Rainfall Rate and Water Quality of Boreholes and Wells in the District of Akassato in the Municipality of Abomey-calavi in Benin, West Africa

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Abstract

The influence of the rhythm on the water quality of boreholes and wells in the district of Akassato municipality of Abomey-Calavi is one of the problems faced by the inhabitants of the study environment. The general objective of this study is to study the rainfall rhythm and the water quality of boreholes and wells in the district of Akassato municipality of Abomey-Calavi.

To achieve this goal, rainfall data from 1981 to 2020 were collected. A direct observation of the state of play and the administration of a questionnaire allowing to list the wells and the boreholes according to defined criteria were carried out. The physical, chemical and bacteriological analyses were carried out respectively by spectrophotometry, titrimetry and the membrane filtration method. Indeed, 36 wells and 64 boreholes have been inventoried and 267 people have been investigated.

The results obtained from the analyzes revealed that the temperature of the well and borehole water exceeds the recommended norm. These waters are acidic and cloudy on a physical level. Only the sample from well 2 during the rainy season is chemically polluted. The microbial germs (Fecal coliforms and Escherichia coli) sought are strongly present in the analyzed water samples, but the fecal streptococcal germs did not undergo pollution during the dry and rainy season. In sum, all the water samples studied are at least polluted by one of the physical, chemical and / or bacteriological variables and are therefore unsuitable for direct consumption by humans.

Keywords: Rainfall rhythm, Akassato, Drilling, Well, Quality

1. Introduction

Water is the most important natural resource that makes life possible on earth for both animals, humans and plants (A.O. Denonsi et al., 2023, p 48). Water is therefore both a strategic resource and the fundamental element necessary for a healthy economy (L. Odoulami, 2009, p. 19). Past and current climatic cycles have shaped the geography of water resources (G. de Marsily, 2008,

p. 25). Groundwater is a vital natural resource for a safe and economical drinking water supply in urban and rural areas (Magesh et al., 2012, p. 12). Groundwater has the immense advantage of being a distributed resource that allows diffuse withdrawals without the need for a water transport network (Marsily and Besbe, 2017, p. 31). This water flows to springs, rivers or directly into the sea and it can be captured by humans through wells or boreholes. According to WHO (2017, p. 1) it is the most widespread mineral substance on the surface of the globe; it is also stored in the cavities of its subsoil and suspended in the atmosphere; it comes in three forms (solid, liquid and gaseous) and of various qualities.

According to A. O. Denonsi (2017, p. 11), these water resources can undergo more or less significant physical, chemical and bacteriological contamination from waste discharged into nature. The groundwater captured by large-diameter wells in the metropolis of Cotonou (Southern Benin) is drawn from the Quaternary aquifer which belongs to the Coastal Sedimentary Basin. This coastal aquifer is particularly vulnerable not only because of its superficial character and the influence of anthropogenic activities, but also because of its proximity to the salt waters of Lake Nokoué and contaminated ponds (H. Houemenou, 2020, p. 4). Domestic wastewater is discharged directly into nature without any prior treatment, following the absence or malfunction of existing wastewater treatment plants. These waters are likely to pollute the soil and subsoil, and subsequently groundwater (M. Hondjenou et al., 2019, p. 58). In a context of constantly increasing and uncontrolled pollution, the physico-chemical quality of groundwater can be altered naturally or anthropically by undesirable or toxic substances from livestock, agriculture, industry, humans and the surrounding rock. These parameters can in one way or another make groundwater unsuitable for consumption (S. Moussa et al., 2018, p. 319). Like some districts of the municipality of Abomey-Calavi, the district of Akassato is facing many problems related to the quality of water consumed in households (L.H. Honfin, 2020, p.3).

Studies must be carried out to understand the likely factors favoring the pollution of drilling and well water and the risks that these run so that adequate solutions are found for the well-being of the population of the district of Akassato.

1.1. Area of study

Akassato, the study area for this present research is one of the nine districts of the municipality of Abomey-Calavi which is one of the municipalities of the Atlantic Department is located between 2 °19'25" and 2 °24'32" East longitude and 6 °28'6" and 6 °35'56" North latitude and has ten villages namely: Adjagbo, Agassa Godomey, Agonsoudja, Akassato-Center, Gbétagbo, Glotakpa, Houéké-gbo, Houèkè-honou, Missessinto and Kpodji The Mountains. The capital of the district is located in the village of Akassato Center. Our study took place in the villages of Agassa Godomey, Akassato-Center and Gbétagbo. Figure 1 shows the map of the geographical location of Akassato.

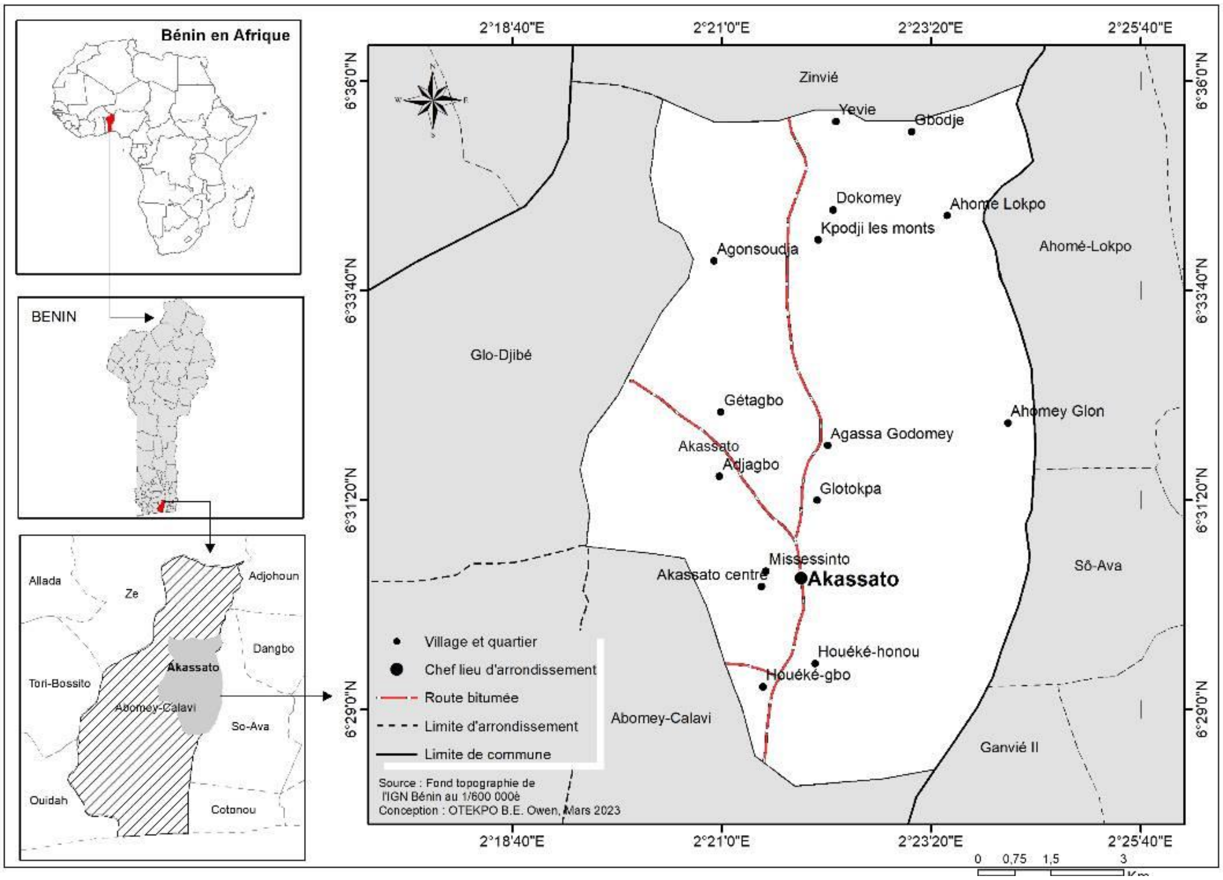

Figure 1: Geographical location of the district of Akassato

The climate observed in the district of Akassato is of the subequatorial type marked by two rainy seasons and two dry seasons. The average annual rainfall is close to 1200 mm, of which 700 to 800 mm for the first rainy season, and 400 to 500 mm for the second, The average monthly temperatures vary quite little, between 27 ° C and 31 ° C approximately (F. D. Assogba, 2017, p. 20). Two main types of soils are distinguished in the district of Akassato. Ferralitic soils which are often very porous, which means that they can store large amounts of water in the pores of the soil. Apart from these types of soils we have very floodable hydromorphic soils. The hydrographic network consists essentially of Lake Nokoué. We distinguish in the municipality of Abomey-Calavi, several horizons of aquifers more or less well differentiated. From the bottom up we have :

- The aquifer of sands (fine to coarse), sandstones and gravels with clay-sandy levels (lateritic red, variegated, black or colored) of the Continental Terminal. Indeed, it is this aquifer that is solicited by all the boreholes and some modern wells in our study area.

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- The aquifer made of clay, gravelled sands and clay-sandy alluvium from the Quaternary. It is a superficial aquifer, generally exploited by the traditional wells found practically in all the concessions of the municipality (L. H. Honfin, 2020, p.16).

2. Data and methods

2.1. Data used

Several types of data are used as part of our study. These are among others: rainfall data for the period 1981-2020 obtained from Météo-Benin. It made it possible to characterize the variability of the rains in the District of Akassato; demographic data, from the INStad database used to assess the evolution of the population of the District of Akassato and its distribution over time and space; its influence on the rainfall rhythm and the water quality of the boreholes and wells in the study area ; data concerning the standards of microbiological, physico-chemical quality of borehole and well water; data relating to the different drinking standards required by WHO-BENIN; data on the different rates of diseases recorded in the district related to the consumption of unsuitable water. They are taken from the register of the health center of the district of Akassato.

2.2. Methods used

2.2.1. Data collection tool and material

The materials and tools used in the framework of this study are recorded as well as their respective roles in Table 1.

Table 1: Role of materials and tools

	Materials and Tools	**Role**
Matériels	Cameras and GPS	-Taking of the geographical coordinates of the inventoried wells ; -Shooting of the views on the ground
	Spectrophotometers, pH meter, multi parameter type (HORIBA) etc.	-Analysis of physical, chemical and bacteriological parameters of water
	1.5L bottles	-Collection of samples for physicochemical analyses ;
	Sterilized 500mL bottles	-Taking samples for bacteriological analyses ;
	Labels	-labeling of sampling bottles
	A cooler	- To keep the samples
Outils	Questionnaire	-Collection of data on the mode of management of the rainfall and groundwater rhythm, water supply sources, etc.
	Observation grid	-Taking note of the observations made on the characteristics of the rainfall and groundwater rhythm and the state of their environment

Source: Field survey result, March 2023

In order to achieve the expected results for this research, materials and tools are used either in the field or in the laboratory for data collection or as part of data processing. These materials and tools played a decisive role in achieving the objectives of this study.

2.2.2. Sampling

The basic unit of the sample in this study is the household. Indeed, two methods were used to constitute the sample of the study; on the one hand, the reasoned choice which made it possible to identify and select the wise men, the notables and the resource persons and on the other hand, the random choice which was applied to the selection of the members of the households. Thus, the surveys took place in these three (03) neighborhoods out of the ten (10) that the borough has. In other words, more than 30% of the neighborhoods were taken into account for the surveys.

This choice was made because of the low use of water from its use found at the level of these neighborhoods in the borough of Akassato.

The selection of the surveyed households was made according to a random choice. The sample size is 5% of the total number of households.

For this study, the sample size was determined by the formula of Schwartz (1995). It is entitled: $\mathbf{n = Z\alpha^2 \times pq/i^2}$

With: n = sample size

Za=1.96 Reduced deviation corresponding to an α risk of 5%.

p = n/N with p = proportion of households in the three (03) districts (n) relative to the number of households in the borough (N).

In total, 367 households were interviewed out of 24,188 households in the three (03) neighborhoods that were the subject of this study. Which represents 5% of the total number of households in the district of Akassato. The chief medical officer of health has been subjected to an interview guide developed for their intentions.

2.2.2.1. Taking water samples for analysis

The wells and boreholes have been chosen so as to have an image of the state of the wells and boreholes as well as the physical, chemical and bacteriological characteristics of each of the sources of their water. To achieve this, a survey of 36 wells and 64 functional boreholes distributed in the Akassato-Center, Agassa-Godomey and Gbetagbo districts was carried out. Figure 2 illustrates the geographical position of the 36 wells and 64 boreholes that were sampled in the district of Akassato.

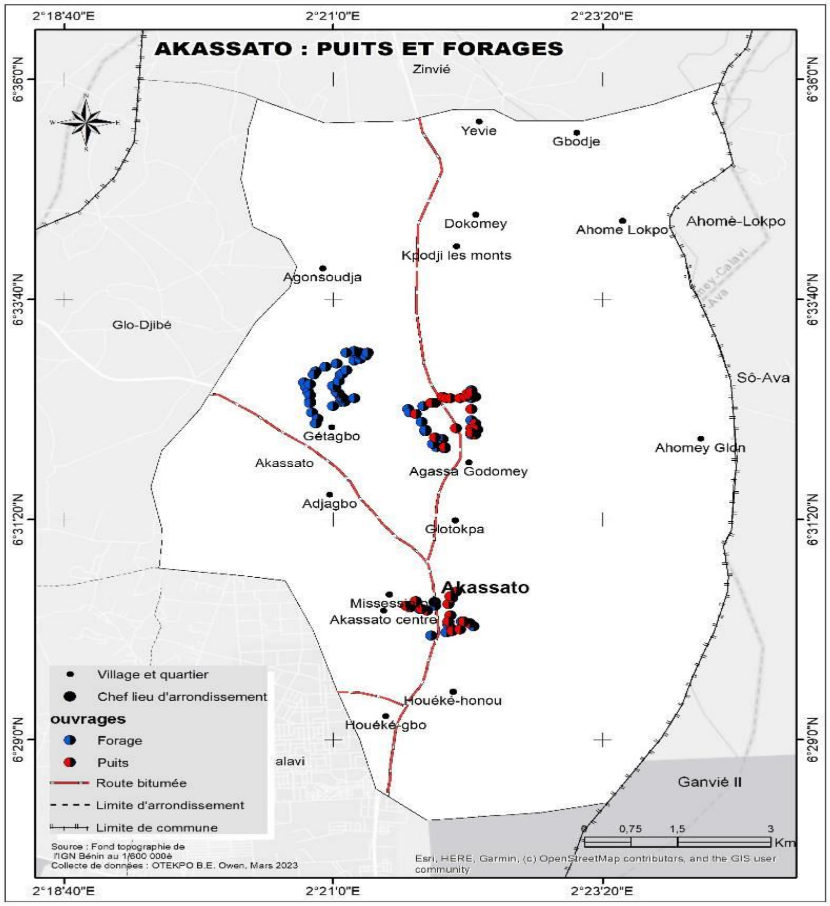

Figure 2: Location of sampled wells and boreholes

As part of this study, two samples were taken according to the rainfall rhythm, that is to say a sample at the level of each well and borehole identified for analysis was carried out during the dry season and another during the rainy season. Indeed, for the physico-chemical analysis, the sampling is carried out in 1.5 L vials. Before sampling, the 1.5 L vials are properly washed and rinsed with distilled water in the laboratory to then be rinsed thoroughly with water to be sampled in the field. The sampling is done carefully so that air bubbles do not form in the vials. As for the bacteriological analysis, the sampling is carried out in vials (bottle) made of 250 ML glasses, washed, rinsed with distilled water before being sterilized in the laboratory. In this case, the sample is taken directly from the bottles (in glasses) while taking care not to fill the bottle completely. Once the sampling is complete, the vials are labeled and stored in a cooler before being transported to the LHA-UAC laboratory. Plate 1 presents a series of photos during the sampling of water from boreholes and wells.

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Plate 1: Series of photos presenting the place of water withdrawal from boreholes and wells.

Deprived of views: MOUHAMED Salmanou, February - April 2023

The 2 wells and 2 boreholes chosen randomly out of the 36 wells and 64 boreholes for the analyses constitute the framework of this research and are represented by figure 3.

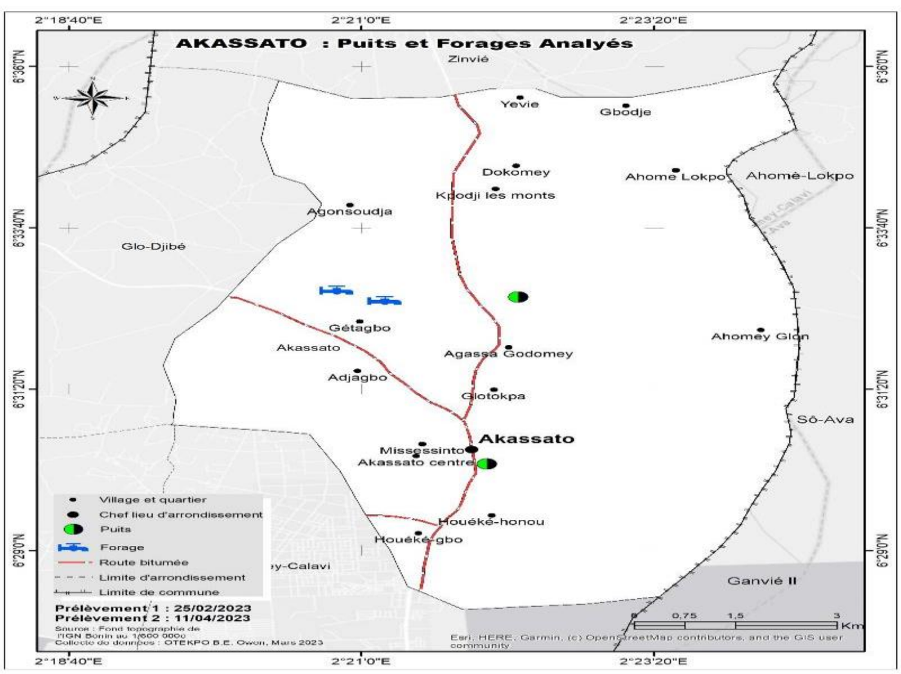

Figure 3: Location of well and borehole water analyzed

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2.2.3. Method of Analysis of samples

The parameters have been chosen to see the degree of potability of well and drilling water in the district of Akassato compared to the standard set by the WHO and or by Benin.

The analysis was carried out in three stages.

2.2.3.1. Analysis of physical parameters

- **Monitor pH and temperature**

Operating procedure:

They are measured using the HORIBA-type pH meter. An average amount of the water to be sampled was taken from a beaker. Then, the electrode is rinsed with tap water before extending the electrode in beakers containing respectively tap water and distilled water. Then the electrode is placed in the water to be analyzed and then the pH and the temperature of the sample are read. The pH makes it possible to know the acidic or basic character of the water while the temperature makes it possible to know the state of the water and is expressed in degrees Celsius (° C). The pH of a drinking water varies around 6.5 and 8.5 while the pH of distilled water turns around 7.

- **Good Conductivity and TDS**

Operating procedure:

They are measured using the HORIBA type conductivity meter. An average amount of the water to be sampled was taken from a beaker. Then, the electrode is rinsed with tap water before extending the electrode in beakers containing respectively tap water and distilled water. The electrode is then placed in the water to be analyzed and then the conductivity and the TDS of the water to be analyzed are read. The conductivity of distilled water is generally less than 5µS.

- **low Turbidity**

Operating procedure:

The turbidity is determined by a device called a COLORIMETER. Indeed, it consists first of making the white with distilled water then, take 10 ml of water from the sample to be analyzed in a well-rinsed tube; put the glass tube in the well of the COLORIMETER and press the "Read" button. Finally, read the value displayed in UTC on the device screen. Plate 2 shows the devices used in the case of certain physical analyzes.

Plate 2: a HORIBA and COLORIMETER type device for the analysis of pH, CE, temperature, TDS and Turbidity

Deprived of views: MOUHAMED Salmanou, February - April 2023

2.2.3.2. Analysis of chemical parameters

These chemical variables are determined by spectrophotometry

- **Nitrate**

Operating procedure:

25 ml of the water to be sampled are taken from two different vials. A sachet of Nitra ver is added to one of the bottles and then it is stirred for 1 min, the second bottle serving as a control. After 5 minutes of reaction, the control is read and then that of the sample to be analyzed. The value obtained after reading the sample is the nitrate content of the analyzed water. The determination of the Nitrate concentration is carried out in the following way :

$[NO^{3-}]$ = Read value x 4.43

- **Nitrite**

Operating procedure:

The procedure is the same as for nitrate except that the reagent used is Nitriver and the reaction time is 20 minutes. The reading is done with a spectrometer at a wavelength of 515 nm. The determination of the Nitrite concentration is carried out in the following way :

$[NO^{2-}]$ = Read value x 3.33

- **Phosphate Group**

Operating procedure:

25 ml of the water to be sampled are taken from two different vials. A sachet of Phosver is added to one of the bottles and then it is stirred for 1 minute, the second bottle serving as a control. After 5 minutes of reaction, the control is read and then that of the sample to be analyzed. The reading is done with a spectrometer at a wavelength of 880 nm. The value obtained after reading the sample is the phosphate content of the analyzed water.

❖ **Sulfate Solution**

Operating procedure:

25 ml of the water to be sampled are taken from two different vials. A bag of Sulfaver is added to one of the bottles and then it is stirred for 1 minute, the second bottle serving as a control. After 5 minutes of reaction, the control is read and then that of the sample to be analyzed. The reading is done with a spectrometer at a wavelength of 450 nm. The value obtained after reading the sample is the sulfate content of the analyzed water. Plate 3 shows the process of analyzing sulfate ions.

Plate 3: Analysis of the sulfate ions of the samples

Deprived of sight: MOUHAMED Salmanou, February - April 2023

2.2.3.3. Bacteriological analysis

The bacteriological analysis carried out aims to search for three germs responsible for the contamination of drilling and well water. These are fecal coliforms, Escherichia coli and fecal streptococci.

❖ **Preparation of culture media**

Operating procedure:

37 g of rapid agar are weighed using the electric scale which is poured into 1 L of distilled water. The mixture is waited for 5 minutes before mixing until a homogeneous solution is obtained. The mixture is then brought to a boil with constant stirring until completely dissolved on a heating plate. Then it is sterilized in an autoclave at 121 °C. for 15 minutes. Finally, the medium is allowed to cool to 45 °C. before pouring into the petri dishes.

❖ **Casting and seeding**

Operating procedure:

The pouring is carried out in petri dishes sterilized beforehand near a flame and then the inoculation of the poured media is carried out by the membrane filtration method. The filtered membranes are then deposited in the petri dishes prepared for each indicator and each petri dish is finally labeled. Anaerobic conditions are created by taking care to turn the dishes over well before incubation. The sprouts are incubated at 37 °C.

3. Results

3.1. Evolution of the rainfall of the municipality of Abomey-Calavi

Figure 4 shows the evolution of the monthly rainfall heights over the period from 1981 to 2020.

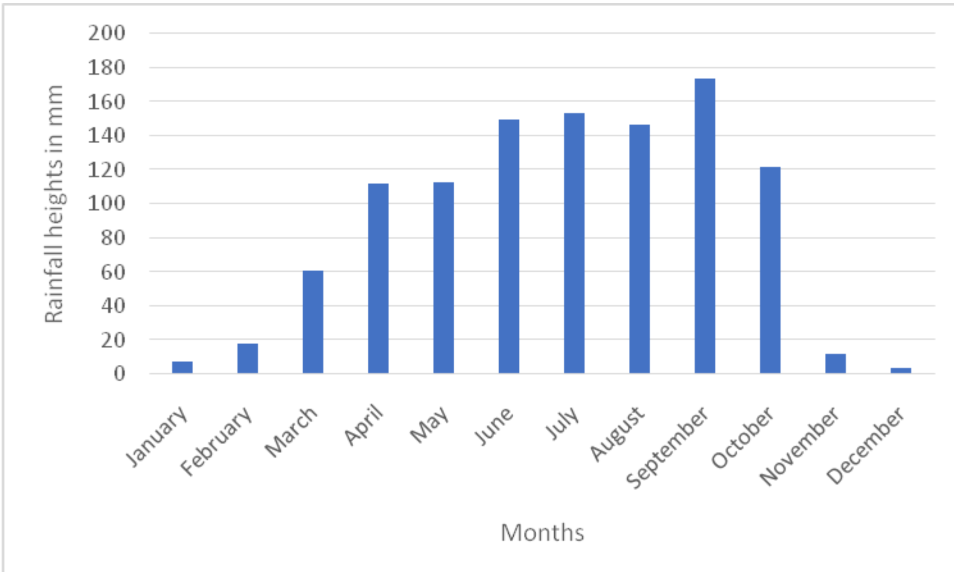

Figure 4: Average rainfall over the period from 1981 to 2020

It can be seen from Figure 4 that the rain reaches its maximum level in June and its minimum in December. Unfortunately, it should be noted that part of mid-March, April, May, June and July, these months characterize the great rainy season in the study area. Likewise, from September, October to mid-November, these months characterize the short rainy season. On the other hand, the short dry season begins from mid-July to mid-November, this area is characterized by the rise of the waters to the surface in August which is the cause of the known coolness at this time. A great dry season from mid-November to mid-March. This variation in the observed rainfall can have influences on the water quality in the study area.

3.2. Source of drinking water supply

Water is a natural resource necessary for the life of living beings. The sources of drinking water supply are not the same in the study area. They vary from one individual to another. Figure 5 shows the different sources of drinking water supply in the district of Akassato.

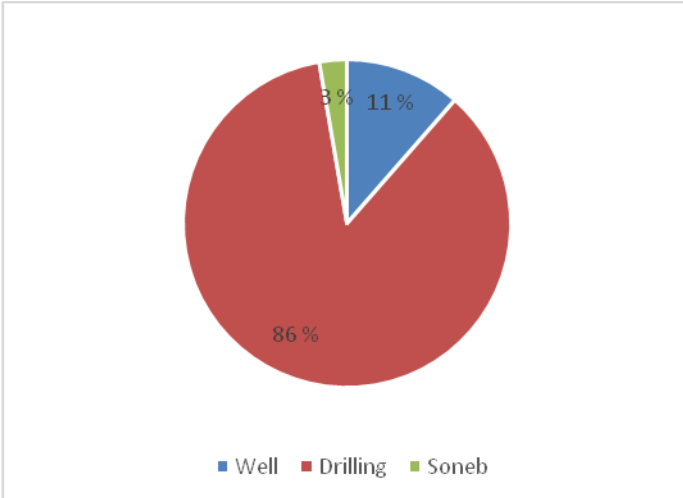

Figure 5: Proportion of different sources of water supply

Figure 5 shows the proportion of water supply methods that varies from one area to another and from one household to another. Indeed, it should be remembered from this figure that 42 out of 367 respondents (11%) use well water as a source of drinking water supply and 10 out of 367 respondents, i.e. 2.72%, use SONEB water for consumption on a daily basis. On the other hand, of the 367 surveyed, 315 or 86% source water from boreholes for various uses use drilling water as a drinking bucket and only 10 individuals of the 367 surveyed use SONEB water. In short, the population of the study area mainly uses borehole water as a source of drinking water supply

3.3. Physical, chemical and bacteriological characteristics of drilling and well water under study during the dry season.

The results of water analyzes of boreholes and wells under study during the dry season for the determination of the values of the physical, chemical and bacteriological parameters that characterize them are recorded in Tables 2,3 and 4.

3.3.1. Case of physical parameters

The result of the analysis of the physical parameters carried out in the laboratory during the dry season on temperature, electrical conductivity, turbidity, pH and total dissolved solids is recorded in Table 2.

Table 2: Result of analysis of the physical parameters

Physical Parameters	Standards: Beninese/WHO	Samples			
		Drilling 1	Drilling 2	Well 1	Well 2
Temperature (T°C)	25	29,1	29,2	29	29
Hydrogen potential	6,5-8,5	5,79	5,48	6,54	5,24
Electrical Conductivity (µs/cm)	2000	65,3	117	790	1061
Total Dissolved Solids	2000	33	58	395	530
Turbidity (UTN)	5	2	24	23	17

Source: Physical analysis results in the laboratory, February 2023

It appears from Table 2 presenting the result of the physical parameters highlighted during the dry season that the values of the temperatures and turbidities are in places higher than the various standards recommended by WHO /Benin. With regard to the values of the electrical conductivity and the Total Dissolved Solids recorded, it should be noted that none of the samples presents any value higher than the standards. At the level of the hydrogen potential, only the well 1 to present a value which is within the range recommended by OMS. In short, on the physical plane.

❖ **The temperature of the water sampled**

Figure 6 shows the values of the temperature of the water samples in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry season.

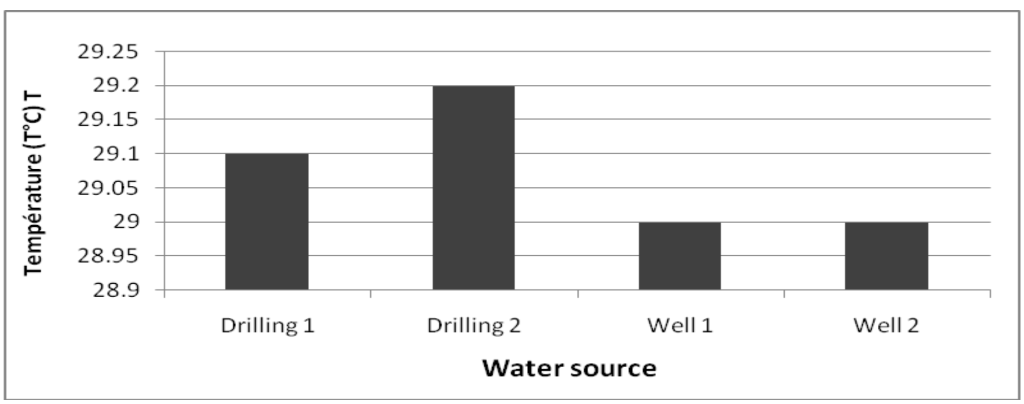

Figure 6: Temperature of the drilling water and wells sampled

It is understood from Fig. 6 that the temperature of these samples varies between 29°C. and 29.2°C.

They are all higher than the recommended national standard which is 25 ° C. All the waters of the districts of Agassa Godomey, Akassato-Center and Gbétagbo in the study environment therefore have temperatures that do not respect the recommended standard for drinking water in the Republic of Benin and favors the proliferation of organic microorganisms

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❖ Hydrogen potential of the water sampled

Figure 7 shows the pH values of the water taken from the various boreholes and wells in the district of Akassato during the dry season.

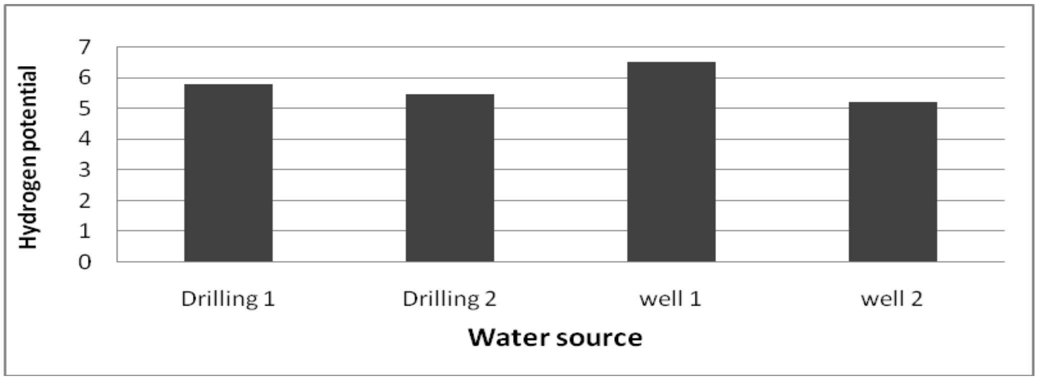

Figure 7: pH values of the drilling and well water sampled.

The pH values obtained in Fig. 7 vary from 5.24 to 6.54. Only the value 6.54 obtained at well 1 in Agassa-godomey complies with the recommended standard for drinking water.

❖ Electrical conductivity of the water sampled

Figure 8 shows the values of the electrical conductivity of the water samples in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry season

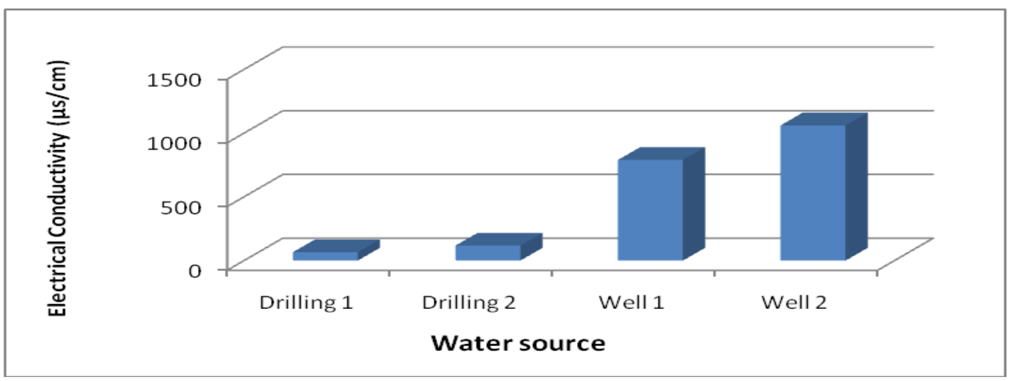

Figure 8: Electrical conductivity of the drilling and well water sampled

The samples of Fig. 8 present electrical conductivity values varying from 65.3 to 1061. They are all lower than the recommended national standard which is 2000 µS/Cm. The waters under study are in places poorly conductive.

❖ Total Dissolved Solids of the water taken

Figure 9 shows the values of the total dissolved solids of the water samples in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry season.

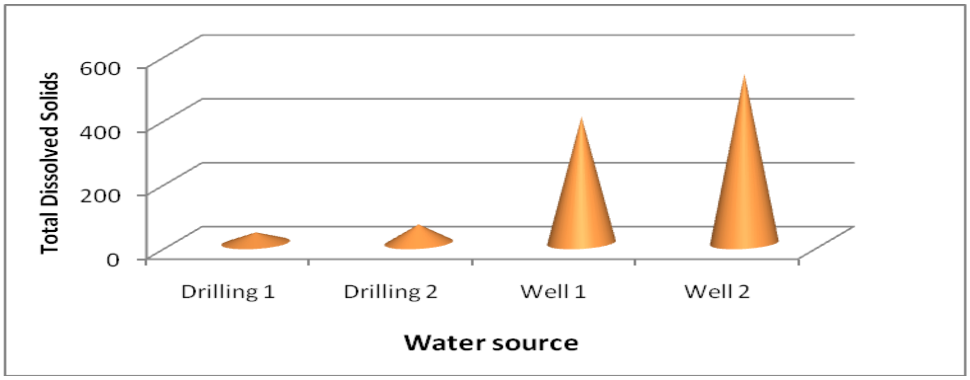

Figure 9: Total dissolved solids of drilling and well water

It can be seen from Fig. 9 that the total dissolved solids of these samples vary between 33 to 530 mg / L. They are all lower than the permissible national standard which is 2000 mg / L. All the waters of the districts of Agassa Godomey, Akassato-Center and Gbétagbo therefore have total dissolved solids lower than the recommended standard for drinking water in the Republic of Benin.

- **Turbidity of the water taken**

Figure 10 shows the turbidity values obtained in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry Season

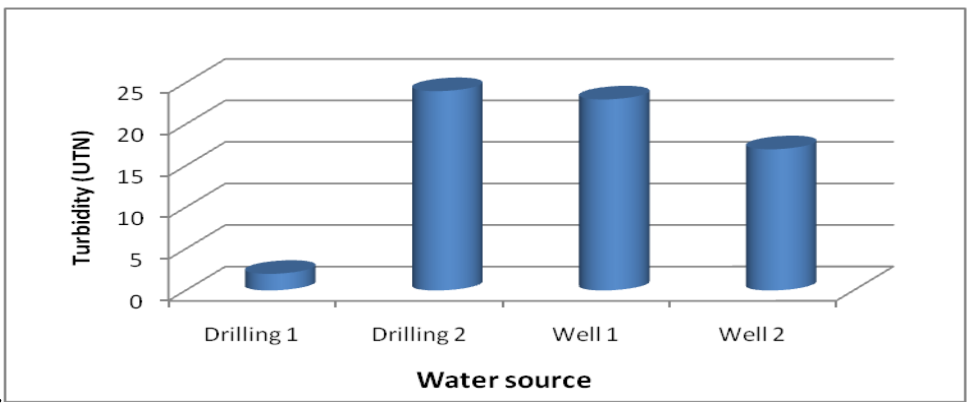

Figure 10: Turbidity of drilling and well water sampled

Figure10 shows values between 02 and 24 UTC. Indeed, the value of the turbidity of the drinking water according to the Benin standard must be less than or equal to 5 NTU. For this study, only the sample from borehole 1 has a value equal to 2 NTU, which is a value less than 5 NTU for drinking water. On the other hand, the samples of the borehole 2 and of the wells (1 and 2) present values which exceed the maximum value fixed by Benin. In sum, these three water samples are cloudy.

3.3.2. Case of chemical parameters

Table 3 shows the results of chemical analyses of well and borehole water during the dry season on the following ions: NO_3^- ; NO_2^- ; $SO4_2^-$; $PO4_3^-$

Table 3: Results of analysis of the chemical parameters

Chemical Parameter	Standards: Beninese/WHO	Echantillons			
		Drilling 1	Drilling 2	Well 1	Well 2
Nitrates (mg/L)	45-50	24	22,5		
Nitrites (mg/L)	3,2-3	<0,001	0,028	0,065	0,052
Phosphates (mg/L)	5	0,12	<0,001	<0,001	<0,001
Sulphates (mg/L)	500	<0,001	<0,001	<0,001	<0,001

Source: Results of chemical analysis in the laboratory, February 2023

The different values recorded in Table 3 during the dry season make it possible to say that chemical variables have values that are below the standards recommended by WHO /Benin. On the other hand, wells 1 and 2 do not have any value at the level of the variable Nitrates. So, drilling and well water are consumable according to the parameters considered on the chemical level during the dry season.

❖ **Nitrate concentration of water**

Figure 11 provides information on the nitrate contents of drilling and well water sampled in the Agassa Godomey, Akassato-Centre and Gbétagbo districts of the Akassato district during the dry season.

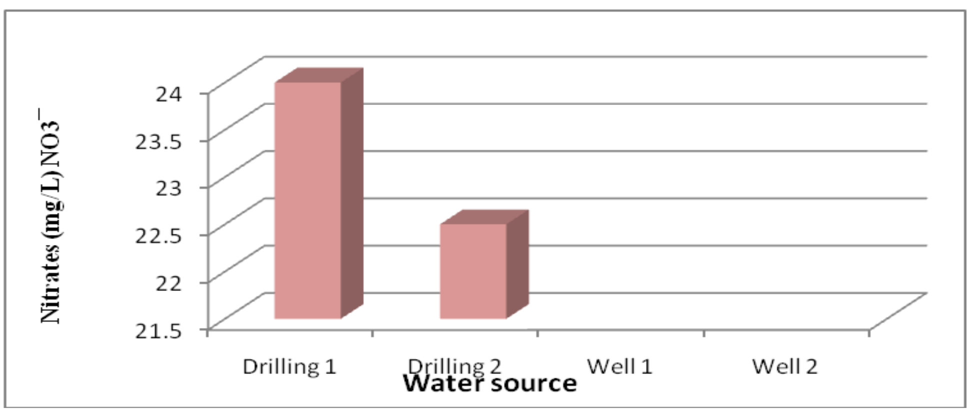

Figure 11: Nitrate concentrations of drilling and well water

In figure 11, these values vary from 22.5mg /l to 24 mg/l. It emerges the inferiority of the values obtained from the samples of boreholes 1 and 2 compared to the standards, which are 45/50 mg

/l. It is noted that at the level of the samples of wells 1 and 2 no trace of presence of nitrate ions is observed.

❖ **Concentration of water in Nitrites**

Figure 12 shows the different concentrations of nitrite ion obtained from the samples of drilling and well water taken in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry season.

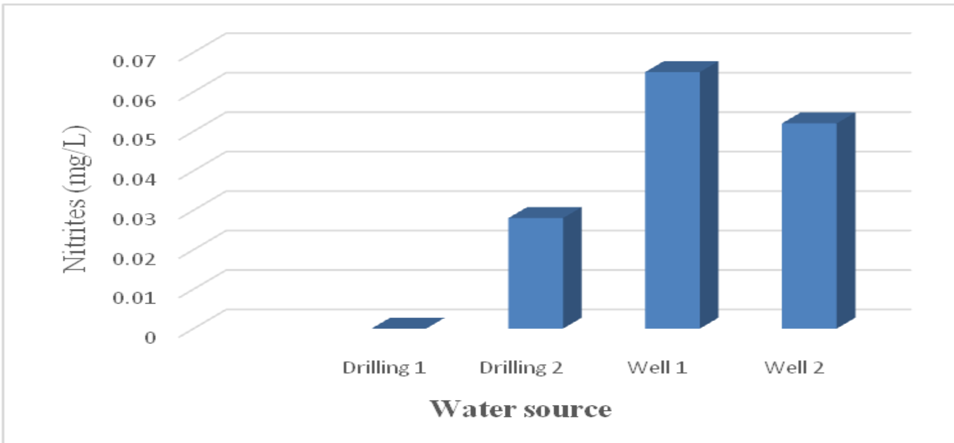

Figure 12: Nitrite concentration of drilling and well water

In figure 12, these different concentrations range from <0.001mg/l to 0.065mg /L. All the values obtained are considerably lower than 3 mg /l which are the standard recommended by WHO /Benin.

Phosphate concentration of water

Figure 13 shows the phosphate contents of drilling and well water taken from the Agassa Godomey, Akassato-Centre and Gbétagbo districts of the Akassato district during the dry season.

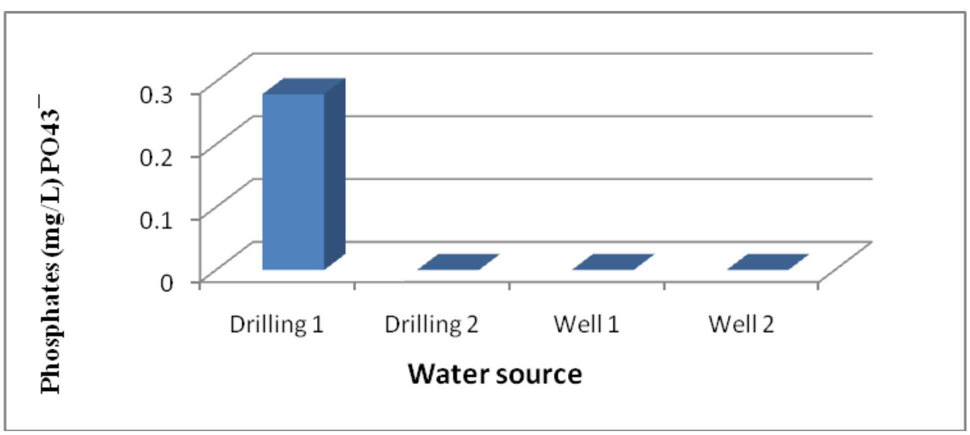

Figure 13: Phosphate concentration of drilling and well water

It can be seen from Figure 13 that these levels vary between < 0.001mg / l and 0.12mg / l. The samples that were the subject of this study presented the values are all below 5 mg / l which is the standard recommended by WHO/Benin for drinking water.

❖ **Concentration of sulphate in water**

Figure 14 shows the sulfate concentrations of drilling water and wells taken in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the dry season.

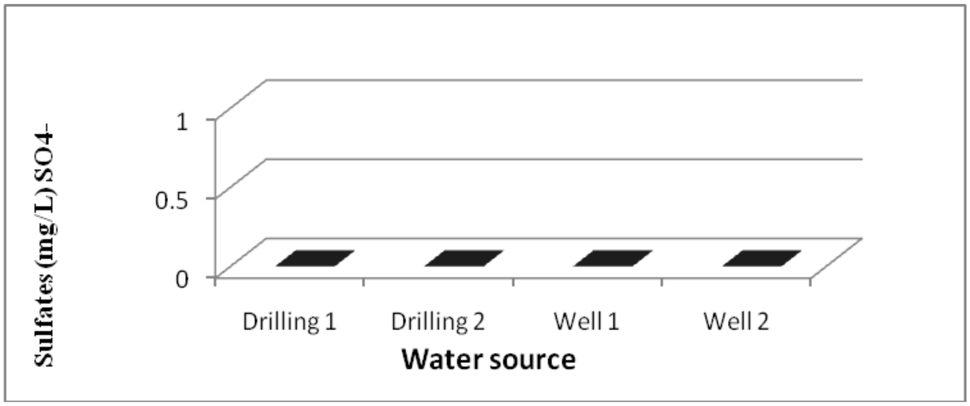

Figure 14: Sulfate concentration of drilling and well water.

In figure 14, all the values obtained are less than 0.001 mg/l and are considerably very low compared to the recommended norm, which is 500 mg/l.

3.3.3. Case of bacteriological parameters

The result of bacteriological analyzes of fecal coliforms; Escherichia coli and fecal streptococci of drilling and well water under study in the neighborhoods made it possible to verify the degree of potability in microbial germs of the samples.

Table 4 presents the results of bacteriological analyzes.

Table 4: Results of bacteriological analysis

Bacteriological Parameters	Standards: Beninese/WHO	Echantillons			
		Drilling 1	Drilling 2	Well 1	Well 2
Fecal Coliforms	00	2	2	16	25
E. coli	00	1	0	5	4
Fecal Streptococci	00	0	0	0	0

Source: Results of bacteriological analysis in the laboratory, February 2023

The different values obtained from the bacteriological analyses reveal the presence of Fecal Coliforms in all the samples. Escherichia coli germs, with the exception of borehole 2, are also present in all waters. On the other hand, fecal streptococci are absent in all the waters studied.

❖ **Fecal coliform from the water taken**

Figure 15 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the dry season.

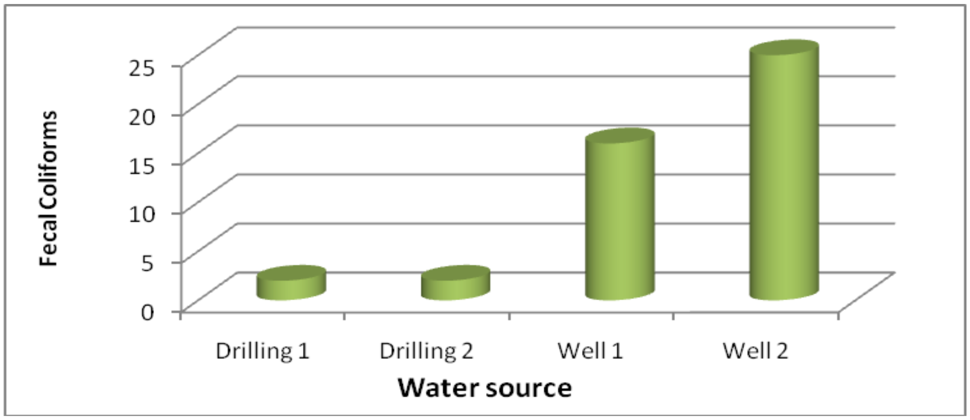

Figure 15: Number of germs obtained in the drilling and well water sampled

It can be seen from Fig. 15 that all the drilling and well water analyzed have values that are clearly higher than 00 CFU /100 ml, which is the Beninese recommended standard for drinking water. Indeed, these germs are harmful to human health. These waters require treatment before consumption.

❖ **Escherichia coli contamination of the water taken**

Figure 16 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the dry season.

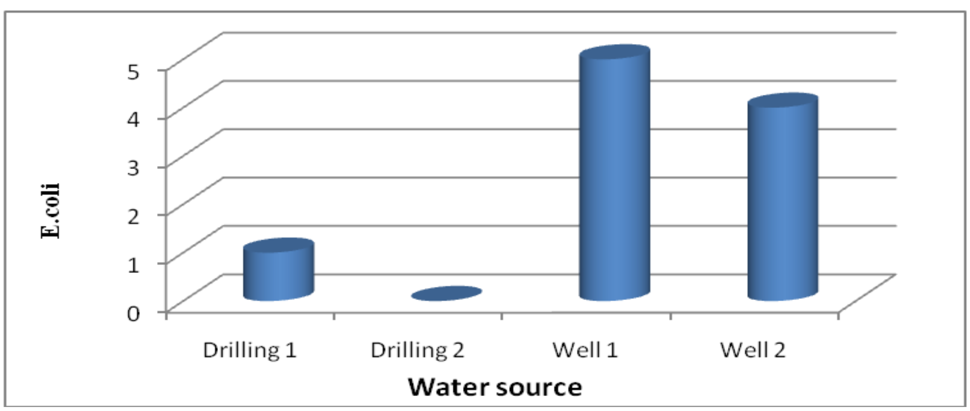

Figure 16: Number of germs obtained in the drilling and well water sampled

Figure 16 shows a variation of 00 to 5 CFU/ml, whereas the accepted norm is 0 CFU/100 ml. Of these samples, only the sample from borehole 2 was not contaminated with Escherichia Coli.

❖ **Fecal Streptococci from the water taken**

Figure 17 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the dry season

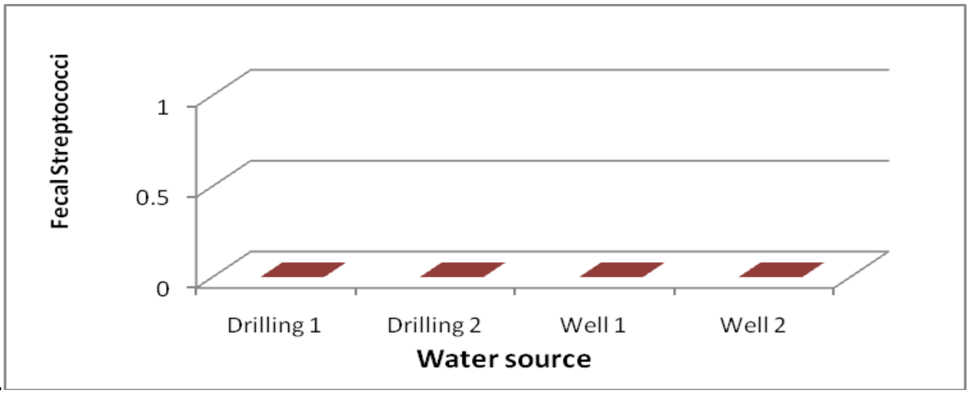

Figure 17: Number of germs obtained in drilling and well water sampled

It can be seen from Fig. 17 that the values of these samples correspond to the accepted standard which is 00 CFU/100 ml. These samples are not contaminated with Fecal Streptococci.

3.3.4. Synthesis of physical, chemical and bacteriological results relative to the degree of potability of drilling and well water studied during the dry season

In short, based on the results of physical, chemical and bacteriological analyses during the dry season, it is found that 75% of well and borehole water is polluted by at least one of the physical variables. Likewise, none of the well and borehole water is not polluted by any of the chemical variables. Thus, 100% of well and borehole water is polluted by at least one of the bacteriological variables. From a physico-chemical and bacteriological point of view, 100% of well and borehole water is polluted by at least one of the variables. The water from wells and boreholes in the study area during the dry season requires treatment before consumption.

3.4. Physical, chemical and bacteriological characteristics of drilling and well water under study during the rainy season.

The results of the analyses of borehole and well water under study during the rainy season for the determination of the values of the physical, chemical and bacteriological parameters which characterize them are recorded in Tables VIII, IX and X.

3.4.1. Case of physical parameters

The result of the physical analyzes carried out in the laboratory during the rainy season on the temperature, the pH meter, the electrical conductivity, the turbidity and the total dissolved solids is recorded in Table 5.

Table 5: Result of analysis of the physical parameters

Physical Parameters	Standards: Beninese/WHO	Echantillons			
		Drilling 1	Drilling 2	Well 1	Well 2
Temperature (T°C)	25	28,4	28,5	28,5	28,6
Hydrogen potential	6,5-8,5	5,77	5,38	6,48	5,16
Electrical Conductivity (µs/cm)	2000	73,9	98,7	783	1076
Total Dissolved Solids	2000	37	49	391	538
Turbidity (NTU)	05	00	00	03	12

Source: Results of the physical analysis in the laboratory, April 2023

According to Table 5, presenting the results of the physical analyses during the rainy season, it can be said that the various values obtained on the electrical conductivity and the Hydrogen potential are all lower than the standard recommended by WHO /Benin. On the other hand, the values obtained on the temperature are all higher than the standard recommended by WHO / Benin. At the level of turbidity, only the well 2 which does not respect the recommended standards. The values obtained on the Total Dissolved Solids show that they do not exceed the standards recommended by WHO/Benin. In short, on a physical level, drilling and well water are not good for consumption.

❖ **Temperature of the water sampled**

Figure 18 shows the values of the temperature of the water samples in the districts of Agassa Godomey, Akassato-Center and Gbétagbo of the district of Akassato during the rainy season.

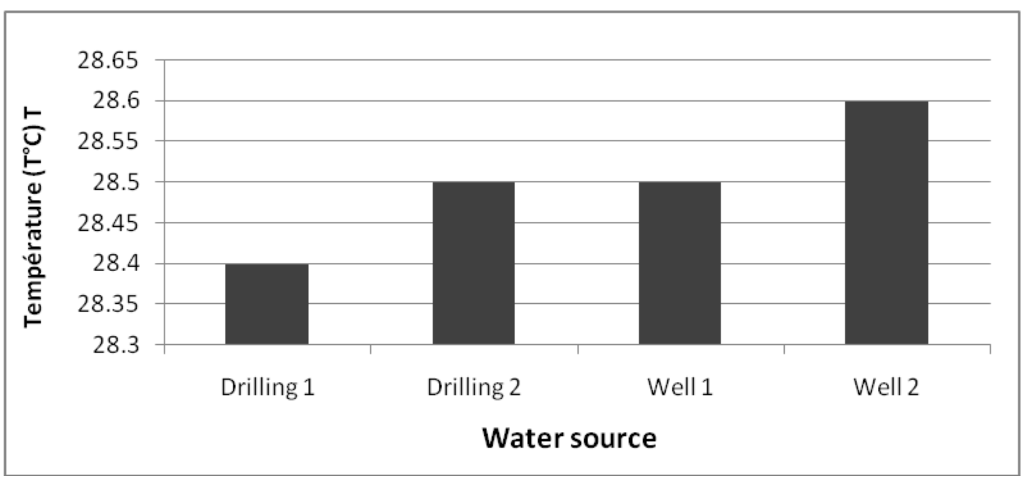

Figure 18: Temperature of the drilling water and wells sampled

It will be noted from Fig. 18 that the temperature of these samples varies between 28.4 °C. and 28.6 °C. This thermal condition is not very favorable for the proliferation of organic microorganisms. All the waters of the study area therefore have temperatures that do not respect the recommended standard which is 25 ° C by WHO /Benin.

❖ **Hydrogen potential of the water sampled**

Figure 19 shows the pH values of the waters of the various boreholes and wells taken in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

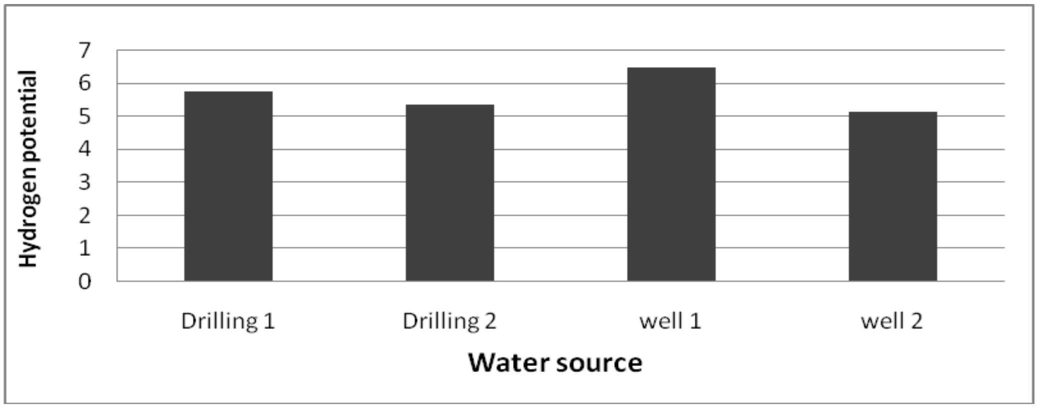

Figure 19: pH of the waters of the various boreholes and wells sampled

It can be seen from Fig. 19 that the pH value of these waters varies from 5.16 to 6.48, these well and borehole waters during the rainy season are acidic. It should be noted that none of the values obtained is within the range of 6.5 to 8.5 set by Benin for drinking water. Consumers of these waters are exposed to osteoporosis.

❖ **Electrical conductivity of the water sampled**

Figure 20 shows the values of the electrical conductivity of the water samples in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

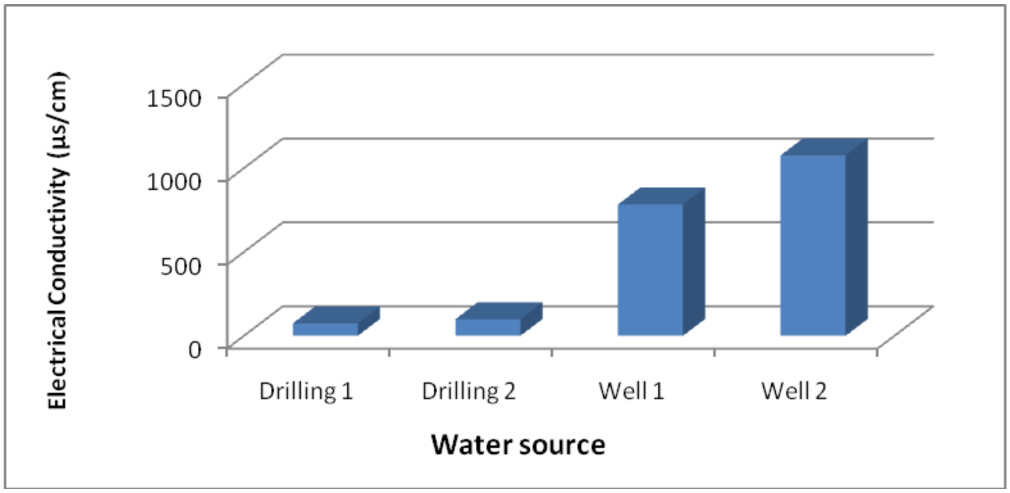

Figure 20: Electrical conductivity of drilling and well water sampled

It is noted from Fig. 20 that the conductivity of these samples vary between 73.9 and 1076 which is lower than the standard set by WHO/Benin which is 2000 µS/Cm. It should be noted that the values of well water are higher than that of drilling. In sum, then the well water is less conductive than the drilling water in the study medium.

❖ **Total Dissolved Solids of the water taken**

Figure 21 shows the values of the total dissolved solids of the water samples in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

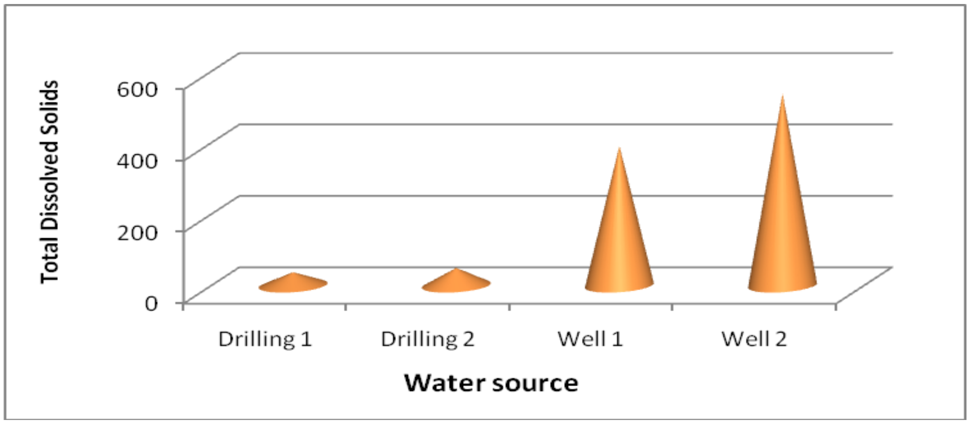

Figure 21: Total dissolved solids from drilling and well water sampled

It is understood from Fig. 31 that the total dissolved solids of these samples vary between 33 to 530 Mg /L. Only the samples from borehole 1 and 2 are lower than the standard recommended by WHO /Benin which is Mg /L. It is then retained that the samples having values higher than the recommended standard have a high content of Total Dissolved Solids.

Turbidity of the water taken

Figure 22 shows the turbidity values obtained in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

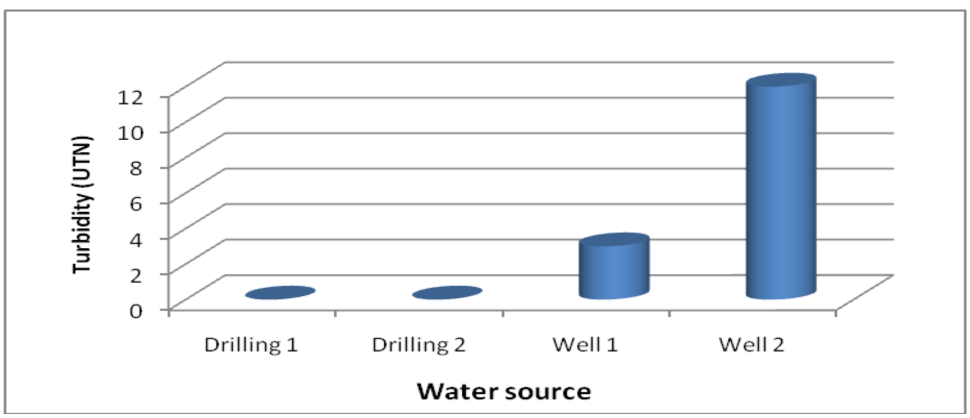

Figure 22: Turbidity of drilling and well water sampled

In Figure 22, the values are between 00 and 12 UTC. Indeed, the value of the turbidity of the drinking water according to the Benin standard must be less than or equal to 5 NTU. For this study, the samples from well 1; borehole 1 and 2 have values lower than that set by Benin. On the other hand, only the sample from well 2 taken in the Agassa-godomey district has values greater than 5 NTU. It is therefore retained that the water of the well 2 is turbid.

3.4.2. Case of chemical parameters

Table 6 presents the result of chemical analyses of well and borehole water during the rainy season on the following ions: NO3-; NO2-; SO42-; PO43-

Table 6: Result of the chemical analyses

Chemical Parameter	Standards: Beninese/WHO	Samples			
		Drilling 1	Drilling 2	Well 1	Well 2
Nitrates (mg/L)	45-50	0,644	4,035	24,348	86,127
Nitrites (mg/L)	3,2-3	<0,001	0,019	0,014	0,107
Phosphates (mg/L)	5	0,027	0,015	0,038	0,045
Sulphates (mg/L)	500	0,027	0,015	0,038	0,045

Source: Results of chemical analysis in the laboratory, April 2023

The chemical analysis of the drilling and well water collected during this study reveals the presence of polluting elements such as nitrates (Well 2), the value obtained of which is recorded in Table 6 during the rainy season. The value of the polluting nitrate exceeds the Benin/WHO standard. On the other hand, the other variables have values that are below the recommended standards. Indeed, the presence of chemical elements having an extraordinary value are the causes of the pollution of well water 2 in Akassato at the chemical level.

❖ **Nitrate concentration of water**

Figure 23 provides information on the nitrate contents of drilling and well water sampled in the districts of Agassa Godomey, Akassato-Centre and Gbétagbo during the rainy season.

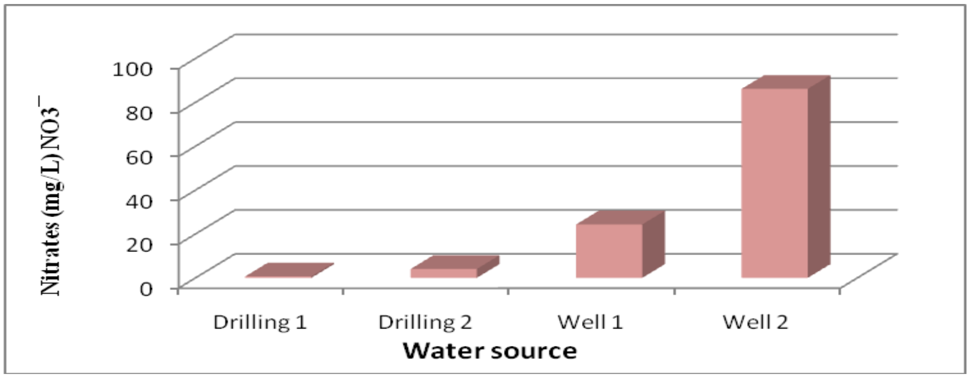

Figure 23: Nitrate concentrations of drilling and well water sampled

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In Figure 23, the nitrate concentration varies from 0.644mg/l to 86.127mg/l. The samples from the borehole (1 and 2) and from well 1 comply with the standards recommended by WHO/Benin which is less than or equal to 45/50 mg /l. Only the sample from well 2 having a value greater than that of the recommended standard. The consumption of waters polluted by nitrate can cause the blue baby syndrome or methemoglobinemia which inhibit the transport of oxygen to the different tissues of the body.

- **Concentration of water in Nitrites**

Figure 24 provides information on the nitrite concentrations contained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

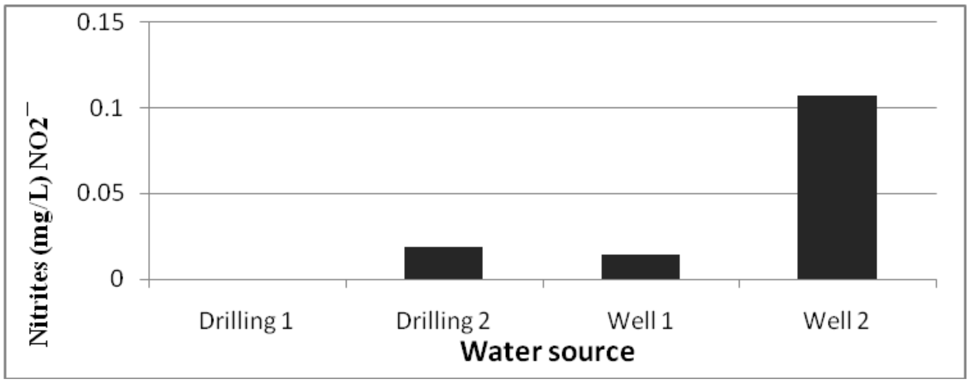

Figure 24: Nitrite concentrations of drilling water and wells sampled

In Figure 24, the nitrite levels obtained at the sampling sites of the different districts vary from a value < 0.001mg / l to 0.107mg / l. The accepted standard for drinking water in Benin must be less than or equal to 3 mg / l, this is not the case with the values obtained from the analyses.

- **Phosphate concentration of water**

Figure 25 shows the phosphate contents of the drilling and well water sampled in the three districts during the rainy season.

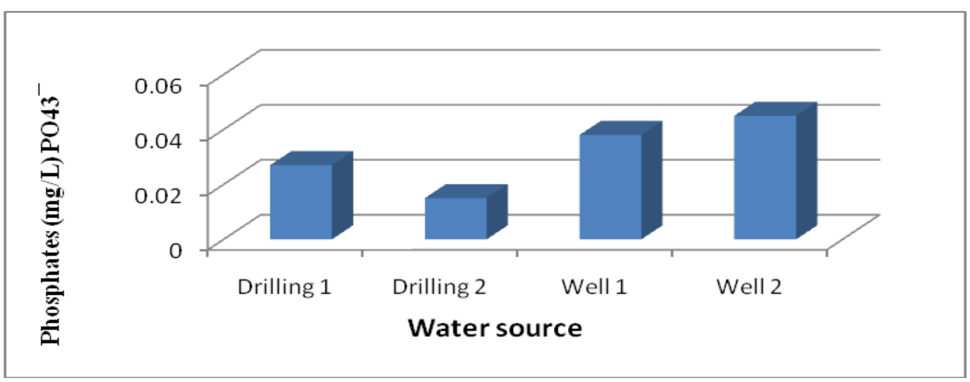

Figure 25: Phosphate concentrations of drilling water and wells sampled

In Figure 25, the phosphate levels vary between 0.015 mg /l and 0.045 mg /l. These different values are considerably lower than the standard set by WHO /Benin which is less than or equal to 5 mg /l. The samples analyzed therefore have values lower than that recommended for drinking water.

❖ **Concentration of sulphate in water**

Figure 26 shows the sulfate concentrations of drilling water and wells taken in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

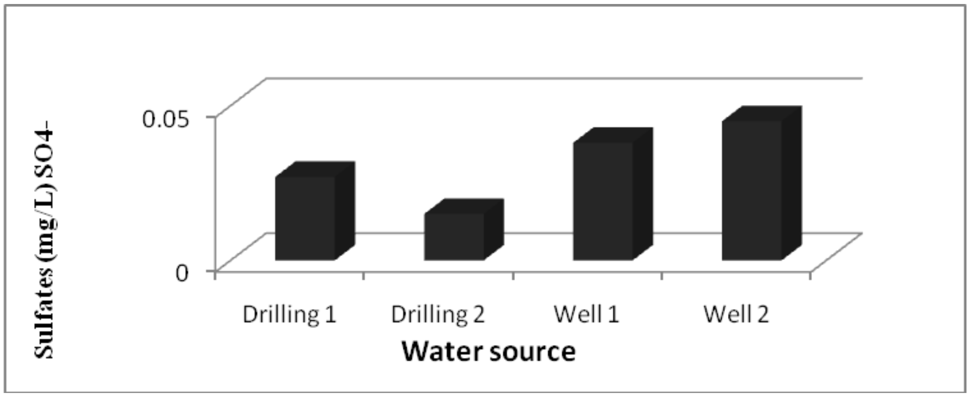

Figure 26: Sulfate concentrations of drilling and well water sampled

In Figure 26, the sulfate levels vary between 0.015 mg / l and 0.045 mg / l. The values obtained are significantly low compared to the standard set by WHO / Benin which is 500 mg / l, the samples analyzed therefore have values lower than that recommended for drinking water.

3.4.3. Case of bacteriological parameters

The result of the bacteriological analysis of fecal coliforms; Escherichia coli and fecal streptococci by drilling and wells is presented in Table.

This Table 7 succinctly gives the result of the analysis of the waters of the boreholes and the wells selected from the three districts specifically to verify their potability in microbial germs during the rainy season.

Table 7: Bacteriological analysis result

Bacteriological Parameter	Standards: Beninese/WHO	Samples			
		Drilling 1	Drilling 2	Well 1	Well 2
Fecal Coliforms	00	27	13	85	195
E. coli	00	2	0	11	5
Fecal Streptococci	00	0	0	0	0

Source: Results of Bacteriological analysis in the laboratory, April 2023

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According to the results obtained from the bacteriological analysis of drilling and well water during the rainy season, the faecal Streptococci present values that respect the standards recommended by WHO /Benin. On the other hand, from Fecal Coliforms, all the values obtained are higher than the recommended norm. At the level, the Escherichia-coli proceeds certain variables whose values are higher than the recommended standards These waters are polluted by the germs sought (Escherichia-coli and Fecal Coliform).

- **Fecal coliforms from the collected water**

Figure 27 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

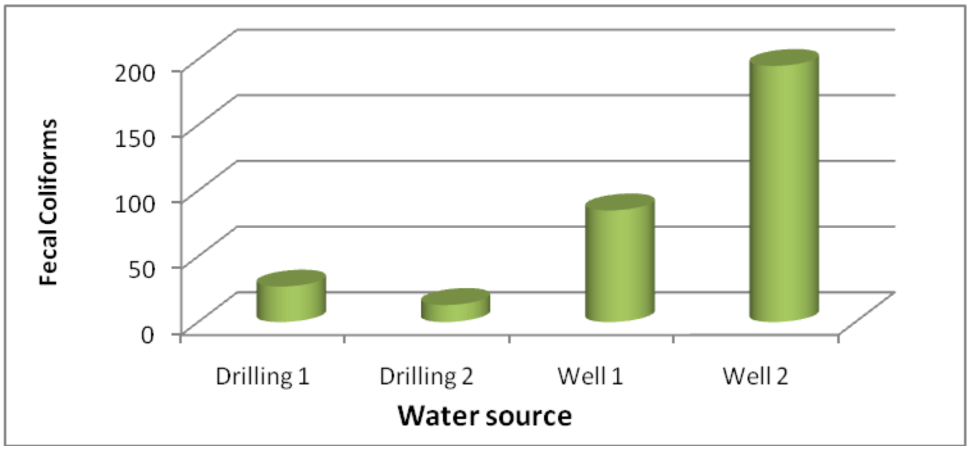

Figure 27: Number of germs obtained in the drilling and well water sampled

It can be seen from Figure 27 that all the drilling and well water analyzed have values that are clearly higher than 00 CFU /100 ml, which is the Beninese recommended standard for drinking water. Indeed, these germs are harmful to human health. The consumption of these waters requires a preliminary treatment

- **Escherichia coli from the collected water**

Figure 28 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

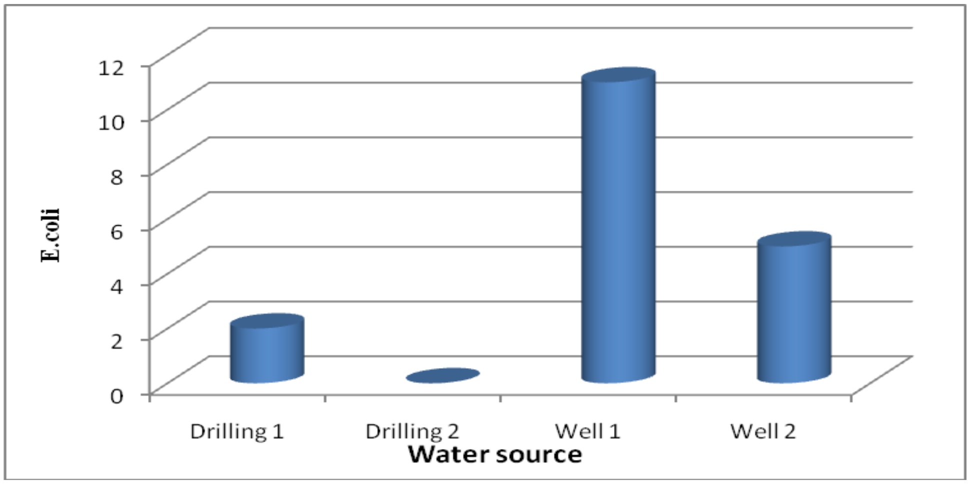

Figure 28: Number of germs obtained in the drilling and well water sampled

Figure 28 shows a variation of 00 to 11 CFU/ml, whereas the accepted standard is 00 CFU/100 ml. Of these samples, only the sample from borehole 2 is not contaminated with Escherichia coli.

❖ **Fecal streptococci from the collected water**

Figure 29 shows the number of germs obtained in the drilling and well water sampled in the neighborhoods of Agassa Godomey, Akassato-Center and Gbétagbo during the rainy season.

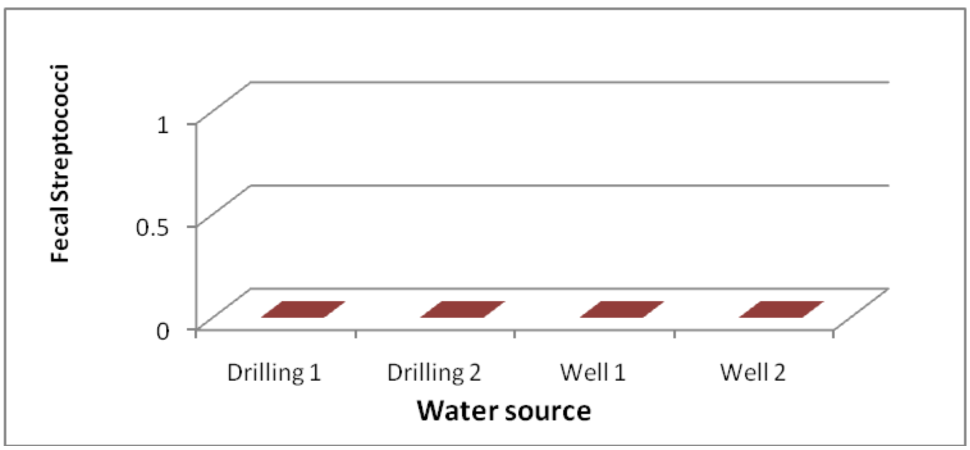

Figure 29: Number of germs obtained in the drilling and well water sampled.

Figure 29 shows a total absence of the number of Faecal streptococcal germs in the well and borehole waters studied.

3.4.4. Synthesis of physical, chemical and bacteriological results relative to the degree of potability of drilling and well water studied during the rainy season.

According to the results of physical, chemical and bacteriological analyzes during the rainy season, 25% of well and borehole water is polluted by at least one of the physical variables.

Similarly, 25% of well and borehole water is polluted by at least one of the chemical variables. On the other hand, 100% of well and borehole water is polluted by at least one of the bacteriological variables. From a physico-chemical and bacteriological point of view, 100% of well and borehole water is polluted by at least one of the variables. The water from wells and boreholes in the study area during the rainy season is unsuitable for human consumption.

3.5. Diseases contracted by the population

During the field investigation, several cases of waterborne diseases were recorded. Indeed, the consumption of water of dubious quality can be the cause of several diseases called waterborne diseases. Figure 30 shows the number of respondents with or without any waterborne disease.

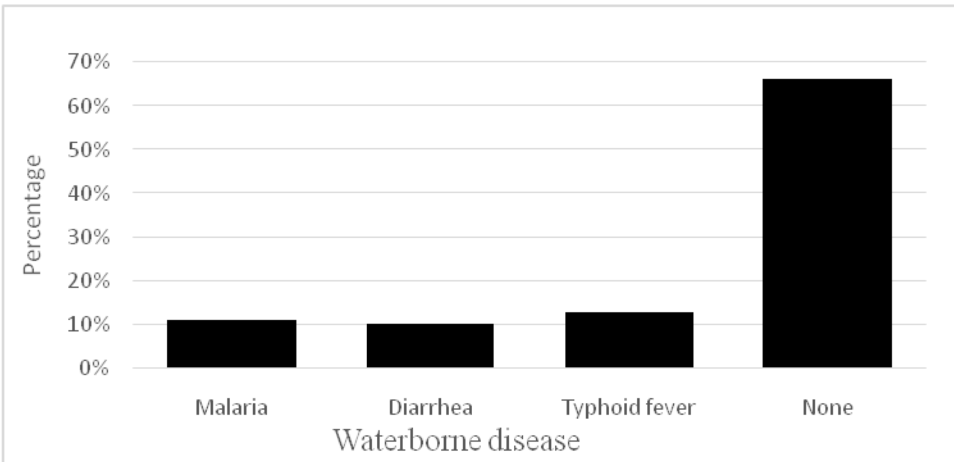

Figure 30: Waterborne diseases recorded in the respondents

It can be seen from Figure 30 that 40 (i.e. 11%), 36 (i.e. 10%) and 46 (i.e. 12.5%) of the respondents respectively suffered from malaria, diarrhea and typhoid fever. On the other hand, 245 (or 66.2%) of the respondents declared that they had never suffered from these cases of waterborne diseases. But the observation is that several respondents do not like to address the issue related to the case of waterborne diseases of which they had been victims and are so discreet on this aspect.

3.6. Probable sources of water pollution

The groundwater considered the most potable is the most commonly used in developing countries for drinking. However, they are vulnerable to physico-chemical and bacteriological pollution. Thus, the determination of the source of pollution of a well and a borehole is essential. It allows users to quickly correct the defect so that the worst does not set in. Figure 31 shows the likely sources of well and borehole water pollution in the district of Akassato.

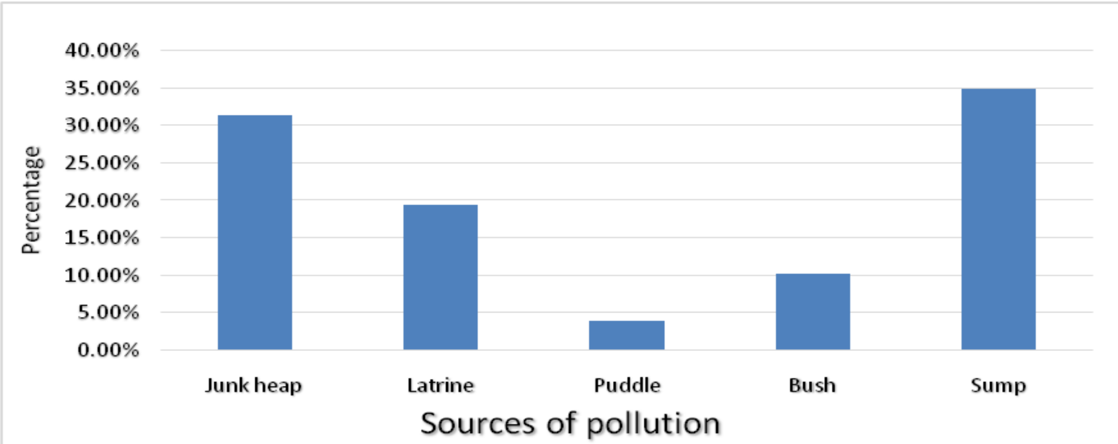

Figure 31: Proportion of probable sources of well and borehole water pollution

From Figure 31, the pollution of wells and boreholes probably comes from various sources. Indeed, according to the proportion of likely sources of pollution (Figure 10) below: 31.4% of the sources of pollution come from piles of garbage in the vicinity of the water point; 19.4% come from latrines in the vicinity of the water point; 3.8% come from puddles ; 10.18% come from sources of supply located in the bush and 35% come from cesspools in the vicinity of the water point. studies show how often well and drilling water are exposed to pollution.

3.7. Type of treatment provided to the water before consumption

Figure 32 shows the types of treatment carried out on the water before its consumption in the district of Akassato.

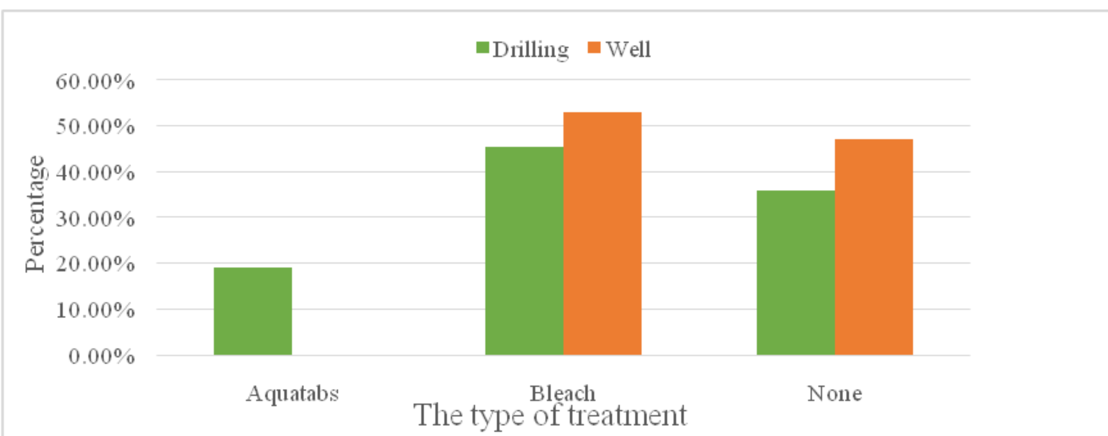

Figure 32: Treatments applied to the drilling water before consumption.

It appears from Figure 32 that either (19%) of the population of Akassato treat the borehole water using the Aquatabs before consuming it and on the other hand no treatment has been applied to the well water using the Aquatabs. In the study environment, 45.3% of the wells and 53% treat borehole and well water using were treated with bleach. On the other hand, the rest of the wells and boreholes sampled whose waters have not been treated have been consumed by a good number of respondents. In short, these consumers of water of dubious quality are exposed to waterborne diseases.

3.7.1. Duration of storage of borehole and well water

The surveys carried out among households in the district of Akassato made it possible to know the conservation time of drilling and well water and the water storage containers. Figure 33 provides information on the storage time of the water.

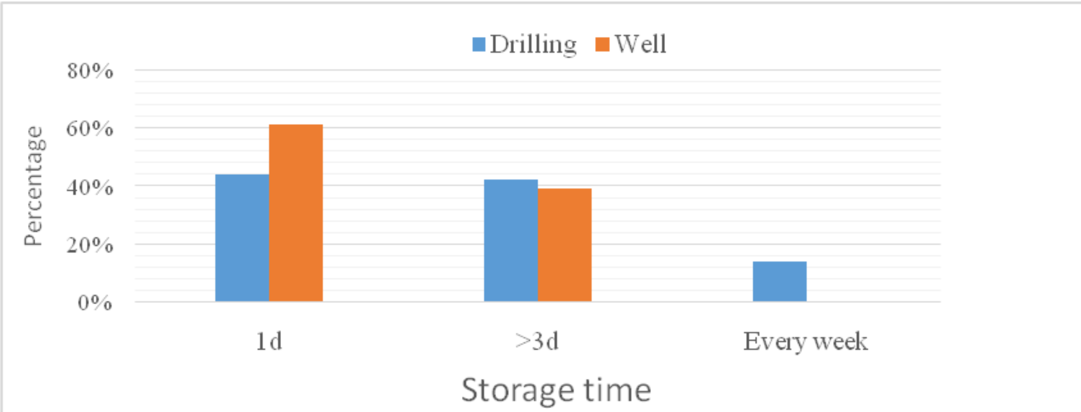

Figure 33: Duration of storage of borehole and well water

From Figure 33, it can be seen that 44% and 61% of households conserve drilling and well water for one day. Similarly, 42% and 39% of households retain drilling and well water beyond three days. However, 14% of households keep water for a period of one week, which is contrary to WHO recommendations which require that household water not be kept beyond 48 hours in tanks and household containers not approved.

3.7.2. Maintenance schedule of water storage containers

This step is subdivided into three parts namely: the maintenance rhythm of the tanks, plastic buckets, cans and finally jars.

❖ **The rhythms of tank maintenance**

During the field investigations, it was observed irregularity of washing of the tanks in the study area. Figure 34 shows the pace of maintenance of tanks by the population of Akassato.

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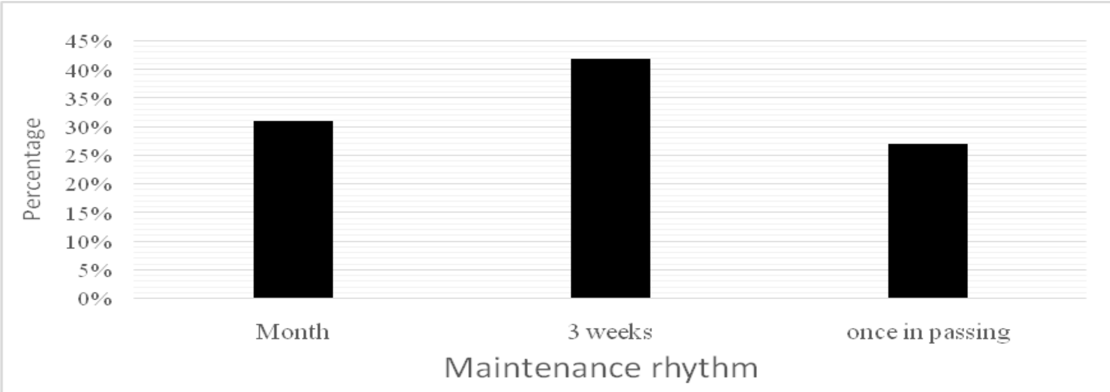

Figure 34: Maintenance rhythm of the tanks

It should be noted from figure 34 that almost half of the households surveyed in akassato ensure regular maintenance of the tanks every three weeks. On the other hand, 31% of the households surveyed do monthly tank maintenance. The strong observation is that 27% of the households surveyed maintain their tanks once when passing through. Plate 4 illustrates the maintenance rhythm of the tanks.

Plate 4: Tanks sampled in Gbétagbo

Deprived of views: OTEKPO B.E. Owen, March 2023

❖ **Rhythm of maintenance of plastic buckets, cans and jars**

Figure 35 shows the maintenance rhythm of plastic buckets, cans and jars.

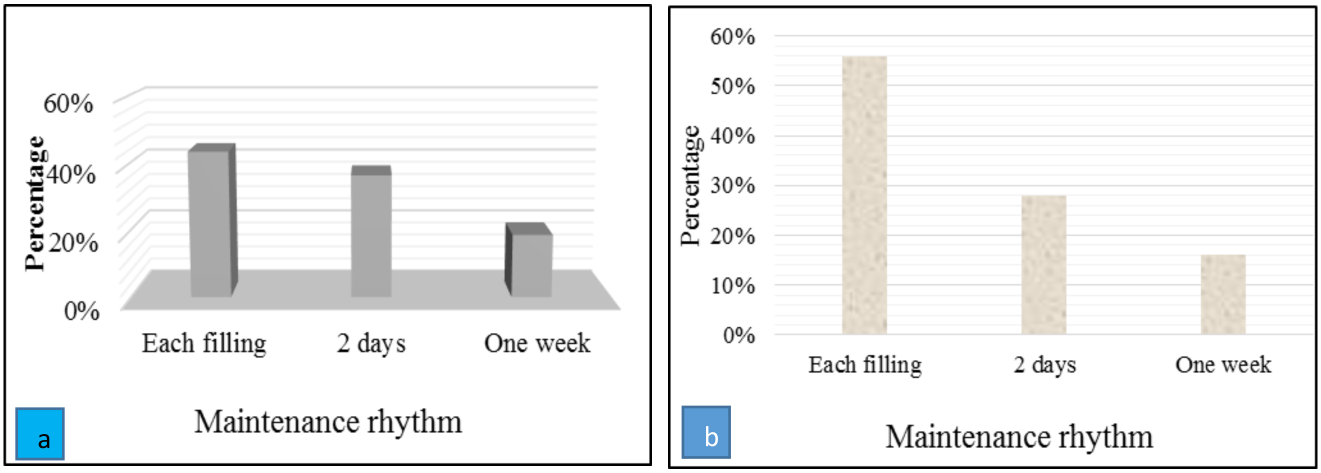

Figure 35: Maintenance rhythms of boreholes (a) and wells (b)

It can be seen from figure 35 that regular maintenance of plastic buckets, cans and jars as part of the conservation of drinking water is essential. It can be seen from figure 35 that half of the population maintains wells each time they are filled, while less than half of the population maintains boreholes every 2 days and less than 20% maintains it for a week.

4. Discussion

This part consists in discussing the results obtained with the results obtained by other authors. The proximity of the boreholes and wells to the likely sources of pollution constitutes a real determining factor of the cases of pollution observed in Akassato, this is confirmed by the short distance between Forage1-sump 13m and latrines 18m; Forage2-pile of garbage 14m and latrines 20m; Puits1- pile of garbage 1s2m and Puits2- pile of garbage 11m and latrines 20m. This is also the observation made by H. L. Honfin (2021, p. 43) in Akassato. In the study area, 100% of the wells are made with curbs. This result is contrary to that of A. O. Denonsi, (2021, p.63) in Ouèsse where nearly 18% of these inventoried wells are without curbs. 78% the sampled wells are without cover. This observation is similar made by A. O. Denonsi, (2017, p. 38) in Parakou where nearly 53.33% of the wells in its study area were uncovered. It is noted that the wells in our study area are exposed to pollution by particles transported by the wind.

The results obtained from the physical, chemical and bacteriological analyses of well water and boreholes in the district of Akassato during the dry and rainy seasons are discussed with the results obtained by other authors.

A temperature variation ranging from 29 °C to 29.2 °C recorded during the dry season and 28.4 to 28.6 recorded during the rainy season. It is noted that this variation in temperatures presents a favorable condition for the multiplication of microbial germs in the study area and is similar to that of A. O. Denonsi (2021, p. 43) in Ouèsse. The pH values obtained during the dry season vary from 5.24 (Well 2) to 6.54 (Well 1) and from 5.16 (Well 2) to 6.48 (Well 1) during the rainy season, any lower than 7 and its consequently acidic. This result is contrary to that obtained in the town of Ouèsse by A. O. Denonsi (2021, p. 41) where the pH of its study medium are alkaline because none of these values obtained is lower than 7.

The electrical conductivity values obtained during the dry season are between 65.3 µS/cm (Borehole 1) at 1061 µS/cm (Well 2) and 73.9 µS/cm (Borehole 1) at 1076 µS/cm (Well 2) during the rainy season. This result is contrary to that of F.D. Assogba (2017, p. 39) in the locality of kpodji les monts in Akassato where the values of its electrical conductivity vary between 42.5 µS/cm to 258 µS/cm.

The TDS or Total Dissolved Solids determines the purity of the water. The values obtained during the dry season vary from 33mg/L (Borehole 1) to 530mg/L (Well 2) and 37mg/L (Borehole 1) to 538mg/L (Well 2) during the rainy season. These values are contrary to that obtained by H. L. Honfin (2021, p. xv) where the TDS values vary between 41.73mg/L to 142.60mg/L.

The analysis of the turbidity of the samples obtained varying from 2 UT (Borehole 1) to 24 UT (Borehole 2) during the dry season and from 00 UT (Borehole 1) to 12 UT (Well 2) during the rainy season. In the dry season, 75% of the well and borehole waters have values higher than the fixed nome and are consequently cloudy. This result is the opposite of that of A.O. Denonsi (2021, p. 44) obtained in the town of Ouèsse where only 1/10 of the sampling analyzed at a value higher than the Beninese standard set at 5 UTC. This same result is in the same order as that obtained in the rainy season or about 25% of the well and borehole water at a value higher than the fixed standard and consequently, the water of well 2 during the rainy season is cloudy.

The nitrate, nitrite, phosphate and sulfate ions obtained during the dry season all have concentrations below 45 mg /l which is the standard set by Benin. This result is in the same order as F.D. Assogba (2017, p. 42) in the locality of kpodji les monts in Akassato where the nitrate, nitrite, phosphate and sulfate ion concentrations obtained are lower than the 45 mg/l standard and contrary to that obtained during the rainy season when only the nitrate ion concentration well 2 (86.127 mg /l) is higher than the 45 mg / l standard. It is then noted that the water from well 2 during the rainy season is subject to chemical pollution caused by the nitrate ion in places.

The bacteriological analysis of the drilling and well waters of the study medium showed that the germs sought (Escherichia coli and Fecal coliforms) are strongly present in the analyzed water samples. This bacteriological pollution rate observed at the well and borehole water level in the study medium is similar to the various results obtained by H.L. Honfin (2021, p. xv). On the other hand, fecal streptococcal germs are absent in all the samples of water tested obtained during the dry season. These results are contrary to that obtained by F. D. Assogba (2017, p. 42) in the locality of kpodji les monts in Akassato where the values of the germs vary between 00 and 148 CFU.

Conclusion

The present study on the rainfall rhythm and quality of drilling and well water in the District of akassato communes of abomey-calavi made it possible to determine the influence of the rainfall rhythm on the qualities of well and well water during dry and rainy periods. There are also a number of factors such as the non-respect in places of the distancing between the source of supplies and the septic tank and the poor management of the sources. It should be noted that 10%; 11% and 12.5% suffered from diarrhea respectively ; of malaria and typhoid fever.

As a result, on the physical level, the temperature values are high both in the dry season and in the rainy season. These waters studied are acidic and are 75% (dry season) and 25% (rainy season) cloudy. The waters are in places conductive. As for the chemical parameters, only the nitrate variables caused the pollution of water from well 2 during the rainy season. Indeed, the values of nitrite, phosphate and sulfate ions obtained are all lower than the recommended standards. As for bacteriological parameters, only fecal streptococci are absent in the water during dry and rainy periods. On the other hand, one of the variables, namely Escherichia coli and fecal coliform, polluted the samples of well and drilling water. These waters for human consumption require treatment before any consumption.

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