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Analysis of the Quality of Physical and Chemical Parameters of Groundwater in Three Localities in the Sub-Prefecture of Zanzra (Ivory Coast)

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Abstract

The availability of groundwater of acceptable quality has become a difficult challenge to meet in many countries, particularly Côte d'Ivoire. The State of Côte d'Ivoire and rural populations are building hydraulic infrastructure for this purpose. However, the quality of water coming from these infrastructures remains to be determined. This study therefore aims to analyze certain physicochemical parameters of the groundwater of Gloazra, Kouezra and Trahonfla. These are temperature, pH, electrical conductivity, TDS, salinity level, hardness, alkalinity, chloride content and bicarbonate. To determine the pH, electrical conductivity, temperature, TDS, and salinity rate, an electrochemical analysis was carried out. The titrimetric analysis made it possible to determine the chloride and bicarbonate content, alkalinity, and hardness. The results indicate that the studied groundwater is soft and acidic with good mineralization. This water does not present a health hazard to consumers but can affect hydraulic equipment and household containers.

Keywords

Ivory Coast, Gloazra, Trahonfla, Kouezra, Physicochemical Parameters, Water, WHO Standards

1. Introduction

Water is a natural resource essential to the life of living beings, namely the life of men, animals and plants. In this sense, the availability of water in sufficient quantity and quality contributes to maintaining the health of these living beings

[1]. On the globe, we find water in abundance, but we must distinguish between fresh water resources and salt water. Most water is contained in the oceans, which represents 98% of the water on earth. Fresh water is mainly contained in groundwater (1.68%), which makes it difficult to access [2]. In addition to this, we are witnessing an unequal distribution of water on Earth. This unequal distribution and strong population growth lead to a sharp increase in the need for access to drinking water and sanitation services. This is why the supply of drinking water and sanitation are among the challenges to be met by States, particularly African States, in order to improve the living conditions of populations [3]. In Ivory Coast, and especially in rural areas, access to drinking water still poses a problem. In fact, several localities with more than 10,000 inhabitants are not yet served with drinking water. Also, in certain villages, the shortage of drinking water pushes populations to travel long distances in order to obtain water which can often be of poor quality [4]. In 2008, the drinking water needs of rural populations were only 50% covered [5]. Koné *et al.* (2018) [6] in turn estimate that the water problem constitutes the third concern of the population after unemployment and at approximately the same level as poverty. To provide solutions to the problem of access to drinking water, the State provides significant funding in its development program to increase hydraulic infrastructure in order to allow both urban and rural populations to have access to drinking water [7]. To this end, in 2020 the Ivorian State planned to invest around 291 billion FCFA in 2020 in hydraulic infrastructure [8]. To make this access to drinking water program a reality, the government is pursuing a policy in three sub-sectors. These are Village Hydraulics (HV), Improved Village Hydraulics (HVA) and Urban Hydraulics (HU) [4]. HVA (Improved Village Hydraulics) is an intermediate technology between manual pumps and the urban water supply system (connection to the SODECI distributor network). It consists of pumping groundwater called borehole water using a submerged electric pump to a water tower which, using gravity, distributes the water to standpipes and around thirty households [9]. Groundwater which, according to the WHO meets drinking water standards, is often polluted. Some research work that has been carried out on the quality of groundwater concludes that the pollution of this groundwater comes from a geological and anthropogenic origin, in particular from the infiltration of wastewater and the use of chemical fertilizers in agriculture [10]. Other studies have revealed that groundwater pollution is linked to the presence of septic tanks, the absence of treatment, the lack of a sanitation network and non-compliance with public hygiene conditions [11]. In the localities of Gloazra, Kouezra and Trahonfla, villagers use HVA and wells as a source of drinking water and support for agricultural activities. However, the findings show the presence of graves, cocoa plantations and wastewater in the vicinity of these water points. In addition, no research work shows studies carried out on the quality of groundwater in these villages. Faced with this observation, this work focuses on the physicochemical analysis of groundwater from these three villages (Gloazra, Kouezra and Trahonfla).

2. Materials and Methods

2.1. Presentation of the Study Area

The study area includes three villages, namely Gloazra, Kouézra and Trahonfla (Figure 1). These villages belong to the sub-prefecture of Zanzra which itself is located in the department of Zuénoula. This department is part of the region of Marahoué in the west center of Ivory Coast. This region is limited to the north by the Béré region, to the south by the Gôh region, to the east by the regions of Gbêkê, Bélier and the autonomous district of Yamoussoukro, to the west by the region of Haut-Sassandra. Its capital is the town of Bouaflé (see Figure 1). Furthermore, it is subdivided into three departments with an area of 9092.48 km^2 of which 3252 km^2 for the Zuénoula department [12]. According to the General Population and Housing Census (RGPH 2021) [13], the population of the Marahoué region is estimated at 981,180 inhabitants, including 184,882 for the department of Zuénoula. The population of the department of Zuénoula is essentially made up of indigenous Gouro people from the Manding Group. We also note the presence of non-native Gouro (coming from other regions), Sénoufo, Baoulé, Agni, Abron, Bété, Koulango etc. and non-African people (Malians, Burkinabés, Guineans, Ghanaians, Mauritanians, Beninese, Nigerians, Nigeriens etc.

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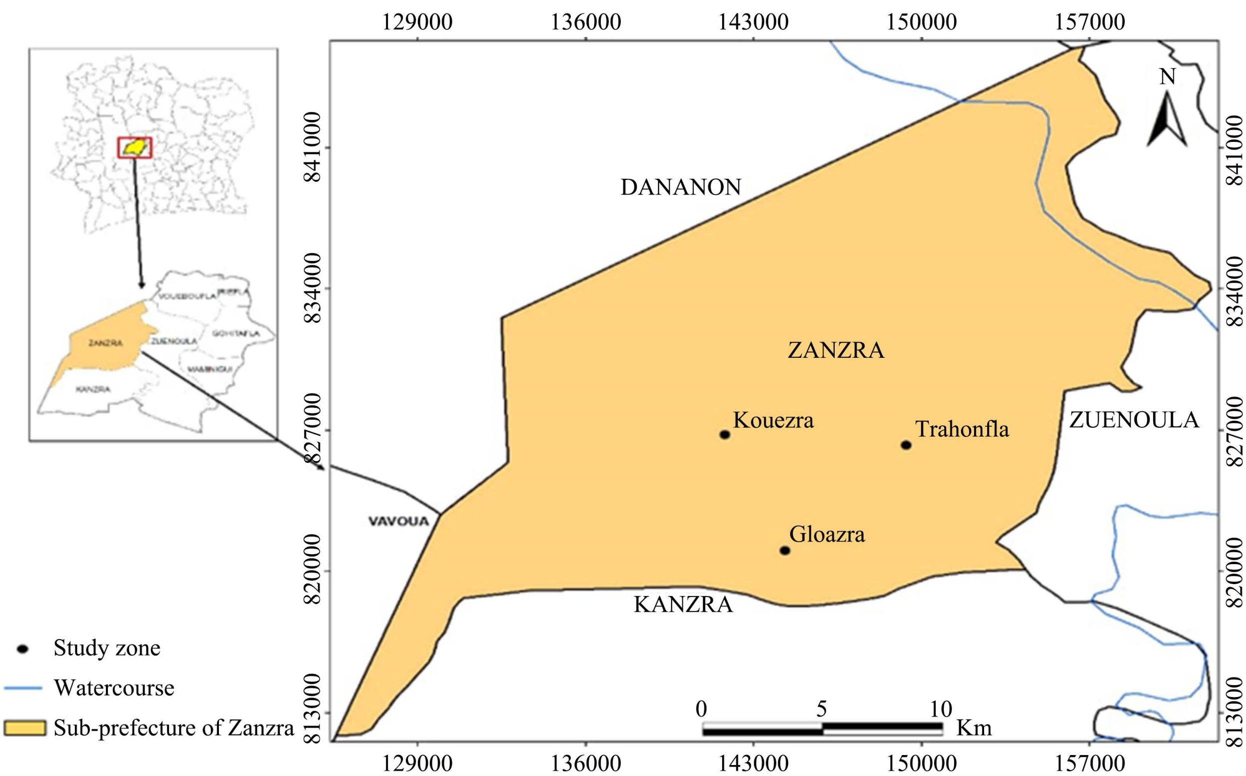

Figure 1. Map of the Zanzra sub-prefecture region.

2.2. Reagents

In this study, we used as reagents: phenolphthalein solution ($C_{20}H_{14}O_4$), bromocresol green solution ($C_{21}H_{14}Br_4O_5S$), potassium chromate solution (K_2CrO_4), EDTA solution ($C_{10}H_{16}N_2O_8$, 99%, Merck), solution hydrochloric acid (HCl, 37%, Chem-Lab), silver nitrate solution ($AgNO_3$, 100%, Chem-Lab), buffer solution pH = 10, eriochrome black T ($C_{20}H_{12}N_3O_7SNa$, 99%, Chem-Lab).

2.3. Sampling

The sample must be homogeneous, representative and obtained without modifying the physicochemical characteristics of the water [14]. Thus, for this study, we took sufficient volume in each village, samples of water from boreholes and wells using new 1 liter plastic bottles, bearing a label with the code, the date, the time and place of collection. The borehole water was collected at the pump and that from the well with a scoop made from rubber. Before collecting the well water, the scoop was rinsed with the raw water in order to eliminate any harmful element capable of modifying the nature of the parameters to be determined in the laboratory. During the sampling, first the bottles were also rinsed three times with the water to be analyzed in order to homogenize the walls and avoid the attachment of external elements to them. Then they were filled up to the neck. Finally, the bottles were closed so that there were no air bubbles and water was not accidentally ejected during transport. All these samples were stored in a refrigerated cooler and then transported to the laboratory for analyses. Storage in the refrigerated cooler avoids fluctuations in the physicochemical parameters of the samples during transport to the laboratory.

2.4. Measurement of Physical and Chemical Parameters

2.4.1. Physical Parameters Data Processing

Physical parameters such as pH and temperature were measured using a HANNA brand HI 2211 multimeter. As for electrical conductivity, total dissolved solids (TDS) and salinity, they were measured using a HANNA brand HI 2300 conductivity meter.

2.4.2. Chemical Parameters

- **Alkalinity and bicarbonate ions**

The determination is based on the titration of a certain volume of water to be analyzed with a strong acid solution in the presence of a colored pH indicator. Thus, the use of phenolphthalein makes it possible to determine the TA and that of helianthin or bromocresol green is used to determine the TAC. At the end of the dosage, the TA, TAC and the bicarbonate ion concentration are respectively calculated using equations (Equation (1)), (Equation (2)) and (Equation (3)). These parameters are expressed in meq/L or in French degrees (˚f).

$$\mathrm{TA} \times V_{Water} = N_a \times V_{pp}$$

$$\mathrm{TA} = \frac{N_a \times V_{PP}}{V_{Water}} \tag{1}$$

$$\text{TAC} \times V_{Water} = N_a \times V_{Vb}$$

$$\text{TAC} = \frac{N_a \times V_{Vb}}{V_{Water}} \quad (2)$$

N_a: *the normality of hydrochloric acid*;

V_{pp}: *the volume of hydrochloric acid corresponding to the change in phenolphthalein*;

V_{bv}: *the volume of hydrochloric acid corresponding to the change in bromocresol green*;

Calf: the volume of water to analyze.

As TA = 0, then

$$\left[\text{HCO}_3^-\right] = \text{TAC} \quad (3)$$

- **Total hardness or total hydrotimetric titer (THT)**

The calcium and magnesium ions present in the water are caused to form a chelate type complex with EDTA at pH = 10. The end of the dosage is detected by the addition of a specific indicator, eriochrome black T (NET), which changes from pink to blue coloring.

After the dosage, the expression of THT is given by Equation (4),

$$\text{THT} = 2 \times V_{eq} \left({}^\circ\text{f}\right) \quad (4)$$

V_{eq}: volume of EDTA at equivalence.

The concentration of chloride ions was determined by the Mohr method. Chloride ions are measured in a neutral environment using a solution of silver nitrate ($AgNO_3$) in the presence of chromate ions, acting as a colored indicator. The equivalence point is identified by the appearance of a brick-red precipitate of silver chromate.

- **Dosage of chloride ions**

The concentration of chloride ions was determined by the Mohr method. Chloride ions are measured in a neutral environment using a solution of silver nitrate ($AgNO_3$) in the presence of chromate ions, acting as a colored indicator. The equivalence point is identified by the appearance of a brick-red precipitate of silver chromate. The molar concentration of the chlorides in mol·L^{-1} is given by Equation (5).

$$\left[\text{Cl}^-\right] = \frac{C_{\text{AgNO}_3} \times V_{eq}}{V_{Wter}} \quad (5)$$

C_{AgNO_3}: *the concentration of the silver nitrate titrating solution*;

$V_{éq}$: *the volume of the silver nitrate titrating solution at the equivalence*;

V_{water}: *the volume of water to analyze.*

Equation (6) makes it possible to determine the weight titer of chloride ions in mg·L^{-1}.

$$t_{\text{Cl}^-} = 10^3 \cdot M_{\text{Cl}^-} \times \left[\text{Cl}^-\right] \quad (6)$$

M_{Cl^-}: the molar mass of chlorine;

$\left[Cl^-\right]$: the molar concentration of chloride ions.

2.4.3. Data Processing

After carrying out a data synthesis using diagrams drawn with Excel, we carried out a second synthesis based on Principal Composition Analysis (PCA) with the XLSTAT software. For 6 samples, 9 variables were analyzed and the results obtained allowed us to interpret the hydrochemical data. The aim of this analysis is to detect the parameters which have an influence on each other.

3. Results and Discussion

3.1. Spatial Variation of the Parameters Studied

3.1.1. Temperature

Figure 2 shows the temperature values measured for each sample. It not only allows you to see the variation in temperature depending on water from different sources, but also to compare them to WHO standards. Thus, on average, during the study period, the groundwater in the study area has a temperature higher than the WHO standard. This average temperature amounts to 31.08˚C unlike the WHO standard which is between 25˚C and 30˚C. The low standard deviation obtained shows that the sample temperatures are better grouped around the mean. To this end, the groundwater of Kouezra and Trahonfla has temperatures higher than the WHO standard. Only the groundwater in the village of Gloazra has temperatures that meet WHO standards (27.4˚C for the borehole and 26.4˚C for the well). Some studies, which are in the same direction as ours, have indicated that the temperature of the water from boreholes meets WHO standards in the city of Daloa [15]. These results only agree with the groundwater temperature of Gloazra. Other studies carried out on groundwater in the Gouroudi watershed straddling the commune of Torodi in Benin and Liptako in Niger revealed temperatures above WHO standards. These values, almost the same as those obtained at Trahonfla and Kouezra, reach 34˚C [16]. However, according to Diabagaté *et al.* (2019) [17] groundwater with temperatures exceeding 25˚C is not dangerous for consumption.

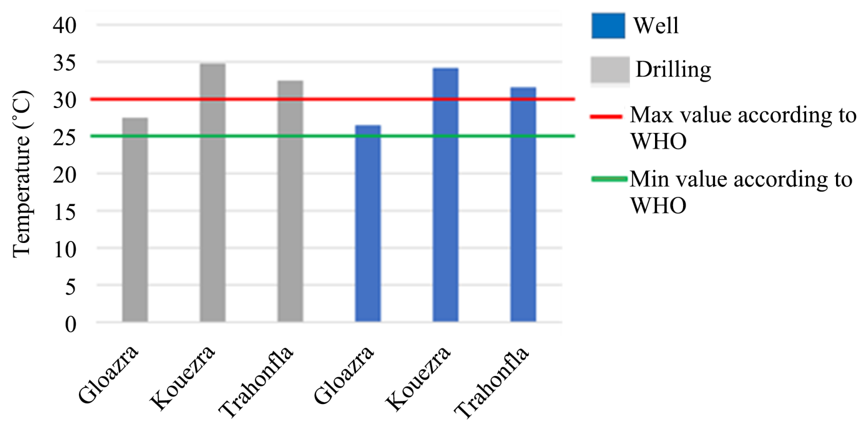

Figure 2. Spatial of temperature (˚C) values of boreholes and wells.

3.1.2. Hydrogen Potential (pH)

Figure 3 allows you to observe the pH value according to each sample. pH values are between 6.19 and 7.06. According to WHO standards, the pH is set between 6.5 and 8.5. The drilling waters in the study area respect the pH limits recommended by the WHO with an average value of 6.92. Well water, for its part, is below WHO standards. On average, their pH is 6.24. Groundwater in the study area is acidic. However, taking into account WHO standards, borehole water is preferable to that of wells. The acidic character obtained in our study area is that observed in the groundwater of Côte d'Ivoire. Indeed, in humid tropical zones, the acidity of groundwater comes mainly from the decomposition of plant organic matter, with the production of CO_2 in the first layers of the soil [18] [19] [20]. In addition, these acidic waters are not a priori prohibited for human consumption, but this acidity gives them a greater corrosive property than cement or pipe metals [15].

3.1.3. Electrical Conductivity (EC)

Figure 4 tells us about the behavior of electrical conductivity from one source to another. Electrical conductivity provides an overall indication of the level of mineralization of water, which tells us about its salinity level [21]. The higher it is, the stronger the mineralization, vice versa. According to the WHO standard, all samples have good conductivity because the recorded values range between 190.8 µS/cm and 991 µS/cm. However, conductivity varies from one sample to another. Consequently, the mineralization is significant at Kouezra with 991 µS/cm for the well and 667 µS/cm for the drilling. That of Gloazra is accentuated (408 µS/cm for the borehole and 633 µS/cm for the well) while it is moderately accentuated at Trahonfla with 389 µS/cm at the borehole and 190.8 µS/cm for the well. The average observed in terms of electrical conductivity is 546.47 µS/cm. It is much higher than that measured in Daloa (246.2 µS/cm) by Yao KOUAME *et al.* (2021) [15]. Further analysis shows that water mineralization is more pronounced in wells (average = 604.93 µS/cm) than in boreholes (average = 488 µS/cm). The high conductivity observed in the well is due to strong

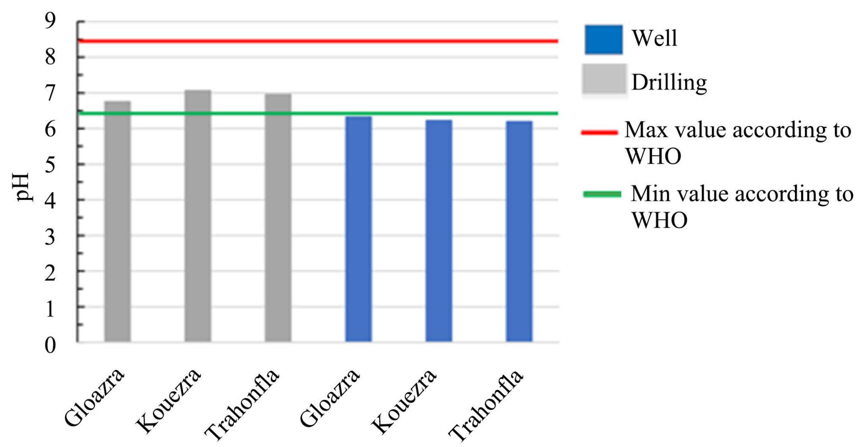

Figure 3. Spatial of pH values of boreholes and wells.

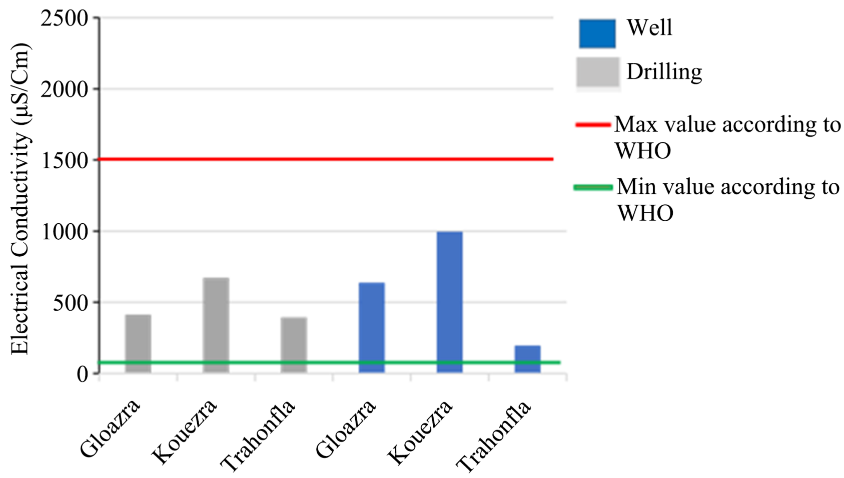

Figure 4. Spatial of electrical conductivity (µS/cm) values of boreholes and wells.

evaporation due to its large diameter and then to its exposure to anthropogenic and atmospheric pollution [22]. AYOUBA *et al.* (2015) [23], indicated that weakly mineralized water is suitable for drinking.

3.1.4. Total Dissolved Solid (TDS)

The TDS values of the different samples analyzed are observed in **Figure 5**. They oscillate between 95.4 mg/L and 496 mg/L and are all below the maximum value set by the WHO (500 mg/L). The TDS is therefore in compliance with the WHO standard. However, it should be noted that the closer the TDS is to 500 mg/L, the more likely the water is unfit for consumption. Therefore, the Kouezra well may present pollution risks because the TDS is 496 mg/L. Generally speaking, borehole water (average TDS = 233.83) presents less risk of pollution than well water (average TDS = 302.8). However, a high concentration of TDS alone is not dangerous for health, but it can have undesirable effects (staining household appliances, corroding pipes and giving a metallic taste to water [24].

3.1.5. Salinity

Salinity reflects the saline nature of the water. In addition, it can help to get an idea of its mineralization. The salinity rate varies from 0.4% in the Tranhonfla well to 2.1% in the Kouezra well (**Figure 6**). The WHO has not set guidelines for salinity levels.

3.1.6. Total Hardiness

Total water hardness is a specific characteristic caused by the presence of calcium and magnesium. These values are visualized in **Figure 7**. The results obtained show that the hardness is between 5.46˚f and 20.2˚f. The minimum value is observed at the Trahonfla well and the maximum value at the Kouezra well. Thus, only two samples comply with WHO standards. This is well and borehole water from Kouezra (19.7˚f for the borehole and 20.2˚f for the well). These waters are moderately fresh. The water in the villages of Gloazra and Trahonfla has

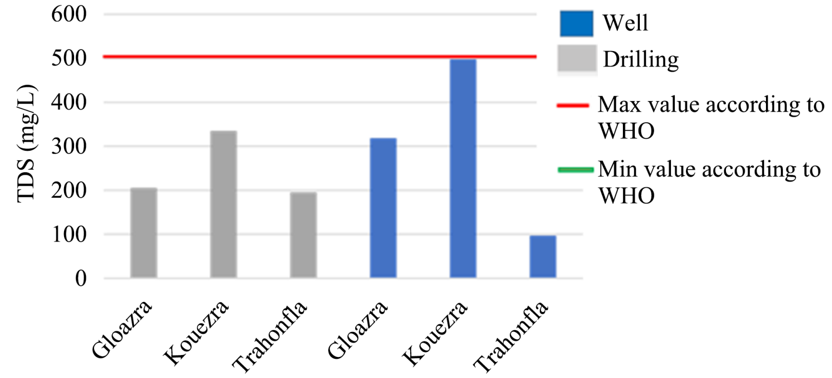

Figure 5. Spatial of TDS (mg/L) values of boreholes and wells.

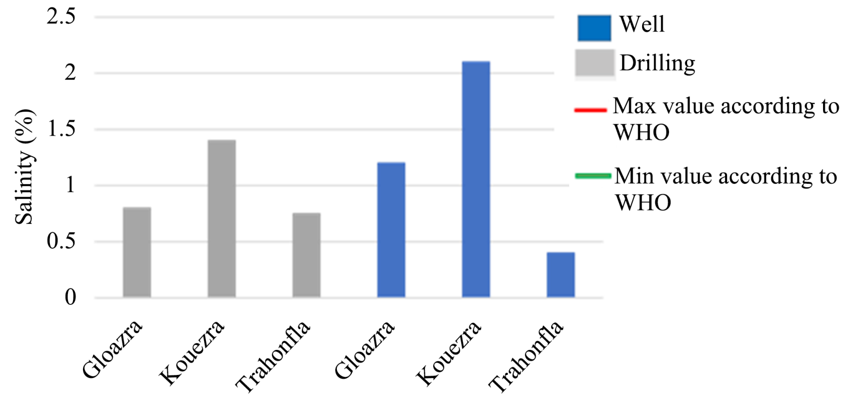

Figure 6. Spatial of salinity values of boreholes and wells.

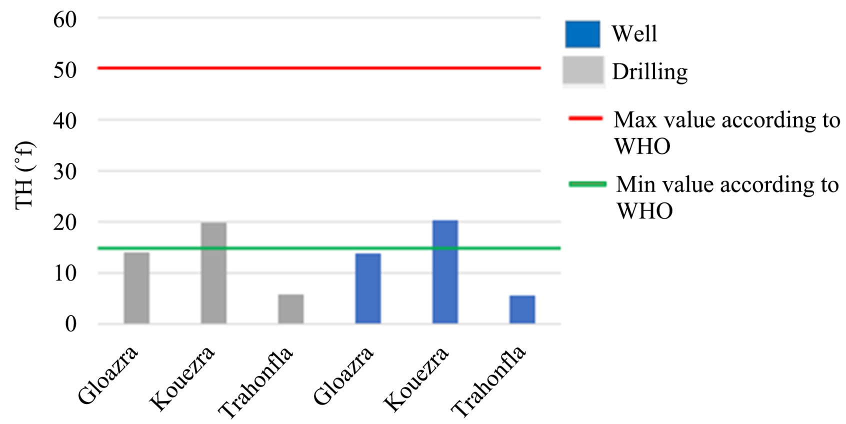

Figure 7. Spatial of Total water Hardiness (TH) values of boreholes and wells.

a hardness lower than the WHO standard. The water of Gloazra is soft (13.9˚f for the borehole and 13.7˚f for the well) and that of Trahonfla is very soft (5.66˚f for the borehole and 5.46˚f for the well). This fresh water is aggressive towards the pipes, thus potentially causing corrosion. Corrosion of lead pipes poses dangers to consumer health [23]. As for hard water, it is not dangerous for health. In addition, KAHOUL M *et al.* (2014) [25] showed that hard water can protect against mortality due to cardiovascular diseases.

3.1.7. Chloride Ions

The variation in the concentration of chloride ions depending on the samples can be seen in **Figure 8**. Its compliance with the WHO standard is achieved through the maximum value of 250 mg/L. Thus, after comparison, the chloride ion contents of all the water samples analyzed comply with WHO standards because they are all lower than the maximum value set. These chloride ion contents range from 32.66 mg/L for the Thrahonfla fodder to 107.56 mg/L for the Gloazra well. WISSEM Ayad (2017) [26] mentioned that chloride ions, at a concentration above 250 mg/L, alter the flavor of water, which can lead to a degradation of its quality. The groundwater in the studied area may therefore not suffer from this degradation, even if the chloride ion content in water is higher than the standard set by the WHO, it may nevertheless prove not to constitute a danger for the consumer [14].

3.1.8. Alkalimetric Titer (TA)

For all samples analyzed, the TA = 0. Therefore the water analyzed only contains sufficient quantities of bicarbonate ions (HCO_3^-). Therefore, the alkalinity of the water analyzed is due to bicarbonate ions.

3.1.9. Complete Alkaline Titer (TAC)

The complete alkaline titer (TAC) is a measure of the content of free alkalis, carbonates (CO_3^{2-}) and hydrogen carbonates (HCO_3^-) in water and is expressed in mg/L of $CaCO_3$ or French degree (˚f). The results show a variation in TAC from 1.3˚f to 21.2˚f. The minimum value is observed for the Trahonfla well and the maximum value for the Kouezra borehole (**Figure 9**). No guidelines have been established by WHO for TAC. However, we note that in all the samples analyzed the TAC is higher in the boreholes than in the wells. The TAC shows the buffering nature of water. According to Corneille BAKOUAN *et al.* (2017) [27], the higher the TAC, the more difficult it is to vary the pH of the water.

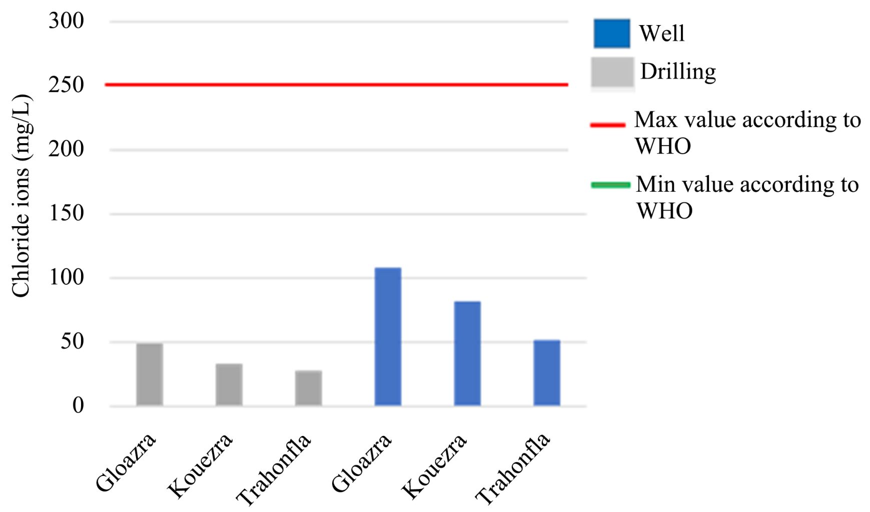

Figure 8. Spatial of Chloride ions values of boreholes and wells.

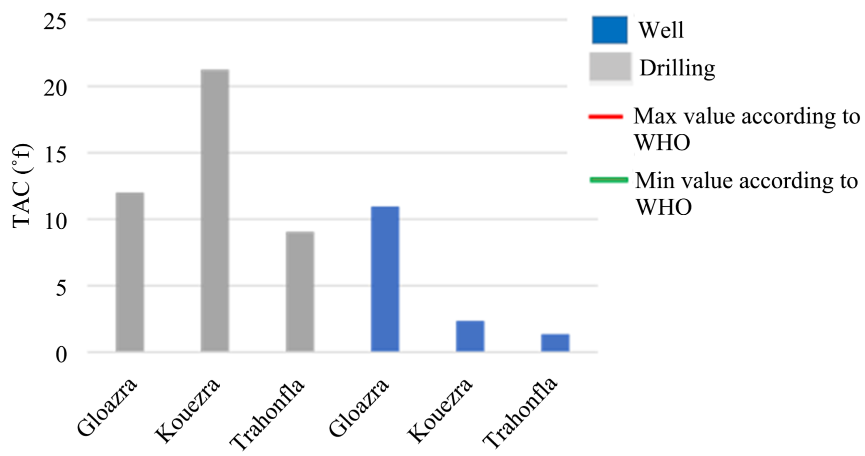

Figure 9. Spatial of Complete Alkaline Titer (TAC) values of boreholes and wells.

3.1.10. Bicarbonates

The bicarbonate content in groundwater depends mainly on the presence of carbonate minerals in the soil and the aquifer, as well as the CO_2 content of the air and soil in the catchment [10]. The bicarbonate contents of the water analyzed vary overall between a minimum of 15.86 mg/L (Trahonfla well) and a maximum of 258.64 mg/L (Kouezra borehole) (**Figure 10**). It is higher in drilling water (on average 171.41 mg/L) than in wells (on average 58.96 mg/L). Bicarbonates constitute the majority of the alkalinity of the waters in our study area. They can come from the dissolution of carbonate formations depending on the reaction:

$$CaCO_3 + H_2O \rightarrow 2HCO_3^- + Ca^{2+}$$

There is no WHO standard for this element, but according to Mahamane *et al.* (2015) [23], a high concentration of bicarbonates gives a salty flavor to the water. The Kouezra borehole water is therefore likely to be saltier than the other waters studied.

3.2. Principal Composition Analysis (ACP)

Looking at **Table 1** of the eigenvalues, only factors 1; 2 and 3 (**Table 1**) with respective values 4.165; 3,146 and 1,182 were retained taking into account the studies carried out by Koné *et al.* (2022) [28] and Zran *et al.* (2022) [29]. Indeed, according to these authors, a factor is chosen when its eigenvalue is greater than or equal to 1. Thus, around these factors, the distribution circles of the physical and chemical parameters have been created. Furthermore, the factorial component analysis of the data made it possible to obtain **Figures 10-12**. By considering the factors F1 and F2 (**Figure 11**), it emerges from this that the formation of two large groups and a third group made up of a single parameter. The first group formed by Cl^-, TDS and NaCl shows that these three parameters are linked. The second group is made up of T, TH, TAC and HCO_3^-. The third is composed of the pH parameter. This time considering factors 1 and 3, three

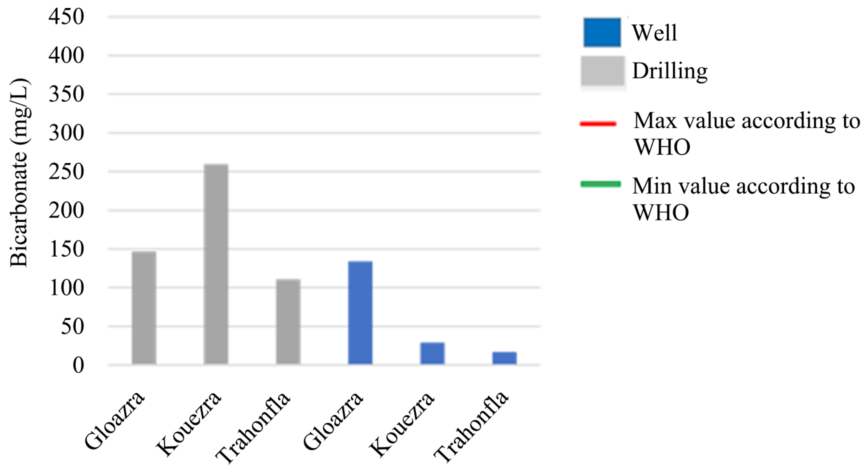

Figure 10. Spatial of bicarbonate values of boreholes and wells.

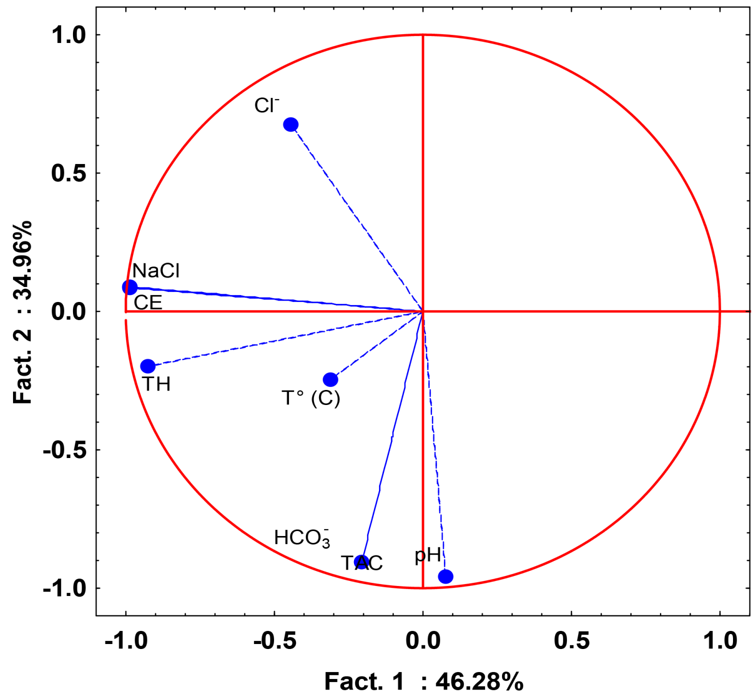

Figure 11. Projection of variables on to factorial plane (1 × 2).

Table 1. Own variables.

Own values (correl. matrix) & stats. associated (Datasheet 1) Active variables alone				
	Own value	% Total	Cumul	Cumul
1	4.165002	46.2778	4.165002	46.2778
2	3.146175	34.9575	7.311178	81.2353
3	1.382473	15.36081	8.69365	96.5961
4	0.182204	2.02448	8.875854	98.6206
5	0.124146	1.3794	9.00000	100.0000

groups were formed and the third was still formed by pH. This could mean that the physicochemical parameters of the collected well samples are not influenced by pH. Figure 13 shows four groups. A group made up of TH, TAC and HCO_3^-; a second group made up of pH and temperature. The third group contains NaCl and TDS. As for the fourth group, it only contains Cl^-.

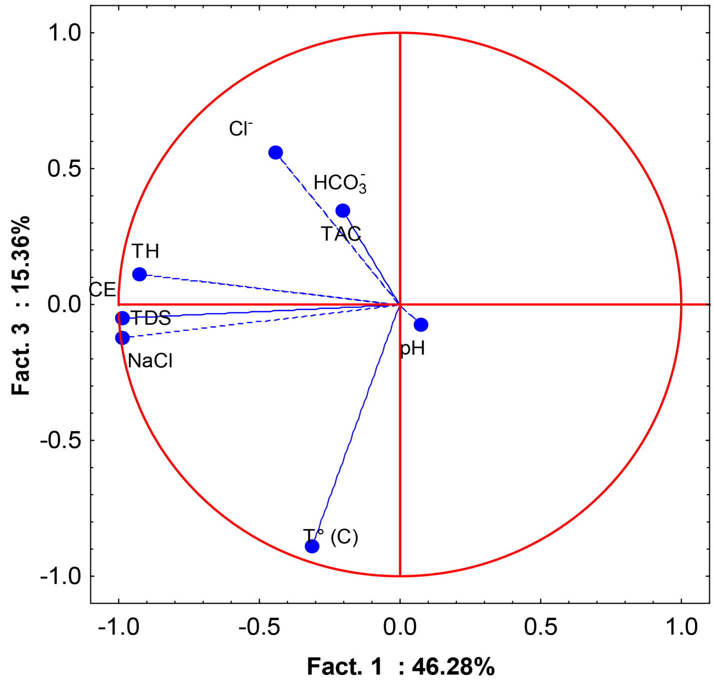

Figure 12. Projection of variables on to factorial plane (1 × 3).

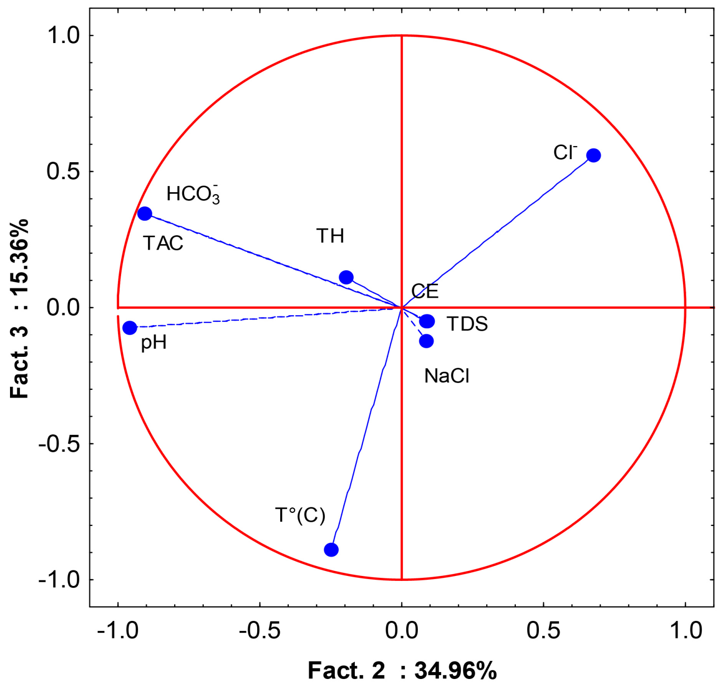

Figure 13. Projection of variables on to factorial plane (2 × 3).

Table 2 and Table 3 respectively indicate the correlations between the different physical and chemical parameters as well as the correlations between wells and sampling boreholes. According to authors such as Koné *et al.* (2022) [28] and Zran *et al.* (2022) [29], a correlation is considered significant when its value is greater than or equal to 0.70. Thus, we can notice by considering Table 2 the following correlations:

pH and TAC (r = 0.8); TDS and CE (r = 0.99); HCO_3^- and pH (r = 0.80); HCO_3^- and TAC (r = 0.99); TH and CE (r = 0.86); TH and TDS (r = 0.86); NaCl and CE (r = 0.98) and NaCl and TH (r = 0.87).

As for Table 3, it presents the correlations between the different wells and boreholes. The correlations between different wells vary from 0.92 to 1. This indicates that the wells behave similarly.

Table 2. Correlation between physical and chemical parameters.

	T (˚C)	PH	CE	TAC	TDS	[HCO_3^-]	TH	[Cl⁻]	NaCl
T (˚C)	1.00								
PH	0.23	1.00							
CE	0.32	−0.13	1.00						
TAC	0.01	**0.80**	0.10	1.00					
TDS	0.32	−0.13	**0.99**	0.10	1.00				
[HCO_3^-]	0.01	**0.80**	0.10	**0.99**	0.10	1.00			
TH	0.24	0.07	**0.86**	0.41	**0.86**	0.41	1.00		
[Cl⁻]	−0.49	**−0.74**	0.47	−0.31	0.47	−0.31	0.30	1.00	
NaCl	0.38	−0.13	**0.98**	0.07	1.00	0.07	**0.87**	0.42	1.00

Table 3. Correlation between wells and boreholes.

	Drilling of Gloazra	Wells of Gloazra	Drilling of Kouezra	Wells of Kouezra	Drilling of Trahonfla	Wells of Trahonfla
Drilling of Gloazra	1.00					
Wells of Gloazra	**0.99**	1.00				
Drilling of Kouezra	1.00	0.98	1.00			
Wells of Kouezra	0.95	0.98	0.94	1.00		
Drilling of Trahonfla	1.00	0.99	0.99	0.97	1.00	
Wells of Trahonfla	0.94	0.98	0.92	0.98	0.95	1.00

4. Conclusion

A comparison of the results obtained with WHO standards showed that the groundwater in the three localities studied is generally normal. Except those of Kouezra and Trahonfla where temperatures are higher than the maximum value set by the WHO. Also, in terms of hardness, the values obtained are below those of the WHO at Gloazra and Trahonfla. Regarding pH, only well water does not meet WHO standards. Consequently, these studied waters have diverse properties. They are sweet and acidic; they present a low risk of pollution overall but more specifically at the drilling level, have an unsalted taste and are not degraded. Their mineralization evolves in a graduated manner. This mineralization is moderately accentuated at Trahohfla, accentuated at Gloazra and significant at Kouezra. In addition, it is more important in wells than in drilling. In view of the aforementioned properties and certain previous studies, it appears from this study that the groundwater studied is suitable for consumption without major risk to the health of populations, especially those in boreholes. However, they can have a corrosive effect on pipeline infrastructures and also leave stains on the containers that contain them. Based on the physicochemical parameters studied, it would be desirable for the Ivorian State to further develop hydraulic infrastructures such as HVA (Improved Village Hydraulics). These infrastructures will allow rural populations to have quality water for consumption.

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Author Contributions

MELEDJE Djedjoss Essoh Jules-César and KRA Drissa Ouattara designed the work and the experiment. MELEDJE Djedjoss Essoh Jules-César and GOULI Bi Irié Marc prepared the materials. ZRAN Vanh Eric-Simon and TROKOUREY Albert carried out the study of parameters physico-chemical. ZRAN Vanh Eric-Simon and KRA Drissa Ouattara wrote the manuscript. TROKOUREY Albert, ZRAN Vanh Eric-Simon and GOULI Bi Irié Marc revised the manuscript critically. All authors read and approved the final manuscript.

Conflicts of Interest

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

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