International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 44 No. 1 Nov. 2024, pp. 11-23

http://www.ijias.issr-journals.org/

Assessment of the quality of water from some wells in remote areas: Case of the Camp Adagbe and Tibona districts

Yovo Franck[1-2], Sakirigui Amoussatou[1], Topanou Nikita[1], Osseni Sèmiyou[1], Fatondji Raymond[1], Sorogou M. Roger[1], Mazou Farouck[1], Souley Mbarack[2], Fatombi K. Jacques[1], and Biaou Dimon[2]

[1]Kaba Laboratory for Research in Chemistry and Applications, Faculty of Science and Technology of Natitingou, (LaKReCA, FAST-NATI, UNSTIM), BP 266 FAST-Natitingou, Benin

[2]Physical Chemistry Laboratory–Materials and Molecular Modeling (LCP3M), Faculty of Science and Technology, University of Abomey-Calavi (LCP3M, FAST-UAC), Benin

ABSTRACT: Drinking water is the source of domestic wastewater, which mainly degrades the environment and therefore affects the health of those involved in the process because the human body contains about 80%. The lack of information on the quality of well water leads the population of northern Benin, where the problem of drinking water is a real one, to use well water like drinking water without any treatment. This study was undertaken in order to better control the quality of wells waters consumed by the inhabitants of the Camp-Adagbe and Tibona districts in a north of Benin. Qualitative studies based on survey sheets and analyses of physicochemical parameters according to standardized methods were used.
The results show that the majority of the population uses well water compared to drilling and SONEB water due to poor coverage of areas with difficult access to drinkable water. The well waters are acidic (pH: 6.47 0.3), turbid (Turb: 67.36 3.70 NTU), coloured (coul: 62.49 12.10 PtCo) and mineral-laden (Conductivity: 962.17±23.51 µS/cm; Ca^{2+}: 75.45±3.46 mg/L; Mg^{2+}: 118.5±1.81 mg/L). The water from the wells in the Camp-Adagbe and Tibona districts contain pathogenic germs such as E.coli (2 CFU) and total coliforms (3 CFU). Therefore, these waters are not suitable for human consumption according to WHO standards and those defined by Benin. It is therefore necessary that certain water from wells in the Camp-Adagbe and Tibona districts be treated before consumption.

KEYWORDS: water, well, consumption, pollution, Tibona, Camp-Adagbe.

1 INTRODUCTION

Water is a natural resource that is essential to life on earth for humans, animals and plants. It represents between 60 and 70% of human body weight and can correspond to 95% sometimes more in certain plants and marine animals [1], [2]. It is a socio-economic and political issue throughout the world. Having it available in sufficient quantity and quality contributes to maintaining health [3]. Despite its importance, approximately 1.1 billion people don’t have access to drinkable water and more than 2 million, especially children under five, die each year from diarrheal diseases [4], [5]. In developing countries where hygiene and sanitation measures are insufficient, access to water is vital for all living beings but also represents a real vector for the transmission of waterborne diseases. Thus, the consumption of poor-quality water contributes to the spread and perpetuation of waterborne diseases [6]. Therefore, it is necessary to have a better knowledge of existing water resources, especially information on the vulnerability of these resources to the environment [4], [7]. In developing countries in general and specifically in Africa, fresh water represents 9% of the world’s total water resources and is unevenly distributed across the continent [8]. This low rate of poorly distributed fresh water is the basis of many conflicts [9]. Consequently, their availability on the continent constitutes a major problem both in quantity and quality. Current threats related to water are due to rapid population growth, the expansion of urbanization and increasing economic development. In addition, floods, pollution of drinking water, the emergence of waterborne diseases constitute many dangers for urban communities [4]. To meet their water needs, urban and rural communities draw on very diverse sources. Data on the Beninese population show that nearly a third of households use water from various sources as drinking water [10]. Similarly, in sub-Saharan Africa, 35% of the population doesn't have access to drinking water compared to North Africa and the Middle East, where this rate is only 8% [11]. Despite the fact that the use of fresh water resources has increased by 1% per year over the last forty years, Benin is not yet immune to problems related to access to drinking water [12]. These problems are particularly noticeable in the northern part and more particularly given the management and inadequacy of hydraulic and sanitation facilities [13], [14]. In the city of Parakou, the quality of well water used by the community as drinking water, depending on household size, more or less complies with the recommendations in this area. To inform the population about the state of the well water used, this study was conducted and aims to assess the quality of this water in order to help municipal officials in implementing population awareness strategies.

2 Study Framework, Materials And Analysis Methods

2.1 Study Framework

2.1.1 Tibona And Camp Adagbe Neighborhoods Of The Commune Of Parakou

The research was carried out in the Camp-Adagbe and Tibona neighborhoods of the commune of Parakou located between 9°21 North latitude and 2°36 East longitude and then extends over an area of 441 km^2 of which 53.3% is occupied by housing with a population of 255,478 inhabitants including 127,328 men and 128,150 women. The climate of the commune is that of the Sudanese and Sudano-Sahelian regions with two rainy seasons (April-July, October-November) and two dry seasons (August-September, December-March) marked by an average rainfall of 1200mm/year then a temperature varying between 24°C and 32°C. The city of Parakou is located in the center of the Republic of Benin, 407 km from the economic capital Cotonou [15].

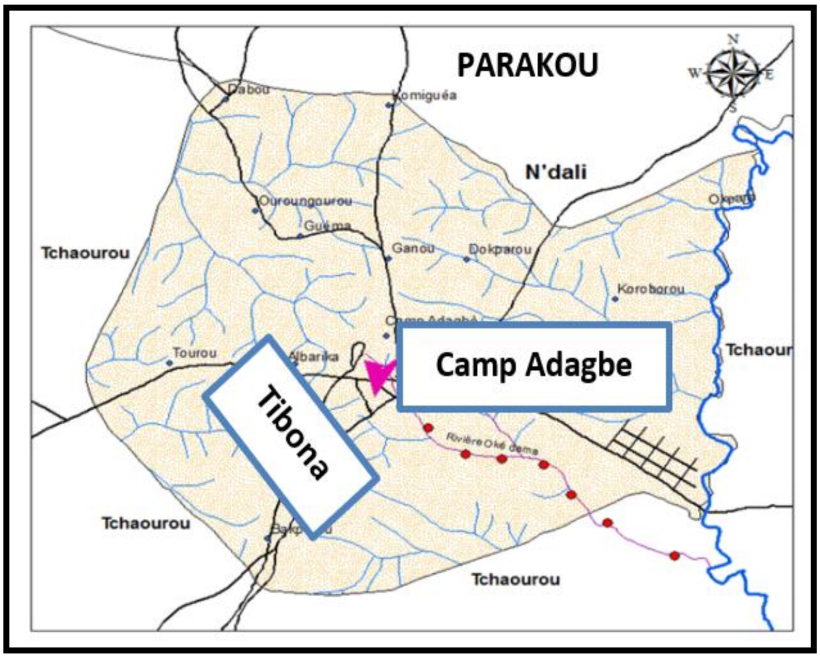

Fig. 1. Map of the Tibona and Camp-Adagbe districts

The drought is almost absolute between January and February, then the rainfall gradually increases from March to September, which is the wettest month. The months of peak rainy season (May to October) receive nearly 90% of the rainfall, or 89.8 mm of water per month in about ten days of rain [16]. The soil of this commune is hydromorphic and mostly rocky, clayey and ferruginous tropical soils where the pedological processes are substantially identical. The analyses methods were carried out in the Kaba Laboratory for Research in Chemistry and Applications (LaKReCA) located in the university center of Natitingou and partner laboratories [17].

2.1.2 Data Collection Material

Data collection was carried out based on field observations to better understand the different types of wells that serve as a drinking water supply for the population of the Tibona and Camp-Adagbe neighborhoods. For this purpose, an observation grid and survey sheets were developed. They made it possible to gradually note data such as: the characteristics of each well, the types of wells, the probable sources of pollution, the different diseases that the population is confronted with, the condition of the wells and their management methods. The observation interview method was used to fill out the sheet [18].

2.1.3 Sampling Methods

The covered wells were chosen, on the one hand, so as to have a more or less global coverage of the neighborhoods as well as the wells without covers. On the other hand, the choice was made to have significant data in relation to the physicochemical and bacteriological parameters. The total filling of the bottles was carried out without trapping air bubbles for the physicochemical analyses. Figure 2 (**a** and **b**) then those (**c** and **d**) indicate respectively the open and closed wells of the Camp-Adagbe and Tibona districts.

Fig. 2. Open and closed wells in the Camp-Adagbe (a, b) and Tibona (c, d) districts

Water samples were collected in 250 mL bottles for bacteriological analysis and then in 1.5 L bottles for physicochemical analyses. These bottles containing the samples were previously sterilized, hermetically sealed and numbered. The sample was collected aseptically according to the NB ISO5667-11 Version 2007 standard [19].

2.2 Analysis Methods

2.2.1 Physicochemical Parameters

The characterization of water through physicochemical parameters, such as: pH, temperature (T) and conductivity (χ), was done using the WTW multi 3420 type multi-parameter according to the NF EN 27888 and NFT 90-008 standards. The color and turbidity were determined using the DR 1900 spectrophotometer using the 120 programs to 455 nm for color and then 950 programs for turbidity according to standard NF EN 27888.

2.2.2 Alkalinity Determination

The alkalinity determination was carried out by adding at least five (5) drops of mixed indicator to 100 ml of the sample and then letting the 0.2N sulfuric acid solution flow drop by drop until the color changes. Let **V** be the volume of the sulfuric acid solution used, the alkalinity (Alc°) is given by the formula:

$$\mathbf{Alc° = V * 50}$$

2.2.3 Determination Of Total Hardness, Calcium And Magnesium

The total hardness or hydrotimetric titer (TH) was determined by taking 50 ml of water and then adding 2 ml of a buffer solution (pH=10) and 5 drops of NET (Eriochrome BlackT). Then titrate with a volume V of the diamine tetraacetic acid solution (EDTA: 0.02N) until the indicator changes from burgundy red (or dark pink) to blue. The total hardness is measured by the EDTA titrimetric method (expressed in French degrees (°f)), according to standard NF T90-003. Let V be the volume of the EDTA solution used in mL, the total hardness is given by the formula:

$$TH = 4.10^{-4} * V \text{ (mg/L) or } TH = 4 * V \text{ (°f)}$$

The waters were classified into different categories so that below 8°f: the water is described as very soft; soft for TH between 8 and 15°f; hard for TH between 15 and 30°f and very hard above 30°f.

The calcium (calcium hardness) was measured, according to the ISO 6059 standard, by adding 2ml of the potassium hydroxide solution, with a pH between 12 and 13 to 50ml of water to be analyzed. Then we titrate with an EDTA solution (0.02N) until the indicator changes from burgundy red (or dark pink) to blue. The calcium content in mg/L is given by the formula below with V1 (ml) the volume of the EDTA solution used.

$$[Ca^{2+}] = 4.10^{-4} * V1 \text{ (mg/L)}$$

The magnesium content (mg/l) is determined according to ISO 6059 by the difference between the total hardness (TH) and the calcium hardness ($[Ca^{2+}]$) according to the formula:

$$[Mg^{2+}] = TH - [Ca^{2+}] \text{ (mg/L)}$$

2.2.4 Chloride Ion Content

Chloride ions were measured by the Mohr method according to NF ISO 9297 / T90-014 by adding 2 to 3 drops of 10% potassium dichromate solution ($K_2Cr_2O_4$) to 100 ml of the sample to obtain a yellow color. The mixture is titrated with a volume V of the silver nitrate solution (0.1N) with stirring until a brick red color appears, marking the end of the chloride dosage. The chloride ion content in mg/L is given by the formula*:*

$$[Cl^-] = 10^{-3} * V$$

2.2.5 Ammonium Content

Ammonium was determined using a LANGE DR 1900 spectrophotometer according to ISO 7150 using program 93 by introducing 1 ml of Rochelle Salt and Nessler reagents into 25 ml of sample, respectively.

2.2.6 Counting Of Microbiological Germs

The indicator parameters of bacteriological pollution, namely: total coliforms and Escherichia-coli, were determined using Chrom-agar culture medium. Using a micropipette, 0.1 ml of each sample is taken and poured into Petri dishes containing the culture medium in the presence of the burner until solidification. The Petri dishes were inoculated in an incubator at 37°C for 48 hours for the enumeration of total coliforms (orange-yellow colonies) according to the NFV-08-05 standards, then at 44°C for 48 hours according to the ISO 9308 standard for Escherichia coli (blue colonies). The bacteria were counted by counting the colonies marked on the bottom of the Petri dish with an indelible marker. The result is expressed in (CFU) colonyformingunits [20].

3 Results

3.1 Statistical Study Of The Mode Of Supply Of Drinking Water In The Camp Adagbe And Tibona Districts

The results from our surveys regarding the modes of supply of drinking water by the inhabitants of the Camp-Adagbe and Tibona districts are recorded in the table below.

Table 1. Statistical study of the mode of supply of drinking water

Consumer	Well water	SONEB water / Borehole	Mineral Rainwater / Backwater	Total
Effective	6	14	0	20
Frequency (%)	30	70	0	100

From the analysis of the table, it emerges that on the ground, the inhabitants adopt several modes of supply of drinking water. The rate of people who consume SONEB water, borehole water or mineral water is 70% against 30% for those who consume well water. The results did not reveal users of rainwater and backwaters as a source of drinking water supply. The surveys revealed that 55% of wells are without covers against 45% covered either by slabs, sheets and/or boards. Indeed, among the covered wells 22.22% are hermetically sealed against 77.77% which are partially closed. Among all the wells surveyed, 60% have dirty surroundings against 40% whose surroundings are clean. The information from the survey did not take into account users of rainwater and watercourses as a source of drinking water supply.

3.2 Physicochemical Parameters Of Water From Some Wells In The Tibona And Camp-Adagbe Districts

The water samples were characterized based on their physicochemical parameters and indicators of the degree of contamination. The results were commented on and made it possible to establish the degree of nuisance of the waters of some closed wells in the Tibona (PFT) and Camp-Adagbe (PFC) districts, then some open wells in the Tibona (POC) and Camp-Adagbe (POC) districts.

3.2.1 Water Content In Conductivity, Turbidity, Colour And Ph

The values obtained for the physicochemical parameters are recorded in the table below.

Table 2. Teneur des eaux en Conductivité, Turbidité, Couleur et pH

Parameters	PFC	POC	PFT	POT	Beninese Standards	Average
Temperature (^{o}C)	31.40±0.06	31.6±0.4	29.6±0.6	29.2±0.7	25	30.45±0.51
Turbidity (NTU)	66.6±8.1	84.7±2.5	66.0±3.7	52.1±0.6	5.0	67.36±3.70
Conductivity(µs/Cm)	1072±63	1171±24	704±3	901.7±3.6	2000	962.2±23.5
pH	5.8±0.3	6,5±0,8	6.74±0.05	6.83±0.02	6.5-8.5	6.5±0.3
Color (PtCo)	14.0±1.1	203±41	16.7±2.9	16.0±3.3	15	62.5±12.1

The conductivity content of well water samples collected in the Camp Adagbe and Tibona neighborhoods varies from 704±3 µs/Cm to 1171±24 µs/Cm. The highest conductivity content is found in the open well of Camp-Adagbe (POC: 1171±24 µs/Cm) and the low value is determined in the closed well water samples of Tibona (PFC: 704±3 µs/Cm). The average values of conductivity contents are found in the waters of the closed wells (PFC: 1072±63 µs/Cm) and open wells (POC: 1171±24.14 µs/Cm) of Camp-Adagbe. The hydrogen potential of the well water samples from Camp-Adagbe and Tibona ranges from 5.80±0.28 to 6.83±0.02. The highest value is found in the open well of Tibona (POT: 6.83±0.02) and the low value is determined in the closed well water samples from Camp-Adagbe (PFC: 5.80±0.28). The average value of the hydrogen potentials (pH: 6.4) is less than 7. It can be said that the well waters are slightly acidic. The temperature of the well water samples taken in the Tibona and Camp-Adagbe districts ranges from 29.16±0.67°C to 31.56±0.40°C. The highest temperature is found at the open well of Camp-Adagbe (POC: 31.56±0.40 °C) and the low value is determined in the water samples of the closed well of Camp-Adagbe (PFC: 31.40±0.06 °C). These recorded values are high compared to the standard set by Benin (25°C). The color of the well water samples varies from 14.0±1.2 PtCo to 203.3±41.1 PtCo. The strongest color is found at the open well of Camp-Adagbe (POC: 203.3±41.1 PtCo) and the low value is determined in the water samples of the closed well of Camp-Adagbe (PFC: 14.0±1.2 PtCo). The waters of the POC, PFT and POT wells have values higher than the Beninese standard (15 PtCo). We can say that these waters are colored and their organoleptic characteristics are high. The highest turbidity of the water samples is found at the open well of Camp-Adagbe (POC: 84.66±2.45 NTU) and the low value is determined at the level of the open well waters of Tibona (POT: 52.13±0.6 NTU). These values exceed the minimum value (5 NTU) set by the Beninese standards. The turbidity contents made it possible to detect the cloudy appearance of the well waters which would be due to the presence of particles suspended in the water. Figure 3 presents the histogram of the physicochemical parameters (Conductivity, Temperature, Turbidity, hydrogen potential, pH) of the waters of the different wells.

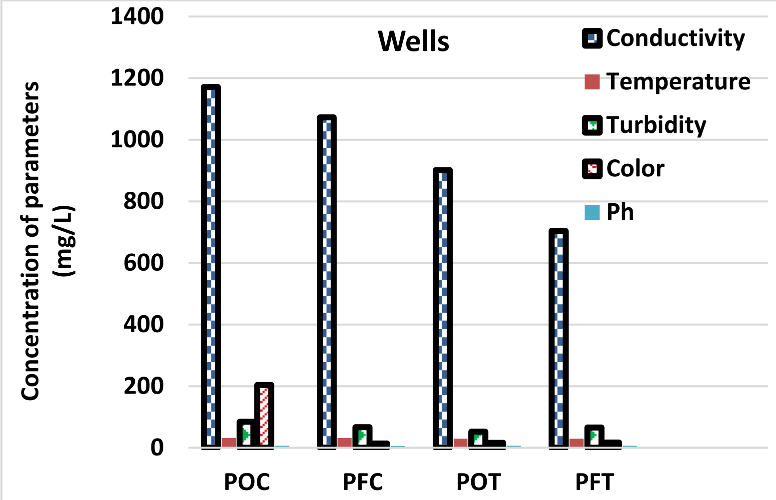

Fig. 3. Histograms of the physicochemical parameters of the wells

It emerges from these histograms that apart from the hydrogen potentials, the turbidities, the colors and the temperatures whose heights are low, only the conductivities of the water samples are high and slightly decreasing from the POT wells to the PFT.

3.2.2 Calcium, Magnesium, Alkalinity And Total Hardness Content Of Water

The values obtained for the Calcium, Magnesium, Alkalinity and Total Hardness content of the waters of Tibona and Camp-Adagbe are found in Table 3.

Table 3. Calcium, Magnesium, Alkalinity and Total Hardness Content of Tibona and Camp-Adagbe Waters

Parameters	PFC	POC	PFT	POT	Beninese Standards	Average
Magnesium mg/L	202.8±1.1	153.59±3.46	68.75±2.65	48.4±1.3	50	118.5±1.8
Calcium mg/L	63.42±4.01	112.07±5.60	74.20±3.65	52.13±0.60	100	75.4±3.4
Total Hardness	266.3±4.6	265.66±4.88	141.3±1.5	219.2±1.3	200	223.1±3.1
Alkalinity mg/L	71.66±1.43	130.00±16.32	583.3±60.5	48.33±1.36	-	208±19

The total hardness of the well water samples is 141.33±1.57 mg/L to 265.66±47.88 mg/L. The open wells of Camp-Adagbe have high total hardnesses (POC: 265.66±47.88 mg/L) compared to those of the closed well water samples of Tranza (PFT: 141.33±1.57). It is noted that only the waters of the closed wells of Tranza meet the Beninese standards (200 mg/L). The waters of the open wells of Tranza and the waters of the closed and open wells of Camp Adagbe do not meet the Beninese standards and are hard. The magnesium ion contents of well water (48.4±1.3 mg/L to 202.79±1.134 mg/L) are high in the closed wells of Camp-Adagbe (PFC: 202.79±1.134 mg/L) and low for the samples of open well water from the Tibona district (PFC; 48.4±1.3 mg/L). These concentrations show that the water from the wells in these areas is hard compared to that of the closed wells of Camp Adagbe. The magnesium contents of the well water are higher than the Beninese standard (50 mg/L) except for the values of the open wells of Tibona. This will allow us to say that the population consuming the sampled water would be exposed to a high dose of magnesium. The calcium content of well water samples taken in the Camp-Adagbe and Tibona districts of the Parakou commune varies from 52.1±0.6mg/L to 112.1±5.6 mg/L. The high calcium content is found in the open well of Camp Adagbe and the low value is determined in the open well water samples of Tibona. The average values of calcium contents are found in the waters of the closed wells of Camp Adagbe (POT: 63.42±4.01 mg/L) and Tibona (74.2±3.6 mg/L) and are of the same order as those of some authors who conducted their research on the waters of the wells of Tchaourou (80.16 mg/L) [4]. Waters with high magnesium and calcium ions content are believed to be contaminated by rocks rich in these minerals such as dolomite (calcium carbonate) and some types of basalt. The alkalinity of well water samples (Camp-Adagbe and Tibona) varies between 48.33±1.36 mg/L and 583.33±60.55 mg/L and the highest value is found in the Tibona closed well (PFT: 583.33±60.55 mg/L) and the low value is determined in the Tibona open well water samples (POT: 48.33±1.36 mg/L). That of the Tibona closed well is higher than the WHO standard and this could be related to the contamination of well water by domestic wastewater containing cleaning products and other chemicals. The analyzed waters of the Tibona and Adagbe districts are alkaline and most of the waters of these wells (75%) meet the Beninese standards and the standard set by the WHO (200 mg/L).

Figure 4 presents the histogram of the water quality parameters (total hardness, magnesium content, calcium and alkalinity).

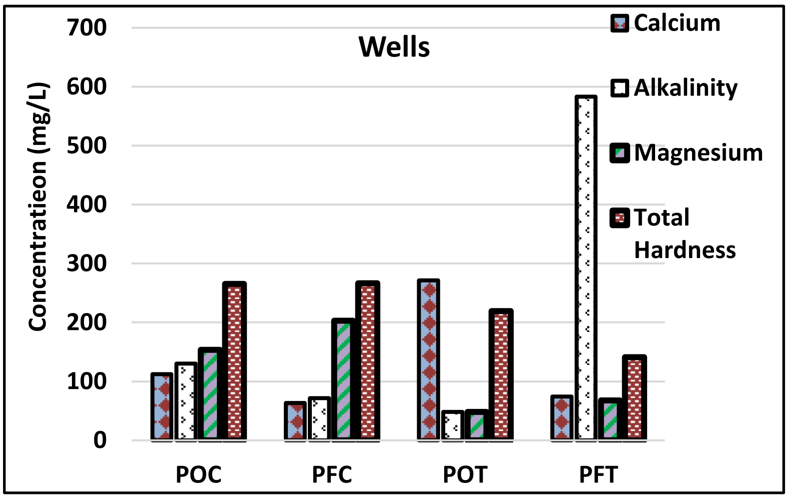

Fig. 4. Histogram of water quality parameters

It is clear from the analysis of Figure 4 that the evolution of the histograms is the same for the waters of the POC and PFC wells. The alkalinity and magnesium content have the same sizes for the waters of the POT well. This observation is observed for the total and calcium hardness of these waters. It is noted that the waters of the PFT wells have a histogram that is the highest in alkalinity compared to the other wells.

3.2.3 Mineral Content Of Water

The mineral content of water (Fluoride, Chloride, Ammonium) was given in Table No. 4.

Table 4. Mineral content of water in the Tibona and Camp-Adagbe districts

Parameters	PFC	POC	PFT	POT	Beninese Standards	Average
Fluoride (mg/L)	0.21±0.04	0.5±0.2	0.4±0.1	0.55±0.08	1.5	0.43±0.1
Chlorine (mg/L)	66.5±9.5	75.6±3.8	120.0±1.2	98.16±2.4	250	90.1±4.2
Ammonia (mg/L)	0.50±0.13	0.3±0.1	0.2±0.6	0.27±0.02	0.5	0.35±0.2

The ammonia content of well water samples from the Camp-Adagbe and Tibona districts is around 0.27±0.02 mg/L to 0.5±0.13 mg/L. The waters of the closed wells of Camp-Adagbe have a high ammonia content (PFC: 0.5±0.13mg/L) compared to those of the closed wells of Tibona (PFC: 0.27±0.017 mg/L. The chlorine contents of the well waters vary from 66.58±9.48mg/L to 120±1.21 mg/L. The high chlorine content is found in the closed well of Tibona (PFT: 120±1.21mg/L). The low chlorine value is found in the closed wells of Camp-Adagbe (PFC: 66.58±9.48 mg/L). It can be said that the values of the chloride ion concentration are generally lower than the Beninese standard set at 250 mg/L and show that these waters are not polluted by chloride ions. The ion contents Fluoride content of the well water samples collected ranges from 0.21±0.04 mg/L to 0.565±0.18 mg/L. The high fluoride content is found in the open well of Camp-Adagbe (POC: 0.565±0.18mg/L) and the low value is determined in the closed well water samples of Camp-Adagbe (PFC: 0.21±0.04 mg/L).

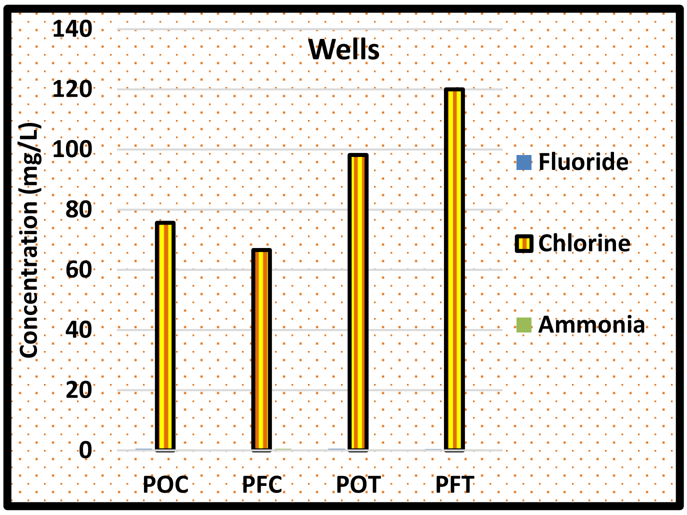

Fig. 5. Histogram of the mineral elements contained in the waters of the wells of the Tibona and Camp Adagbe districts

From the histogram it can be seen that fluorides and ammonium are very small in size compared to chloride ions which are larger in size and increase from PFC, POC to PFT.

3.2.4 Bacteriological Parameters Of The Waters Of Some Wells In The Tibona And Camp-Adagbe Neighbourhoods

The water samples were characterized based on their bacteriological parameters and indicators of the degree of contamination. The results were commented on and made it possible to establish the degree of nuisance of the waters of some closed and open wells in the Tibona (PFT) and Camp-Adagbe (PFC) neighbourhoods.

Table 5. Bacteriological parameters of well water in the Tibona and Camp-Adagbe districts

Parameters	PFC	POC	PFT	POT	Beninese Standards
Total coliforms (UFC)/100mL	88	0	45	340	0
Escherichia coli (UFC)/100mL	0	0	8	0	0

The bacteriological analysis carried out in the laboratory shows that some wells have high values of total coliforms (POT: 340 CFU) whose different concentrations vary from 8 CFU to 340 CFU. The waters of the open wells of the Tibona district have a high content of total coliforms (POT: 340 CFU) and are followed by the waters of the closed wells of the Camp-Adagbe district (PFC: 88 CFU). The rate of coliforms in the waters of the open wells of Tranza shows that these waters are more loaded with total coliforms than those of the closed wells of Camp Adagbe. The results of the microbial analysis in relation to Escherichia coli present concentrations that are zero (0 CFU) for all the waters except those of the closed wells of Tranza (8 CFU). The figure below gives an overview of the distribution of germs at the level of the wells.

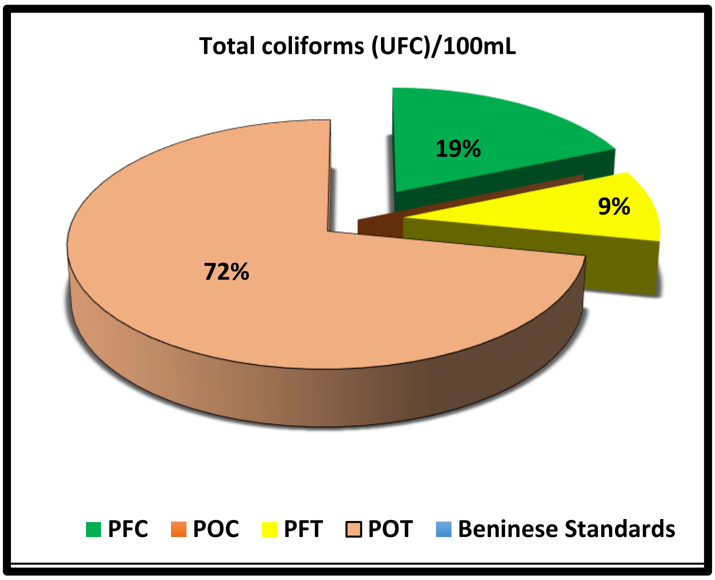

Fig. 6. Distribution of germs in well water

From the analysis of the figure, we note that the waters of the open wells of Tranza (POT: 72%) occupy a large area, followed by the waters of the closed wells of Camp Adagbe (19%) and Tibona (9%). It emerges from this observation that total coliforms are unevenly distributed in the Camp Adagbe and Tibona neighborhoods.

3.2.5 Study Of The Conformity Of The Water Of Some Wells In The Tibona And Camp-Adagbe Neighborhoods

The study of the conformity of the water of some wells in the Tibona and Camp-Adagbe neighborhoods led to the verification of the physicochemical and bacteriological parameters of the water with the standards and it was useful to evaluate their quality. To achieve this, the rates of wells whose parameters respect the standards are recorded in the table below so that a rate of 25% is granted to a parameter for which the water of a well respects the standards.

Table 6. Rate of conformity of wells with Beninese standards

Parameters	PFC	POC	PFT	POT	Beninese Standards	Conformity (%)
Temperature (^oC)	31.4±0.1	31.56±0.40	29.66±0.67	29.16±0.67	25	-
Turbidity (NTU)	66.7±8.1	84.7±2.5	66.0±3.7	52.1±0.6	5.0	0
Magnesium(mg/L)	202.7±1.1	153.6±3.5	68.8±2.7	48.4±1.3	50	25
Fluoride (mg/L)	0.21±0.04	0.57±0.18	0.40±0.07	0.55±0.08	1.5	100
Conductivity (µs/Cm)	1072±63	1171±24	704±3	901.7±3.6	2000	100
Chloride (mg/L)	66.58±9.48	75.66±3.81	120.0±1.2	98.16±2.35	250	100
Ammonia (mg/L)	0.5±0.1	0.32±0.13	0.27±0.64	0.27±0.02	0.5	100
pH	5.8±0.3	6.5±0.8	6.74±0.05	6.83±0.02	6.5-8.5	75
Calcium(mg/L)	63.42±4.01	112.1±5.6	74.2±3.7	52.1±0.6	100	75
Total Hardness (mg/L)	266.3±4.7	265.7±4.9	141.3±1.6	219.2±1.3	200	25
Color (PtCo)	14.0±1.1	203.3±41.1	16.7±2.9	16.0±3.3	15	25
Alkalinity (mg/L)	71.7±1.4	13.0±16.3	583.3±60.5	48.3±1.4	-	-
Total Coliforms	88	0	45	340	0	0
E. coli	0	0	8	0	0	0

From the analysis of the table, it emerges that the physicochemical parameters namely fluoride, conductivity, chloride ions and ammonia of the waters of the wells analyzed have conformities that are equivalent to 100%. It can be deduced that the waters of the wells containing these parameters comply with the Beninese standards. These parameters are followed by the hydrogen potential and the calcium content for which 75% of the waters of the wells comply with the standards. The parameters such as the magnesium content, the total hardness and the color of the waters evaluated have a rate of 25%. On the other hand, the turbidity, the content of total coliforms and E. coli of all the waters of the wells are not in accordance with the Beninese standards. It can be deduced that the waters have varied conformities and out of the fourteen parameters determined at the level of the waters of the wells, only four comply with the Beninese standards.

4 Discussion

4.1 Interpretation Des Resultats

The low rate of consumption of well water would be linked to its poor quality as highlighted by some authors who actually obtained a consumption rate equal to 20% [21]. These waters would probably be sources of waterborne diseases in the study area [22]. It can be said that the wells of the different areas have morphologically varied structures [23]. The inconvenient architecture of the wells studied (partially covered wells) would lead to the deposit of pollutants in these waters and this can be justified by the low financial resources available to the inhabitants of these areas [24]. Among all the wells surveyed, we note that 60% have dirty surroundings compared to 40% and this same observation was made by Faye in 2017 [25]. The average values of conductivity contents are found in the waters of closed wells (PFC: 1072±63 µs/Cm) and open wells (POC: 1171±24.14 µs/Cm) of Camp-Adagbe. These values show that the waters of closed and open wells of Camp-Adagbe are more mineralized than those of Tibona [26]. The ion load of the waters can come from the degradation of geological layers rich in minerals (limestone, gypsum or salt), which leads to contamination of the water table [4]. The geological composition of the subsoil can influence the mineralization of the water. However, the low mineralization of the waters of the closed wells of Tibona is close to the observation made on the waters of the commune of Pobe [3]. The average value of the hydrogen potential lower than 7 shows that the well waters are slightly acidic and this can be linked to the chemical reaction undergone by carbonic acid which dissociates into hydrogen and bicarbonate ions [27]. This observation made on the acidity rate of the waters is close to that made on all the waters of Pobe [3]. These recorded values are high compared to the Beninese standard (25 ° C). The high temperatures could be explained by the influence of ambient heat and also by the geothermal gradient of our study area [28]. The color contents show that these waters are colored and their organoleptic characteristics are high. This observation can be justified by the proximity of the wells to industrial areas, landfills, undesirable substances, sewers or wastewater which contribute to water pollution [29]. These values exceed the minimum value (5 NTU) set by Beninese standards. The cloudy appearance of well water comes from the accumulation of organic matter, algae and other debris in these waters which would increase their turbidity [30]. The authors established a correlation between the high presence of minerals and the acidity of well water [31]. The hardness of the water would be linked to the high concentration of dissolved minerals, mainly calcium and magnesium ions [32]. These concentrations show that the waters of the wells of these areas are hard compared to those of the closed wells of Camp Adagbe and the composition of the sedimentary rocks (dolomitic limestones, Jurassic or Middle Triassic dolomites) on which these wells were built would be responsible for this observation [33]. The average values of calcium contents are found in the waters of the closed wells of Camp Adagbe (POT: 63.42±4.01 mg/L) and Tibona (74.2±3.6 mg/L) and are of the same order as those of some authors who conducted their research on the waters of the wells of Tchaourou (80.16 mg/L) [4]. Individuals who consume the waters which have a high content of magnesium and calcium ions can suffer from cardiovascular and renal problems [34]. The calcium contents of the waters of the closed wells of Tibona are higher than the WHO standard and this could be linked to the contamination of the well waters by domestic wastewater containing cleaning products and other chemical substances [35]. The low value of the alkalinity of the waters of certain wells could be linked to the neutralization of bicarbonate ions in the well waters by acid rain [36]. The ammonium values of the Tibona wells are lower than those of the ammonium concentrations of the well waters of the commune of Abomey-Calavi but are in line with the standards (0.5 mg/L) [37], [38]. The presence of ammonium ions in the well waters may be due to the infiltration of organic waste into the waters [39]. The high chlorine content is found at the level of the closed Tibona well (PFT: 120±1.21mg/L). This high level of chloride ions in the water can give rise to the presence of organic micropollutants, a set of organohalogenated by-products such as trihalomethane (THM), suspected of being toxic and causing digestive disorders and accelerating the corrosion of the pipes [40]. It can be said that the values of the chloride ion concentration are generally lower than the Beninese standard set at 250 mg/L and shows that these waters are not polluted by chloride ions. This result corroborates those of some authors who have conducted studies and who have observed that some waters from wells in Morocco meet the standards (300 mg/) [41]. The fluoride ion concentrations of well waters are similar to those obtained by authors at the level of the wells (0.16 mg/L to 1.16 mg/L) of Tchaourou [4]. The waters contain few fluoride ions, meet Beninese standards and would not be a source of fluorosis (0.81 mg/L) for consumers [42]. The presence of coliforms is an indicator of the fecal contamination of these waters with the presence of pathogens responsible for waterborne diseases [43]. These waters are more loaded with total coliforms than those of the closed wells of Camp Adagbe. This can be explained by the fact that the covering of the wells contributes to the protection of the water and that the maintenance of their immediate environment contributes to the sanitation of these waters [44]. This makes the waters of the wells free of total coliforms like those of the open wells of Camp Adagbe (POC: 0 CFU). Furthermore, these values are higher than 0 CFU and show that these waters do not comply with Beninese standards for consumption with the exception of the open well of the Camp-Adagbe district [45]. The area of implantation close to the places of human dejection and the tools used in drawing these waters could contribute to this observation [46]. The Escherichia coli content of the water subjects consumers to the risks of waterborne diseases (cholera, digestive disorders, hepatitis, etc.) and makes the water unfit for consumption [47].

4.2 Some Strategies For Sanitation Of Well Water

The study of compliance shows that the waters of the wells of Camp Adagbe and Tibona are mostly polluted. The immediate environment of these wells must be sanitized and the waters of these wells must undergo periodic treatment to guarantee good health to consumers. Furthermore, these results are data on which municipal officials can dwell to raise awareness among the populations of these areas on the rules of hygiene and sanitation of the different sources of drinking water. As sanitation rules and measures to be taken to ensure good quality of well water, before any use, we can cite:

- The use of certified water filters to eliminate impurities and pathogens;
- The treatment of water by boiling for at least 5 minutes;
- The use of commercially available water treatment products;
- Protection of water sources, mainly wells, with appropriate or concrete covers to avoid contamination by pollutants;
- Regular monitoring and analysis of well water by quality control laboratories.

5 Conclusion

The survey conducted on the water consumed by the inhabitants of the Tibona and Camp Adagbe districts revealed that well water represents 30% of the population's water supply sources. The physicochemical and bacteriological characteristics of this well water reveal that 87.5% of these wells are polluted. The high levels observed in some wells are linked to the infiltration of wastewater and the use of chemicals upstream or to the proximity of these wells to waste disposal sites. As for microbial germs (Escherichia coli and total coliforms), only some wells in Camp-Adagbe are exempt.

Ultimately, it emerges from the various results that the sources of well water studied have physicochemical and bacteriological parameters that do not comply with Beninese standards. The consumption of this water could contribute to the increase in waterborne diseases among residents. It is up to municipal and community leaders to take the data from this study into consideration when organizing awareness sessions for residents of these neighborhoods.

References

[1] F.S. Gbedemah., A.A. Gbeasor., S.G Hosu-Porbley., L.K. Frimpong., R.Amfo-Otu., K.S. Adanu *and* E.K.Doe. Analysis of heavy metals and pathogen levels in vegetables cultivated using selected water bodies in urban areas of the Greater Accra Metropolis of Ghana.*Heliyon,* 10 (7), pp.1-12, 2024.

[2] C. A. N. Nanfack., F. F. Anyangwe., V. K. Payne., K. Bridget *and* F.J. Muafor. Eaux non conventionnelles: un risque ou une solution aux problèmes d'eau pour les classes pauvres, *Larhyss Journal,* 17, pp.47-64, 2014.

[3] M. Lagnika, M. Ibikounle, J.P.C. Montcho, V.D. Wotto and N.G. Sakiti. Caractéristiques physicochimiques de l'eau des puits dans la commune de Pobè (Bénin, Afrique de l'Ouest), J. App. Biosci, 79, pp.6887 – 6897, 2014.

[4] A. Adjagodo, M. Agassounon Djikpo Tchibozo, C. Kelome, N. Ahouangnivo and R. Lawani. Flux des polluants lies aux activités anthropiques et risques sur les ressources en eau de surface à travers le monde, *Larhyss Journal,* 28, pp.7 – 23,2016.

[5] OMS, 1996. Directives de qualité pour l'eau de boisson. Critères d'hygiène et Documentation a l'appui. volume 2; 2e Edition; Genève, 1050 p.

[6] F. Yovo, B. Dimon, F. Suanon, C.E. Azandegbe, I. Agani *and* V. Wotto. Phytoremediation: Synergistic Effect of *Thalia geniculata and Crassipes Eichhornia* (Water Hyacinth) During Domestic Wastewater Treatment, Plant, 5 (1), pp.1-8, 2017.

[7] D. Belghyti, Y. El guamri, G. Ztit, O. M. Lahcen, M.B. Joti, A. Harchrass, H.Amghar, O. Bouchouata, K.El kharrim *and* H.Bounouira. Caractérisation physico-chimique des eaux usées d'abattoir en vue de la mise en œuvre d'un traitement adéquat: cas de Kenitra au Maroc Afrique, Science, 05 (2): 199 – 216.

[8] B. Odoulami. Approvisionnement en eau potable dans les grandes villes du Bénin. Quelles politiques pour l'avenir ? Cas de Cotonou, Porto- Novo et Parakou DINEPA (Petite – ville), 55p, 1999.

[9] Kandalaft, J.-P. (2017). L'accès à l'eau douce dans le monde : Ses principaux enjeux. *Proche-Orient Études en management, 29,* 159-185.

[10] K.A.R. Kpegli, F. Adandedji, C. Ahouandogbo, M.B. Djihouessi, J.Hounkpe, Y. M'Po N'Tcha, A.Y. Bossa, A. Alassane, L.O. Sintondji *and* D. Mama. Groundwater Recharge Assessment in Central Benin: The Case of the Collines Region (West Africa), *Water,* 16, 1-21, 2024.

[11] P.K. Masawula, C.N. Luwesi, Y.I. Bomangwa, J.K. Shikayi, D.K. Kinakina, R.G. Sabimana, E.O. Djamba. Analyse des paramètres de potabilité des sources d'approvisionnement en eau par les ménages dans la zone de santé de Mbanza-Ngungu au Kongo Central en RD Congo, *American Journal of Multidisciplinary Research & Development (AJMRD),* 6, 8, pp.27-38,2024.

[12] UNESCO. Rapport mondial des Nations Unies sur la mise en valeur des ressources en eau 2023, *UN WATER,* p16,2023.

[13] C. A. Agbota., E. Tévoedjre *and* J.D. Hessou. Mettre la politique nutritionnelle au cœur du développement -Comprendre les facteurs institutionnels et politiques du changement politique: Etude de cas de Bénin, Health, *Nutrition and Population (HNP) Discussion Paper,* 112p, 2010.

[14] J. M. Essou., G. M. A. Dedehouanou., M. Avoutou *and* K.G. Mohamed. Modes de gestion des infrastructures agropastorales du Programme d'Appui au Secteur du Développement Rural dans les départements du Borgou-Alibori au Benin: analyse et enjeux, *International Journal of Strategic Management and Economic Studies (IJSMES), 2* (6), 2410–2444, 2023. https://doi.org/10.5281/zenodo.10636771.

[15] M. E. Agbota., C. J. Hadonou., J. B. K. Vodounou and Y. O. Doubogan. Vulnérabilité des producteurs périurbains de vivrières face aux contraintes agro météo-climatiques et socioéconomiques à Parakou, Collection Recherches et Regards d'Afrique, (2), 5, pp: 216-242,2023.

[16] A. R. Abdoulaye. Gestion des eaux pluviales en milieu urbain pour un développement durable : Cas de la ville de Parakou, DEA de Université d'Abomey-Calavi, 2006.

[17] A. K. Baba Cheick. Impact environnemental des retenues d'hydraulique pastorale dans la commune de Nikki, Mémoire de la Faculté des Lettres, Arts et Sciences Humaines de l'Université D'Abomey-Calavi, p170,2004.

[18] R.Tremblay., N.Brunot., S. Fernandez., A-S. Saus and F. Xavier. L'évaluation des interventions éducatives. *Sexualités et société,* 271-280,2020.

[19] H. Nasiba and B. Y. Benzine Bornia Yasm. Traitement et contrôle de la qualité de deux types d'eau à usage pharmaceutique: eau purifiée et eau pour préparations injectables, Mémoire présenté en vue de l'obtention du Diplôme de Master Professionnel en Science de la Nature et de la Vie à l'Université Frères Mentouri Constantine, 2002-2021, p67.

[20] D.M. Khababa and M Tabet. Analyses physico chimiques et bactériologiques des eaux des puits de la wilaya de Bordj Bou Arreridj (la commune de Zemmoura), Memoire de la Faculté des Sciences de la Nature et de la Vie et des Sciences de la Terre et de l'Univers, Université Mohammed El Bachir El Ibrahimi B.B.A, 72p, 2023.

[21] C. Belakhedar and K. Belkhiri. Enquête sur le niveau de connaissance en eau et assainissement chez le citoyen Algérien, Mémoire de l'Université Mohamed El Bachir El Ibrahimi B.B.A, Sciences de la Nature et de la Vie, p63, 2022.

[22] K.M. Yéo, A.N.B. Kouadio *and* D.L. Goné. Evaluation de la qualité des eaux de forages et de puits destinées à la consommation humaine: Approches d'analyses multivariées, *International Journal of Innovation and Applied Studies*; 40 (4); pp: 1299-1311, 2023.

[23] O. Kyakimwa Kyalwahi, B. Musoki Furaha *and* S. Nyanzereka Mokala. Évaluation de la qualité bactériologique des eaux de puits de la Commune Mususa en Ville de Butembo. Parcours Et Initiatives: *Revue Interdisciplinaire Du Graben (PIRIG),* (25), 111–126, 2023. https://doi.org/10.57988/crig-2426.

[24] E. K. Tchouongsi, B.Mougoue, C.T. Tagne, F.M. Touoyem *and* N.S.Bonganjum. Approvisionnement en eau et risques sanitaires dans le bassin versant amont de l'Abiergué à Yaoundé (Cameroun), *European Scientific Journal,* 16 (8); pp: 102-123, 2020.

[25] C. FAYE. Water pollution challenges, a threat to public health: strengths and weaknesses of water laws and policies in Senegal, *Larhyss Journal,* 32, pp: 107-126, 2017.

[26] S.C. Eddine *and* A. Tria. Impact de la pollution agricole et domestique sur la qualité des eaux du barrage de Bouhamdane, *Mémoire de Master de la Faculté des Sciences de la Nature et de la Vie,* Sciences de la Terre et de l'Univers de l'Université 8 Mai 1945 Guelma, p93,2023.

[27] S. M. Tounkara *and* M. Soudani. L'Education au Développement Durable par Problématisation de Phénomènes de Pollution Environnementale en Formation Initiale des Enseignants au Mali. *ESI Preprints, 32,* pp: 478-501, 2024.

[28] C. Degbey, M. Makoutode, E-M. Ouendo, B. Fayomi *and* C. De Brouwer. La qualité de l'eau de puits dans la commune d'Abomey-Calavi au Bénin, *Environnement, Risques et Santé,* 7, 4, pp: 279 – 283, 2008.

[29] D. Saada, A. Soumaya, T. Zahra. Nouvelles technologies de traitement de l'eau: Magnétisation de l'eau potable, *Mémoire de Master en Sciences Biologique, Biochimie Appliquée,* Université Ahmed DRAÏA – Adrar, 80p, 2022.

[30] A.N. Ben *and* G. Chouireb. Traitement des eaux usées urbaines, par la technique d'infiltration-percolation sur filtre à sable cas commune de Berriane (Ghardaïa), *Mémoire de la Faculté des Sciences de la Nature et de la Vie et des Sciences de la terre,* Université de Ghardaïa, 59p, 2022.

[31] R. Mediani *and* I. Bekraoui. Evaluation de la qualité des eaux des puits à usage agricole dans la région d'adrar, *Mémoire de la Faculté des Sciences et de la Technologie de l'Université Ahmed Draïa Adrar,* 74p, 2020.

[32] H. Chahinez. Etude comparative de la qualité physico-chimique et bactériologique entre eau de puits de Si Abdelghani (Tiaret) et Puits de Daïa (Ghardaïa)., Faculté des Sciences et Technologies Département de Génie des procédés, Université de Ghardaïa, 87p, 2020.

[33] B. Tayeb. Caractérisation des Calcaires de Ia de Tebessa, Mémoire de l'Institut des mines de l'Université EchahidEsheikh Larbi Tebessi – Tébessa, 78p, 2023.

[34] K. I. El-Khalil. Profil phosphocalcique chez les insuffisants rénaux chroniques hémodialysés, *Mémoire de la Faculté des Sciences de la Nature et de Vie et Sciences de la Terre,* Université de Ghardaia, Université de Ghardaia, p79,2023.

[35] G. Boutteyna. Étude comparative de la composition et de la charge polluante des eaux usées résidentielles et des eaux usées des Établissements Publics de Santé de Proximité (Ghardaïa), *Mémoire de la Faculté des Sciences et de la Technologie de l'Université de Ghardaïa,* p93,2024.

[36] H. Chileg. Étude de la variation spatiale de la salinité des eaux phréatique de la commune de METLILI (Wilaya de GHARDAIA), *Mémoire de la Faculté des Sciences de la Nature et de la Vie de l'Université KASDI MERBAH – OUARGLA,* p107,2023.

[37] M. Makoutode, C. Degbey, E-M. Ouendo, B. Fayomi and C. de Brouwer, La qualité de l'eau de puits dans la commune d'Abomey-Calavi au Bénin. Environnement, Risques et Santé. 7, 4 279 – 283,2008.

[38] OMS, Directives de qualité pour l'eau de boisson, Quatrième édition. Publication Organisation Mondiale de Santé. Genève, Suisse, 307 – 447,2011.

[39] P. Agbohessi, L. Guedegba, R. Pelebe and I.I. Toko. Exposition de la faune ichthyenne et autres animaux aquatiques aux polluants organiques, chimiques et biologiques dans le lac Nokoué au Sud du Bénin: Synthèse documentaire, *Rev. Mar. Sci. Agron. Vét,* 11 (3), pp: 360-372,2023.

[40] D.R.Rahal *and* N.Toubi. Etude de l'efficacité du processus de chloration au niveau de la station de traitement de l'eau du barrage Bouhamdane- Guelma, *Mémoire de la Faculté des Mathématiques et de l'Informatique et des Sciences de la Matière de l' Université de 08 Mai 1945 de Guelma,* p176,2023.

[41] Y. El Hammoudani, F. Dimane, K. Haboubi, A. Bourjila, C. Benaissa, I. Achoukhi *and* Haboubi C. Assessment of groundwater quality in the lower wadi of the nekor valley, al-hoceima-Morocco, *Environmental Engineering & Management Journal (EEMJ),* Vol 22, 3, p: 399-409, 2023.

[42] G. Das, V. Tirth, S. Arora, A. Algahtani, M. Kafeel, A.H.G Alqarni, P. Saluja, H. Vij, S.S. Bavabeedu *and* A. Tirth. Effect of Fluoride Concentration in Drinking Water on Dental Fluorosis in Southwest Saudi *Arabia. Int. J. Environ. Res. Public Health,* 17, pp: 14-39, 2020.

[43] S. Verhille. Les indicateurs microbiens dans l'évaluation de l'eau potable: interpréter les résultats de laboratoire et comprendre leur signification pour la santé publique, *National Collaborating Centre for Environmental Health,* 1-13,2013.

[44] O.B. Yapo, V. Mambo, A.M. Seka *and* M. Ohou. Evaluation de la qualité des eaux des puits à usage domestique dans les quartiers défavorisés de quatre commun es d'Abidjan (Côte d'Ivoire): Koumassi, Marcory, Port-Bouet et Treichville, *Revue Internationale des sciences biologiques et chimiques,* 4, (2), 289-307,2010.

[45] S. Some, R. Mondal, D. Mitra, D. Jain, D. Verma *and* S. Das. Microbial pollution of water with special reference to coliform bacteria and their nexus with environment, *Energy Nexus, Elsivier,* 1, pp: 1-9, 2021.

[46] K.K. Tandoh *and* S.F. Gbedemah. Spatial variability of water quality from hand-dug wells and their contaminant sources in peri-urban areas of Koforidua, Ghana, *Environmental Contaminants Reviews (ECR),* 7 (2), 79-84,2024.

[47] C. Alutu, N. Ezeama *and* P. Adogu. Preferred drinking water and waterborne infections among households a rural community in Anambra State, Southeast, Nigeria, *West African Journal on Sustainable Development (WAJSD),* 1 (2), pp: 228-240.