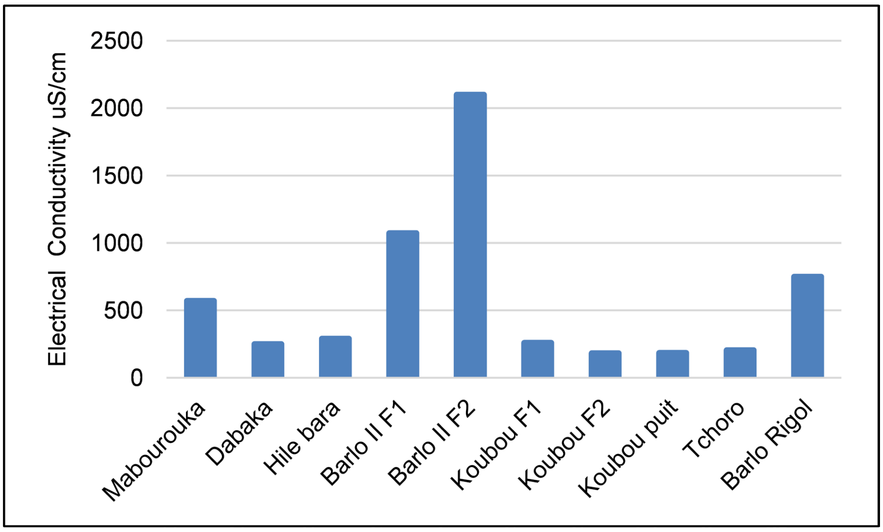

Figure 8. The electrical conductivity (CE) of the groundwater.

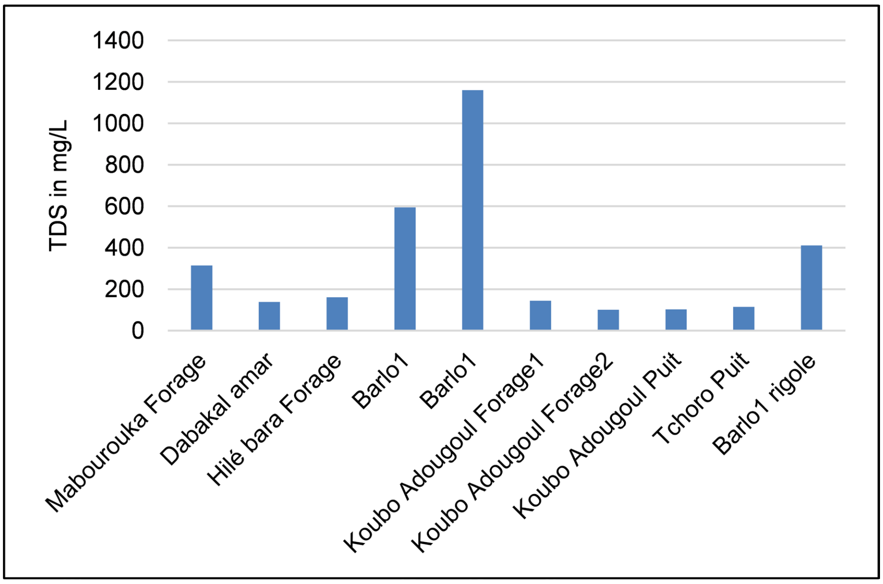

Figure 9. The total dissolved solids of water.

3.2. Chemical Parameters of Water

3.2.1. Anions

The proportions of anions such as bicarbonates, chlorides, sulfates, fluorides are normal in all water points (boreholes, wells, channels) according to WHO standards as shown in (**Table 1**). The waters of Barlo II F1 and Barlo II F2 have very high nitrate levels, respectively 87.9 mg/l and 110.5 mg/l.

The origin of the nitrates in the groundwater of the study area would therefore be attributed to pollution by the agropastoral activities carried out (use of chemical, organic and inorganic fertilizers, pesticides and herbicides, establishment of livestock farms, etc.), defections in the open air and the decomposition of organic matter.

Table 1. Anions of analyzed water.

Anions	Unit	Min	Maxi	Moy	Norme
Bicarbonates (HCO_3^-)	mg/L	0.2	1.6	0.68	
Chlorides (Cl^-)	mg/L	0	3	1.3	≤250
Sulphates (SO_4^-)	mg/L	0	115	24.7	≤250
Nitrates (NO_3^-)	mg/L	0	110.5	23.24	≤50
Fluorine (F^-)	mg/L	0	1.1	0.26	≤2

3.2.2. Cations

Cations such as calcium, magnesium, sodium and potassium in the waters of the study area are in proportions that meet WHO standards. Total iron and ammonium values do not meet WHO standards as shown in (**Table 2**). Total iron is elevated to Dabakal channel (0.56 mg/l), Hilé Bara channel (0.53 mg/l), Barlo II channel 2 (1.16 mg/l), and Barlo channel 1 (2.12 mg/l). Ammonium is elevated to Barlo II Drill 2 (3.8 mg/l) and Barlo Channel 1 (3.5 mg/l). The presence of iron is thought to be linked to the alteration of ferromagnesian minerals such as biotite (Kouassy, 2010). This hypothesis is justified by the predominance of biotite-rich granitic formations.

As a result, high iron concentrations pose a health risk. The ingestion of large quantities of iron leads to haemochromatosis, a condition in which the normal regulatory mechanisms function insufficiently, leading to tissue damage caused by iron loading (WHO, 1997). This result corroborates that of (Allhabo, 2015) who found iron concentration values higher than the maximum value (0.3 mg/l).

Table 2. Cations of analyzed water.

Cations	Unit	Min	Maxi	Moy	Norme
Calcium (Ca^{2+})	mg/L	0.4	6.4	1.87	≤200
Magnesium (Mg^{2+})	mg/L	3.4	17.73	13.5	≤50
Sodium (Na^+)	mg/L	0.5	7.8	4.64	≤200
Potassium (K^+)	mg/L	0.1	3.3	0.98	≤12
Ammonium (NH_4^+)	mg/L	0.0	**3.8**	0.95	≤1.5
Total Iron	mg/L	0.02	**1.16**	0.51	≤0.3

The ionic balance established to confirm the accuracy of the analyzes is not excellent because all the samples have an ionic balance greater than 5% except two samples showing a BI less than 5% as shown in **Table 3**.

According to (Kouassi et al., 2013) chemical analysis of water is only considered representative and acceptable when the ionic balance is less than or equal to 10%

Excellent when BI < 5%;

Acceptable when 5% < BI < 10%;

Doubtful when BI ≥ 10%.

Table 3. Ionic balance of chemical water.

NAME	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3	Cl^-	SO_4^{2-}	NO_3^-	Cations	Anions	BI
Mabourouka Forage	0.32	0.14	0.13	0.03	0.00	0.00	0.34	0.09	0.61	0.44	17%
Dabakal amar	0.08	0.08	0.05	0.00	0.01	0.00	0.02	0.00	0.21	0.03	74%
Hilé bara Forage	0.20	0.08	0.07	0.03	0.01	0.00	0.06	0.07	0.37	0.14	45%
Barlo1	1.28	0.92	0.04	0.01	0.00	0.08	0.85	1.42	2.25	2.36	−2%
Barlo1	0.26	2.11	0.34	0.08	0.01	0.03	1.20	1.78	2.80	3.02	−4%
Koubo Adougoul Forage1	0.52	0.10	0.04	0.03	0.03	0.06	0.00	0.04	0.69	0.12	70%
Koubo Adougoul Forage2	0.12	0.20	0.05	0.03	0.01	0.03	0.02	0.04	0.40	0.10	60%
Koubo Adougoul Puits	0.30	0.22	0.02	0.00	0.01	0.06	0.06	0.19	0.54	0.32	26%
Tchoro Puits	0.32	0.18	0.03	0.01	0.01	0.08	0.00	0.00	0.54	0.10	70%
Barlo1 rigole	0.34	0.04	0.07	0.03	0.01	0.03	0.01	0.12	0.48	0.17	48%

3.2.3. Order of Abundance of Chemical Elements

The anion concentrations are decreasing in the order $SO_3^{2-} > HCO_3^- > Cl^- > NO_3^-$ for the groundwater of the zone as shown in Figure 10. The sulfate anion SO_4^- is the most abundant which represents 49.5% of the sum of the anions (in mg·l⁻¹). Chloride ions account for only about 2.60% of the negative charge, carbonates 46.6% and nitrates 1.36%.

Cation abundance varies in the following order: $Mg^{2+} > Na^+ > Ca^{2+} > K^+$. The cation: Mg^{2+} is dominant (on average) with more than 74% of the sum of cations (in mg·l⁻¹).

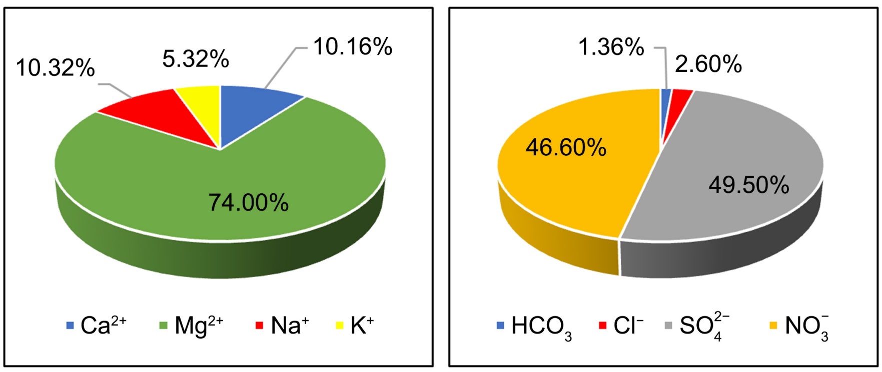

Figure 10. Order abundance of chemical.

3.2.4. Distribution of Chemical Elements

For the distribution of chemical elements, Calcium concentration is high in the Barlo1 Drilling and low in Dabakal and Kouba Table 2. The magnesium concentration is high in the Hille Bara and Barlo1 Well Drilling next, low in mabrouka. Sodium is always present in water in widely varying proportions. The minimum is recorded at the Kouba-Adougoul well with a value of 0.5 mg/l and the maximum is 8 at the Barlo1 F2 borehole. The potassium values are between 0.2 mg/l and 3.5 mg/l recorded respectively at the Dabakal amar and Barlo1 F2 boreholes. While in Mabrouka, kouba and barlo laugh almost constant.

Based on the results obtained, the minimum value of bicarbonate is 0.2 mg/l and recorded at the Barlo and Mabrouka drilling and the maximum value is at the Kouba-Adougoul drilling with 1.6 mg/l as shown in (**Figure 10**). The water samples taken show that chloride values are between 0 and 3 mg/l, the minimum of which is observed in the Mabrouka, Dabakal and Hillé Bara boreholes and the maximum at the Barlo1 and tchoro well boreholes. The sulfate maximum value is at the barlo1 borehole located at the municipal school with 115 mg/l and the minimum value is 0 mg/l of the Drilling Tchoro Puit and Kouba. Nitrate values range from 110.5 to 0 mg/l. The minimum is at the drilling level Dabakal. The maximum is observed at Barlo1 drilling1 and drilling2.

The laboratory's Fluor results show that there is no fluorine at the Dabakalamar, Tchoro and Barlo rigole boreholes. On the other hand, the highest value is reported to Barlo1 drilling1 (1.1 mg/l). The total iron reported that at the mabrouka, Kouba-Adougoul Drilling and Well wells, there was not enough iron; it was high (1.16 mg/L) at the F2 Drilling of Barlo 2 and at the Barlo1 Drill with 2.5 mg/L.

3.2.5. Chemical Facies

The groundwater studied has a type of facies as showing in (**Figure 11**): hyperchlorinated facies and the deterioration in groundwater quality could have both geological and anthropogenic origins.

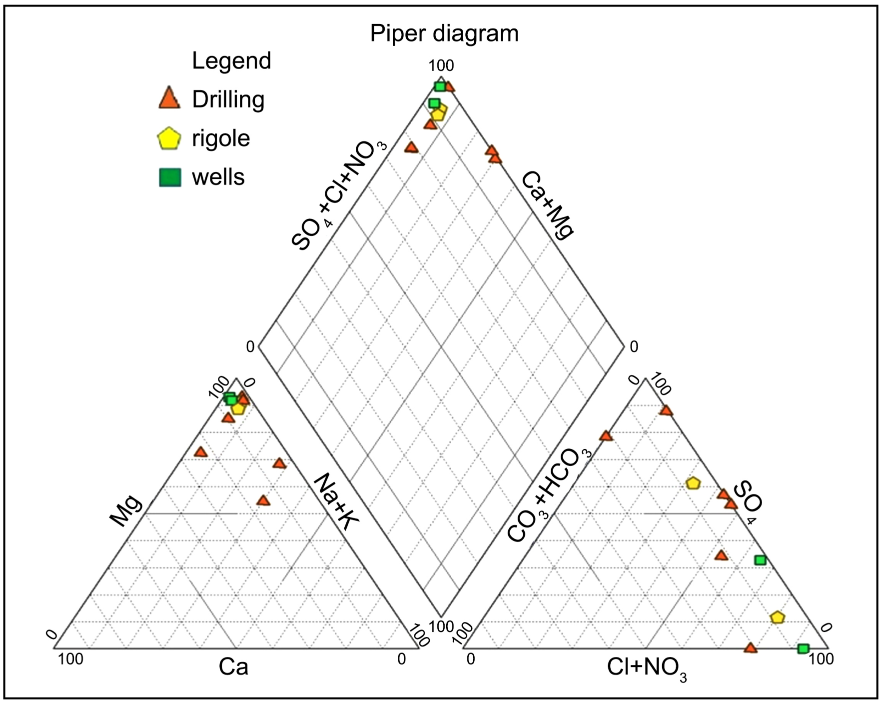

Figure 11. Piper diagram.

3.2.6. Bacteriological Parameters

Drilling waters at Mabourouka, Dabakal amar, Koubo F2, Koubo well, Barlo1 rigole and Barlo2 borehole F1; F2 are bacteriogically not in accordance with WHO/Chad Drinking Water Guidelines as showing in **Table 4**. The presence of indicator germs in these waters has been demonstrated and deserves treatment (chlorination).

According to WHO/CHAD, drinking water should not contain coliforms, i.e. 0 CFU/100 ml. The presence of this pollutant in water can be the cause of water-borne diseases such as gastro-enteritis.

Table 4. Bacteriological parameters.

Works	Total coliforms	Thermotolerants coliforms
Mabourouka (F)	>100	0
Dabakal (gully)	>100	>100
Hilé (F)	0	0
Barlo (F1)	]0	6
Barlo (F2)	3	0
Koubou (F1)	0	0
Koubou (F2)	>100	57
Koubou (w)	>100	>100
Tchoro (w)	>100	>100
Barlo (gully)	>100	>100

4. Discussion

Temperature plays a very important role in the solubility of salts and gases (Ballouki, 2012). It conditions the dissociation equilibria. It varies with outdoor temperature (air), seasons, geological nature and depth of water level relative to the soil surface.

When water is shallow, room temperature occurs because water contacts the atmosphere. When the water is deep, the temperature is high. It varies from 24.4˚C. to 27.6˚C as shown in (**Figure 5**). The importance of temperature as a decisive factor in water quality is its relationship to other other parameters. Most of these relationships concern aspects of the organoleptic quality of water; others are indirectly linked to health

The pH is used to quantify the concentration of H^+ ions in the water that gives it its acidic or basic character in the water (Berradia-Serisser, 2019). The results show that the values are highly variable as shown in **Figure 6**. The low value is observed at the level of the borehole F 8 with a value of 6.24 and high is located at the level of the borehole F 3 with a value of 7.12. The pH of the water in the works measured varies between 6.15 (Barlo F2) and 7.78 (Koubou Adougoul F2). The average is 6.77 as showing in (**Figure 6**).

The turbidity of water is due to the presence of particles in suspension, in particular colloidal particles: clays, silt, sand, grains of silica, organic matter, etc. (Rodier, 2009, 9th Edition). The assessment of the abundance of these particles measures its degree of turbidity. The lower the response rate, the more effective the treatment. The results show that the low value is observed at Drilling F2, F1 and BarloII F1 and the high value is reported at Drilling Mabrouka and Dabaka as shown in (**Figure 7**). Local waters have turbidity ranging from 0.52 to 101. The samples of Dabakal, Barlo II F2, Tchoro and Barlo rigole have proportions which are considerably greater than the norm. Some of the drilling water conforms to the parameters analyzed for drinking water, with the exception of Choro well, Dabakal amar drilling, Barlo rigol and Barlo2 are turbid and rich in nitrate, iron and ammonium according to the parameters given by WHO/Chad.

Conductivity is the property of water to promote the passage of an electrical current. It is expressed in microsiemens per centimeter (µS/cm) and is the inverse of resistivity. The instrument used to measure it is called a conductimeter (Rejsek, 2002).

The results show that the minimum is fixed at the level of the borehole F10 with a value of 214 uS/cm and the maximum at the level of the borehole of the Barlo2 borehole (1 and 2) with a value of 855 uS/cm as showing in (**Figure 8**). These waters comply with WHO/Chad guidelines stipulating that the conductivity of clean water should be less than 2500 µS/cm.

The values below give some indication of the relationship between mineralization and conductivity:

Conductivity ≤ 100µS/cm: very low mineralization;

100 µS/cm ≤ conductivity ≤ 200 µS/cm: low mineralization;

200 µS/cm ≤ conductivity ≤ 333 µS/cm: mean mineralization;

333 µS/cm ≤ conductivity ≤ 666 µS/cm: increased mean mineralization;

666 µS/cm ≤ conductivity ≤ 1000 µS/cm: significant mineralization;

Conductivity > 1000 µS/cm: high mineralization.

The more ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), chloride (Cl^-) are present in the water, the more capable it is of conducting an electric current and the higher the conductivity measured.

This is a particular quality of water due to the presence of calcium and magnesium bicarbonates, chlorides and sulfates detected mainly by the fact that it more or less prevents soapy water from foaming (Berradia-Serisser, 2019). It is measured as the sum of the concentrations in degrees of calcium and magnesium and expressed as the hydrometric titer (TH). The unit of the hydrometric titre is the milliequivalent per liter (or the French degree, ˚F). We observe a minimum total hardness of 0.1 mg/l recorded at the Dabakal amar drilling and a maximum total hardness of 10 mg/l at the Barlo F1 and F2 drilling. For water intended for human consumption, WHO does not recommend values but indicates that high hardness can cause deposits while low hardness can cause corrosion problems. Apart from nitrate, the other parameters have values which comply with the standard. On the other hand, the high value of Nitrate in some boreholes can be explained by anthropogenic and agricultural activities.

The dominant metal is iron. Iron can be elevated in groundwater compared to surface water because it is much more exposed to the effects of corrosion. Given that the limit value of 0.3 and the results obtained for iron exceeding WHO standards, it can be said that the waters of our boreholes are not free from corrosion.

According to Rodier, the parameter like ammonium (NH_4^+) is a parameter that can be used to assess the level of organic pollution in water. The highest values are naturally observed in surface waters, whereas the highest values are observed in groundwater, as shown by the results.

Water intended for human consumption contains a multitude of pathogenic microorganisms, which are agents of dreaded human infections. They are bacteria, viruses and even fungi and algae.

The different microorganisms that can be detected in water are: Bacteria (*Salmonelta, Escherichia coli, Shigelle, Campylobacter, Yersinia, enterolitica* …) (Kreiria & Chita, 2017).

Viruses (hepatitis virus, rotavirus, adenovirus …)

The protozoa (*Cryptosporidium, Giardia lambliase, Entamoebahistolytica* …) In our case, they are total coliforms and heat-tolerant coliforms.

These results are inconsistent with results from other studies in other regions of central Chad, identifying Geological and hydrogeological features as well as hydrochemistry and hydrochemistry as the main factors influencing the geochemical evolution of groundwater Bourrie (1978) and Abderamane (2012).

5. Conclusion

At the end of this study focused on water quality on the basement areas in Kouba-Adougoul and its surroundings, Guera Province, we can say that our community has good water quality for the boreholes we had drilled and has only one facies hyperchlorinated and calcium sulphated. These waters meet the standards and are acceptable for consumption with regards to physico-chemical parameters.

Bacteriological analysis revealed that all boreholes and wells are affected by fecal and total germs and this compromises WHO recommendations in this regard. This is believed to be responsible for the pollution caused by human activities, as we have also seen distressing practices such as increased washing and stagnation of excrement and other impurities all around boreholes and wells. It would be desirable to treat them by chlorination in order to provide the population with access to safe water and to reduce water-related diseases.

This hydrochemical study has also made it possible to clarify the processes of circulation and mineralization of the groundwater of the anthropized crystalline basement.

The interpretations made it possible to demonstrate the heterogeneity of the medium studied.

Direct infiltration of effective rainfall rapidly reaches the aquifer with renewal times of the order of a year or a few years; this infiltration benefits the aquifer from the granular arenas and the cracked rock where it mixes with previous recharges. This ensures a high stability of the physico-chemical parameters of the deep resource. The renewal time of this resource is likely to be several decades, at least when drilling is noticeable in low-lying wells as well as in polluted drilling in stagnant areas. This reflects delayed infiltration from the surface which can take place in deep boreholes either by transfer within the weathering profile or by defective equipment in these boreholes.

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Conflicts of Interest

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

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