Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **8(3),** 1-10, March **(2018)** *Res. J. Chem. Sci.*

Hydrochemical characteristics of Djirwal groundwater in Burkina Faso

Koné Martine[1*], Nimi Mamadou[2], Traoré Oumar[3] and Bonou Lucien[4]
[1]National Center of Scientific and Technological Research, 03 BP 7047 Ouagadougou 03 Burkina Faso
[2]Mine and Geology Office of Burkina Faso, Regional Direction of Bobo-Dioulasso, Laboratory of Geochemistry BP 195 Bobo-Dioulasso, Burkina Faso
[3]National Laboratory of Public Health, 09 BP 24 Ouagadougou 09, Burkina Faso
[4]UniversityPr Joseph Ki-Zerbo of Ouagadougou1, 03 BP 7021, Ouagadougou, Burkina Faso
koneba2003@yahoo.fr

Available online at: www.isca.in, www.isca.me
Received 11th December 2017, revised 11th March 2018, accepted 16th March 2018

Abstract

Humanity is increasingly facing the issues related to the availability of water in quantity and quality. Its poor quality is the source of many diseases. Burkina Faso is not exempted from these difficulties given its demographic outgrowth. This work aims to check physical and chemical parameters of wells and boreholes water of the village of Djirwal located in the Haut-Bassin region in Burkina Faso. Various techniques were used to determine the pH, the temperature, the electrical conductivity (Ec), the turbidity, the hydrometric titration, the various cations and anions like calcium (Ca^{2+}), magnesium (Mg^{2+}), iron, nitrates (NO_3^-), and orthophosphates (PO_4^{3-}). The boreholes were found to be highly contaminated by iron above the accepted values with contents reaching 5.97mg/l. The contents in Ca^{2+} and Mg^{2+} are higher for the boreholes compare to the wells with contents reaching up to 77 and 38mg/l respectively. In sum, the qualities of the wells and some boreholes water were not indicated for human consumption without adequate treatment.

Keywords: Wells, boreholes, iron, turbidity, electrical conductivity.

Introduction

Water is necessary for life; however, it can also be a source of disease. At the end of Millennium Development Goals, World Health Organization reported a lake of access to clean drinking water for 884 million people. More than a third of them are from developing countries[1].

In general, in Burkina Faso, 85% of need in drinking water are met by underground sources while the remaining 15% are covered by surface water[2]. In rural areas, groundwater is the first source of drinking water, through large diameter wells and boreholes[3].

However, most of the time, boreholes start operating without prior water quality check and without control of the hydro-chemical characteristics to ensure the conformity of the water with standards of clean drinking water. This situation exposes the population to the risk of drinking water polluted by some minerals and micro-pollutants.

The population of Djirwal was confronted to the poor quality of groundwater of some wells and boreholes in the village in terms of organoleptic characteristics[4].

A situation with such a magnitude requires efficient and effective investigations. This study is therefore justified in seeking to assess the characteristics of boreholes and wells of Djirwal in terms of the physicochemical and mineral quality and to propose adequate solutions.

Materials and methods

Locating the study area: Geographical location: Djirwal is a Fulani village located in Bama, in the province of Houet, in the region of Hauts-Bassins. The geographical location of the village of Djirwal is 34°14' North latitude and 12°59' West longitude. It is located 35 kilometres north of the cityof Bobo-Dioulasso, in the Kou basin which is found in the south-western part of Burkina Faso (Figure-1). The main activities of the population are agriculture and breeding.

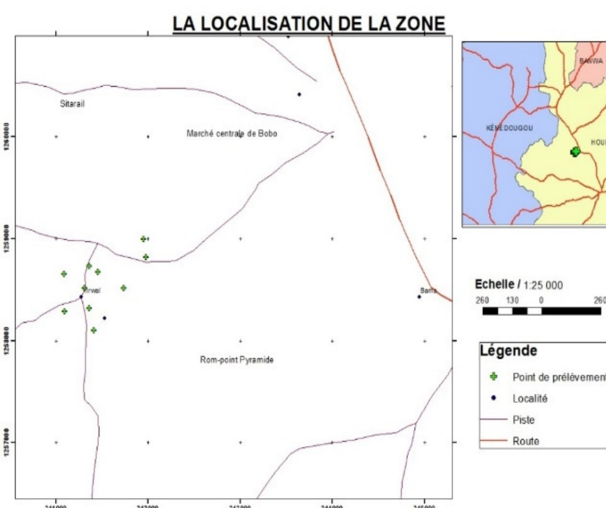

Figure-1: Location of sampling spots.

The geological formations of the Kou basin: According to the works of Kam, the Kou watershed presents five geological formations superseded by sandstones of sedimentary formations, characterized by high porosity and fractures[5]. The geological map indicates that Djirwal located in the west of Bama belongs to the area of clay and carbonates geological formations, but outcropping the pink sandstone formation (Figure-2).

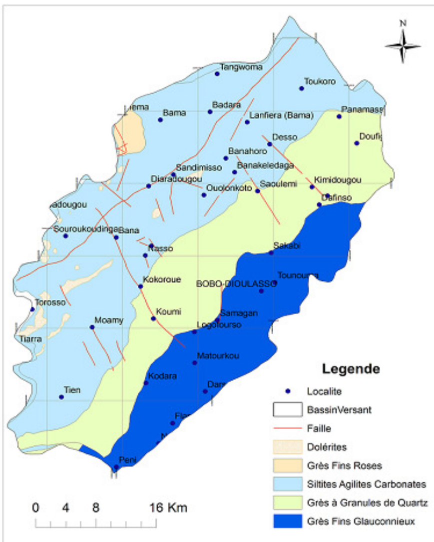

Figure-2: Geological map of the Kou basin.

Pedology and Hydrogeology: In 2007 Kam reports that the soils are characterized by iron and manganese oxides in carapace or cuirass, and the texture of the porous soil is generally of the silty or sandy loam type, with a little hard consistency, favourable to drainage[5] (Figure-3).

Kou basin has many aquifers. In West Africa, it is one of the most important emerging zones. In this region it is noted an alternation of 2 seasons: a rainy season which starts in may for six months and a dry season the rest of time. The groundwater in the Kou basin feeds the town of Bobo Dioulasso for the production of drinking water and it is also used by two mineral water production and distribution companies[5].

Context and choice of Djirwal: The village of Djirwal which has 7 wells and two deserted boreholes benefited of the drilling of a new borehole and the rehabilitation of the two previous ones thanks to the financial assistance of the MAIA association. When the leaders of this association realized that the women from the village had big difficulties to get clean drinking water, they decided to help them fill their need of water for domestic, agricultural and breeding activities.

After the drilling was commissioned, the population realized that the water collected there changed colour after some time, with the appearance of spot and rust-coloured deposits with an unpleasant taste as indicated by Figures-4 and 5.

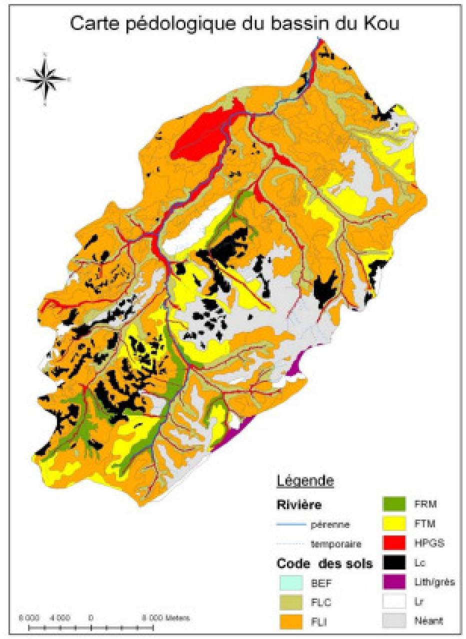

Figure-3: Pedological map of the Kou basin.

This issue justified the inventories of physical and chemical characteristics of all sources of drinking water (boreholes and wells) to assess the health risks.

All the water supply spots in the village, namely the 3 boreholes and 7 wells with large diameter were affected (Figure-6). The list and the GPS coordinates of sampling spots are given in the Table-1.

Table-1: GPS identification of sampling spots.

N°	Source	GPS references	
		X	Y
1	D1	0341091	1258657
2	D2	0341366	1258317
3	D3	0341098	1258286
4	W1	0341456	1258675
5	W2	0341362	1258731
6	W3	0341314	1258515
7	W4	0341415	1258105
8	W5	0341740	1258513
9	W6	0341977	1258821
10	W7	0341955	1258996

Figure-4: The colorless water at the time of sampling.

Figure-5: The water turned red after a few moments.

Figure-6: Overall view of the sampling sites.

Sampling methodology: The samplings were realized in one (1) litre plastic bottle, previously washed and rinsed twice (2) with the sample to be collected.

For the boreholes, the sampling was carried out after the water flew for 15 minutes to ensure the sampling comes from the source. With regard to the wells, we inserted a clean plastic scoop liner in the well while avoiding touching the walls or the bottom and the water was collected below the surface to avoid turbulence. For each sampling spot, two (2) samplings were carried out, with one sample acidified with concentrated pure analytical nitric acid (HNO_3, 1cm^3 in 1litre of water) which served for the determination of metals and the other non-acidified sample was used to determine the other parameters. The bottles were filled and closed hermetically while avoiding the appearance of air bubbles. Each bottle had a label (date, hour, sampling spot, temperature, conductivity pH). The samplings were carried in a cooler to the laboratory for analysis.

Analysed parameters: Field analyses targeted temperature, turbidity, electrical conductivity (Ec) and potential of hydrogen (pH).

The other parameters analysis was done in laboratory. These are complete alkalimetric title (CAT), the water hardness (HT), the contents of anions and cations, and the contents of the various targeted metals.

Measurement of the pH and temperature: The pH indicates the acidity or the alkalinity of an aqueous solution (pH = -log [H_3O^+] where [H_3O^+] is given in mole per litre). This is an essential parameter for the calculation of the thermodynamic equilibrium, but it is sensitive to many factors such as temperature variations.

The temperature of water is a comfort parameter for the users. It also makes it possible to correct the analysis parameters whose values are related to temperature (especially conductivity).

A portable pH meter, brand HANNA and series 93327, with waterproof microprocessors and pH electrode coupled with a temperature probe was used to perform pH and temperature measurements.

Measurement of electrical conductivity: The measurement of the electrical conductivity in micro Siemens per centimetre (µS/cm) evaluates the overall mineralization of water. Indeed, the ions found in the aqueous medium makes the water electrically conductive.

A portable conductivity meter with waterproof microprocessors equipped with conductivity sensors and an automatic temperature compensation of WTW, brand LF 91, was used to carry out electrical conductivity measurements.

Measurement of the alkalimetric title and the complete alkalimetric title (CAT): Water alkalinity corresponds to the existence of different ions such as hydrogen carbonate (HCO_3^-), carbonate (CO_3^{2-}) and hydroxide ions (OH^-).The alkalimetric title measures the water content in free alkali and caustic alkaline carbonates. The complete alkalimetric title is equivalent to the water content in hydroxides (OH^-), carbonates (CO_3^{2-}) and hydrogen carbonates (HCO_3^-).

Prior knowledge of the value of the sample pH provides useful information: i. if pH>8.3 the AT is not zero. AT and TAC are dosed. ii. if 4.5<pH <8.3; AT=0 and CO_3^{2-}=0. In this case, CAT is directly dosed. iii. if pH<4.5 theAT and the TAC are considered zero.

Measurement of water hardness (complete, calcium and magnesium hardness): The hardness of water or hydrotimetric titration is the amount of metal cations concentrations excepted those of alkali metals and hydrogen ions. Generally, the hardness is principally due to the calcium and magnesium ions. The Table-2 shows groundwater classification. i. The total hardness or hydrotimetric title (HT) is the sum of the calcium and magnesium concentrations; ii. Calcium hardness corresponds to the overall calcium salt content; iii. Magnesium hardness corresponds to the overall magnesium salt content.

Table-2: Ground water Classification according to HT values.

HT (mg/L de $CaCO_3$)	0 à 75	75 à 150	150 à 300	>300
Water quality	Soft	Moderately sweet water	Hard	Very hard

Measurement of turbidity: The measurement is carried out with a turbid meter and is expressed in NTU (nephelometric turbidity unit). Turbidity is due to suspended and colloidal substances in water. This is a very important parameter in the analysis of the quality of water.

Determination of sodium, potassium, iron, manganese, zinc contents by atomic absorption spectrometry: The determination of these cations was carried out with the atomic absorption (flame) spectrometer, SHIMADZU Model AA 7000 and Perkin Elmer Model 2380.

Principle of the method: When the atoms of an element are excited, their return to ground state is followed by the emission of photons, with a well-defined frequency F specific to the element. The use of this phenomenon is the basis of emission spectrometry. The same element, dispersed in the atomic state in a flame also possesses the characteristic of absorbing any radiation of the same frequency F. This results in an absorption of the incident radiation related to the concentration of the element under consideration by a relation: $Log\frac{I_0}{I} = KLC$.

Where: I_0=Incident radiation Intensity. I=Radiation Intensity after passing through the flame. L=Length of optical path. C=Concentration in the solution of the element under consideration. K=specific constant of the element to be determined. i. For the determination of Na^+ and K^+ ions, the analysis is carried out in the presence of caesium chloride to prevent interference. ii. The other cations are determined without a particular preparation; the instrument is calibrated with the standard of the element to be determined.

Determination of contents in arsenic: The content in arsenic (As) analysed by the electro thermal method with a flame because the sensitivity is comparable to that which is obtained with flame but the precision is improved.

Determination of nutrients and chlorides: Analytical methods using the DR 2400 spectrophotometer was used to determine nitrate(NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), orthophosphate (PO_4^{3-}), sulphate (SO_4^{2-}) and the volumetric method for the determination of chlorides.

Ryznar's Index: The index of RYZNAR (IR or IRYZ) or index of stability of Ryznar (ISR) is an index, called stability index. It is determined by a "DBase" hydrochemistry program used for water data processing that allows us to perform ion balance (IB). It indicates the aggressive or scaling trend of an aerated water. The Table-3 shows the relationship between the stability index and the incrusting or corrosive trend of water. It can be calculated by using equation-1, where pH is the real pH of the measured water and pHs is the pH of the water if it was saturated with calcium carbonate.

$$ISR = 2\,(pH_s) - pH \qquad (1)$$

Table-3: Incrusting an corrosive trend of the water.

IR	Trend
4 to 5	High scaling
5 to 6	Weak scaling
6 to 7	Equilibrium
7 to 7,5	Light hot corrosivity
7,5 to 8	Hot corrosivity
8 to 12,5	High corrosivity
> 12,5	Very high corrosivity

Ryznar index guides the choice of treatment to apply to a source of water to avoid any inconvenience related to the equipment used but also to preserve the health status of the consumers from the risks of corrosive reactions with the surfaces and metal materials.

Results and discussion

The pollution level of the different sources was quantified due to the analyses carried out. To facilitate the interpretation, the results are presented in three groups, namely physicochemical parameters, cations (including metals) and anions.

Boreholes water: Physico-chemical parameters: Table-4 indicates physical and chemical parameters values of all samples. It is clear from the analyses carried out on the waters from the three boreholes in the village that only D3 has a neutral pH with a value of 7.5 while the samples from the other two boreholes are acidic with respective pHs of 6 and 6.1 for D1 and D2 (Figure-7). As for the temperature, it ranged between 31.5 and 32°C or slightly higher. The strongest mineralization was recorded at borehole D3 with a conductivity of 430µS/cm while the other two had conductivity values of 97 and 81µS/cm respectively for D1 and D2 (Figure-8). Eblin and his collaborators in Ivory Coast revealed that three phenomena were at the origin of the mineralization of the waters: the contributions of the anthropogenic activities, leaching of soils by rainfall and the contact between water and rock (principal mechanism of production of ions).

In the same logic, D3 is the borehole that has the highest CAT and HT with values of 384 for the first parameter and 352mg/L for the second, while the other two boreholes yielded values lower or equal to 80mg/L for these same parameters.

D1 and D3 gave the highest turbidity values with the respective values of 13.5 and 15.2 NTU. Figure-9 shows that the Ryznar index is the lowest for D3 with a value of 6.8, when D1 and D2 have indices of 11.07 and 11.55 respectively.

The cationic and anionic compounds: Tables-5 and 6 gives respectively cations and anions content of different samples. Borehole D3 appears to have the highest Ca^{2+} and Mg^{2+} contents with respective values of 77.76 and 38.33mg/L compared to D1 and D2 which have respective values of 11, 22 and 8.74 mg/L for D1 and 6.31 and 12.02 for the second. If the contents in Na^+, K^+, Cu^{2+}, Zn^{2+}, Mn^{2+} and As remain well below the required standards for all the boreholes water except for borehole D1, which has a K^+ content of 14.55mg/L for a value limit below 12 mg/L, it is not the same for the contents in iron where the values recorded is far above the required standards for boreholes D1 and D3 with respective values of 5.97 and 5.14mg/L with a value limit below 0.3mg/L.

As for the anions, the boreholes have no issue with respect to the contents of the target anions apart from the HCO_3- ions for which the concentrations recorded are 98, 80, and 468 mg/L respectively for the boreholes D1, D2 and D3 on the one hand and nitrites with a content of 0.34 mg /L little higher than the standard for borehole D3.

It can be noted the absence of agriculture pollution by nutrients through the concentrations of NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-} and NH_4^+ which are lower in general. The diagram of Piper which represents a method to classify ground water through cations and anions distribution shows their characteristics (Figure-10).

Table-4: Physical and chemical parameters of the anaysed waters.

Samples	T (°C)	pH	EC (µS/cm)	TA (mg/L)	TAC (mg/L)	TH (mg/L)	Turbidity (NTU)	*IRYZ*
D1	32.0	6.0	97.0	0.0	80.0	64.0	13.5	11.07
D2	31.5	6.1	81.0	0.0	66.0	56.0	3.2	11.55
D3	31.8	7.5	430.0	0.0	384.0	352.0	15.2	6.80
W1	30.2	4.3	49.0	0.0	28.0	24.0	7.5	13.76
W2	29.6	5.1	87.0	0.0	38.0	32.0	2.9	12.21
W3	29.6	6.7	92.0	0.0	72.0	48.0	5.0	10.36
W4	29.6	6.5	76.0	0.0	62.0	68.0	3.7	10.86
W5	29.9	6.2	135.0	0.0	84.0	60.0	3.3	9.55
W6	31.0	5.0	26.0	0.0	26.0	16.0	7.1	12.89
W7	29.9	5.5	48.0	0.0	38.0	32.0	4.7	11.65

Table-5: Cations content of different samples.

Samples	Cations Concentration (mg/L)								
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cu^{2+}	Mn^{2+}	NH^{4+}	Fe^{2+}	Zn^{2+}	As (µg/L)
D1	11.22	8.74	0.92	14.5	0.00	0.08	0.00	5.97	0.37	1.78
D2	12.02	6.31	1.11	4.02	0.00	0.07	0.00	0.05	0.16	0.80
D3	77.76	38.33	1.50	5.19	0.00	0.13	0.00	5.14	1.90	1.29
W1	4.01	3.40	3.34	0.26	0.00	0.09	0.00	0.18	0.17	0.42
W2	8.02	3.88	2.46	3.14	0.00	0.09	0.00	0.00	0.04	0.00
W3	16.03	1.93	1.18	4.03	0.00	0.02	0.00	0.02	0.00	0.42
W4	14.43	7.76	1.11	1.98	0.00	0.03	0.00	0.10	0.00	0.00
W5	29.66	0.00	3.51	4.33	0.00	0.21	0.00	0.57	0.00	0.37
W6	8.02	0.00	1.33	1.75	0.00	0.04	0.00	0.64	0.00	0.00
W7	12.02	0.48	3.35	1.95	0.00	0.05	0.00	0.54	0.00	0.00
National standards							<1.5	<0.3		
WHO standards	80	80	≤ 200	≤12	≤2	≤ 0.1		≤ 0.3	≤ 3	≤ 10

Table-6: Anions content of different samples.

Samples	Anions concentration (mg/L)							
	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	PO_4^{2-}	NO_3^-	NO_2^-	F^-
D1	0.00	8.49	0.00	97.60	0.03	0.00	0.04	0.19
D2	0.50	0.00	0.00	80.52	0.03	0.61	0.11	0.22
D3	1.00	0.00	0.00	468.48	0.00	0.00	0.34	0.25
W1	0.50	0.00	0.00	34.16	0.00	0.00	0.04	0.18
W2	1.00	0.00	0.00	46.36	0.00	0.00	0.00	0.18
W3	1.00	0.00	0.00	87.84	0.00	0.00	0.00	0.20
W4	2.00	0.00	0.00	75.64	0.00	0.00	0.40	0.19
W5	2.50	10.93	0.00	102.48	0.00	0.00	0.00	0.26
W6	0.50	0.00	0.00	31.72	0.00	0.00	0.00	0.20
W7	2.00	19.42	0.00	46.36	0.00	0.00	0.00	0.19
National standards	≤ 250	≤ 250				≤ 50		≤ 1.5
WHO standards					≤ 0.5	≤ 50	≤ 0.2	≤1.5

The wells water: Physicochemical parameters: Table-4 presents the results of the analyses of the physicochemical parameters that were carried out. These results indicate that the wells water, all have a pH of less than 7 with values between 4.3 and 6.7 (Figure-7) and their temperatures were between the limit values of 29.6 and 31°C. They are therefore acidic, the alkalimetric titre (AT) is zero for all the samples. Kam and Lorenzini have found similar results in the same area with pH values below 6. The waters of the Kou basin are generally acidic[5,6]. And similarly, Eblinand his collaborators also reported that the groundwater in the city of Abidjan and in the region of Adiake in Ivory Coast are acidic[7].

As for the complete alkalimetric titre (CAT) it ranged between 26 and 84°F, while the electrical conductivity ranged between 26 and 135µS/cm with an average of 73µS/cm (Figure-8). In general, electrical conductivity gives information about existence of dissolved solids and contaminants such as electrolytes but nothing about detailed chemical composition of water[8]. Similar works carried out by Lorenzinion waters in the same watershed confirms the pH, temperature and conductivity values[6]. In other area, GBOHAIDA and his collaborators revealed the conductivity low to 500µS/cm in two town of Benin[4]. As indicated by Figure-8, HT ranged between 16 and 68 mg/L of $CaCO_3$, indicating that the wells water is not mineralized enough. Turbidity ranged from 2.9 to 7.5NTU, while the RYZNAR index, which ranged from 9.55 to 13.75 with an average of 11.61, indicates significant corrosivity (W3, W4, W5 and W7) and very significant corrosivity (W1, W2 and W6)of the wells of Djirwal (Figure-9).

The acidity of the water explains their strong corrosivity with Ryznar indices above 9. The reddish colour of the water collected is possibly caused by the corrosion of the pipes but also the iron oxides contained in the rock, especially since soil studies have revealed that the leached tropical ferruginous soils indurated in some places and deep soils with clay limono texture above and clay in the rest of the profile in other places[5]. This is more plausible as the rock of the area is very rich in iron.

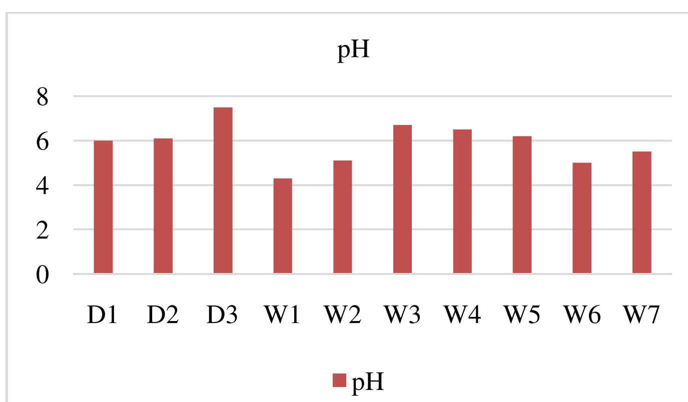

Figure-6: pH values of the different samples of ground water.

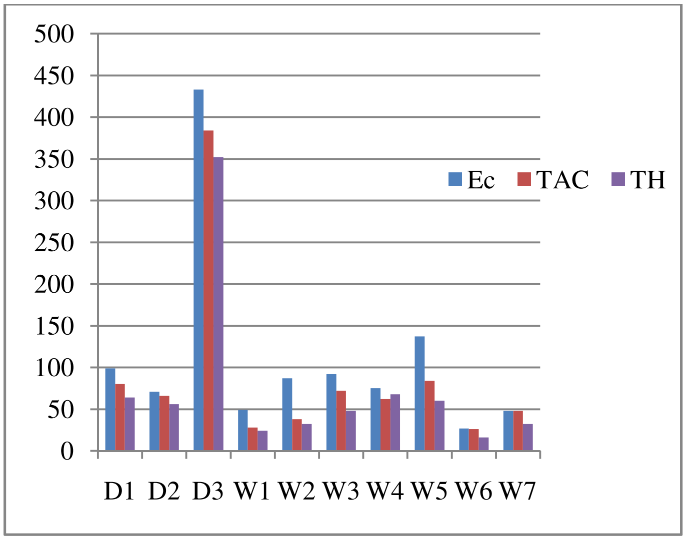

Figure-8: Representation of state of ground water ionization.

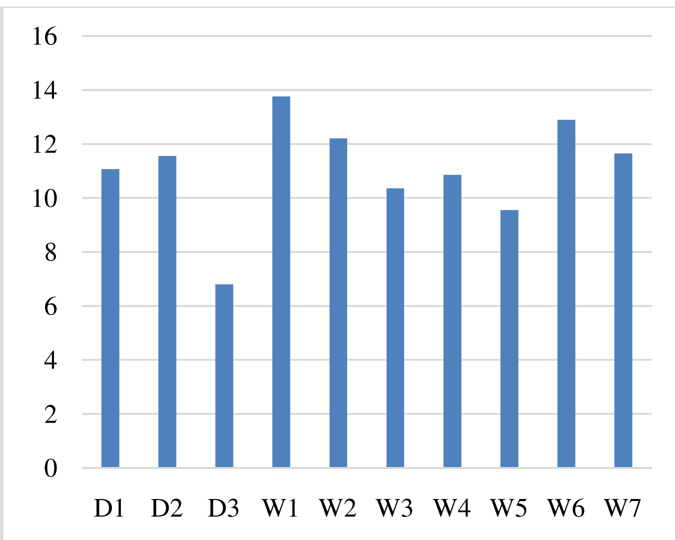

Figure-9: Ryznar Stability Index for the different samples of groundwater.

The cationic and anionic compounds: In the case of the anions, there was a total absence of Cu^{2+} and NH_4^+ and an almost absence of Mn^{2+} with all the wells water samples.

Contents in Ca^{2+} varied between 4.01 and 29.66mg/L of $CaCO_3$, while those of Mg^{2+} varied from 00 to 7.76mg/L. The contents in potassium and sodium remain well below the WHO limit values. For the iron, three wells have concentrations above the WHO limit with respective values of 0.57, 0.54 and 0.64mg/L for wells W5, W6 and W7. In the case of zinc and arsenic all the sources meet the required standards.

With regards to anionic compounds, only the presence of HCO_3^- is noticeable with concentrations ranging between 31.72 and 102.48 mg / L with the wells water samples. The other anions are almost absent or in very low concentrations.

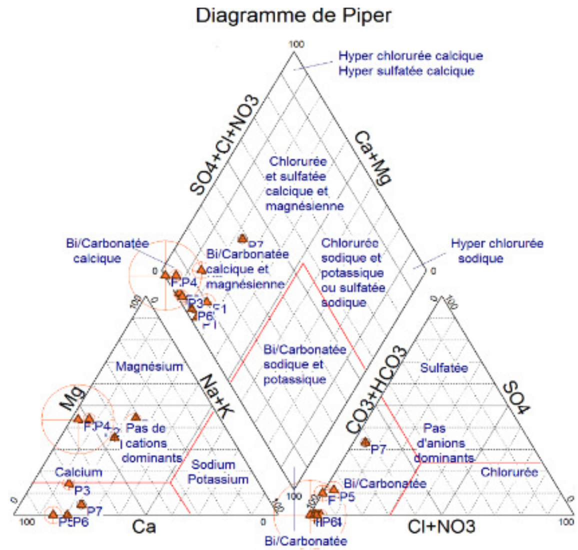

Figure-7: Hydrochemical classification of ground water of Djiwal.

Discussion: Physical characteristics of groundwater: It will be noted that all the values of the electrical conductivity of the waters analysed are below the limit defined as the limit of average mineralization (200≤Ec≤333) except for borehole D3 whose conductivity is slightly higher. In general, the wells and boreholes waters have practically the same values of electrical conductivity. Concerning the degree of mineralization, it is noticeable that the wells and boreholes waters are good quality and suitable for drinking[7,9]. The mineralization of water increases its conductivity and thus reduces its resistance to corrosion current.

At the pH level, only the borehole D3 gets a pH within the limit set by the WHO (6.5≤ pH≤ .5), W3 and W4 are below the limit of the normal pH range (Figure-7).

The acidity of the water can lead to the degradation of the cement or to the corrosion of the pipe metals with the result of carrying the ions generated in the aquatic environment. With the temperature ranging from 29.6°C to 32°C, this temperature is normal and seasonal for all sources, in line with the results of Lorenzini's work[6].

Characterization nature of ground waters: The aggressiveness or scaling of water is dependent from different factors among which the most important are mineralization, carbon dioxide, calcium content, alkalinity, pH and temperature. The calco-carbonic reaction below shows the transformations likely to occur between water and limestone (equation 2):

$$Ca^{2+} + 2HCO_3^- \leftrightarrow CaCO_3 + CO_2 + H_2O \quad (2)$$

If one or more of these elements are modify the physico-chemical equilibrium of the water changes resulting in the increase of the incrustation and aggressiveness trends.

As for Djirwal waters, it should be noted that the equilibrium of the above reaction is shifted towards the formation of calcium ions, particularly at borehole D3. Indeed, as indicated by Figure-8, the analyses reveal a higher hardness for this sample with respective calcium and magnesium contents of 78 and 38mg/L[7].

Moreover, the representation of the major elements through the Piper diagram indicates a homogeneous chemical composition of groundwater (wells and boreholes) with a calcium carbonate type facies (Figure-10) where bicarbonates, calcium, magnesium, sodium and chlorides predominate.

It should be noted that 90% of Ryznar indices for the sources (wells and boreholes) are above 8. The sources D1, D2, W2, W3, W4, W5 and W7 have a Ryznar index ranging between 8 and 12.5, thus reflecting a high corrosivity of these waters while W1, W6have a very high corrosivity with values of IRZ >12.5 (Figure-9). Only the sample from the boreholeD3is in equilibrium with a Ryznar index of 6.80.

In sum, the waters of Djirwal are corrosive in general and could be aggressive with the drainage pipes. This is corroborated by the presence of perforation in the piping of the old boreholes, which justified their repair. This corrosivity could originate from rocks and soils that the water flows through. The corrosivity becomes acute due to some factors such as temperature, total dissolved mineral concentration, calcium hardness, alkalinity and pH[7]. It increases when the pH of the water decreases or when the alkalinity is low.

When water is corrosive, it becomes a danger for health because it favours the dissolution of metals found in the medium, both those of the rock and those of plumbing materials such as iron, lead, cadmium, zinc or copper.

This could explain the very high iron concentrations of the boreholes (D1, D3) water. The borehole D2 and the wells W1, W2, W3, and W4 have an iron concentration below the accepted limit value. It is important to note that the drilling of this borehole D2 are recent, while boreholes D1and D3 drilled many years before have iron concentrations twenty times above the required standard. This highlights the fact that the presence of iron could come from the equipment of the borehole. Nevertheless, the possibility that these concentrations come from the rock that contains the water cannot be ruled out, since the phenomenon is also observable with water from wells W5, W6and W7where the iron concentrations though not as high as in the boreholes D1 and D3, still remain above the standard with the respective values of 0.54, 0.64 and 0.57mg/L. Eblin and his Collaborators, got similar results at Affiénou in Ivory Coast[7].

Moreover, the iron may come from the piping of boreholes or rock in contact with acidic water. Indeed, some substances found naturally in rocks or soils, such as iron, manganese, chlorides, arsenic, fluorides or sulphates can be dissolved in groundwater and some of them can causediseases[10].

This assumption is confirmed by the hydrotimetric title and the Ryznar Stability Index (RSI) which is between 3.80 and 13.76 for all samples.

The colour change of samples from boreholes D1 and D3, combined with greater turbidity of the same samples, suggests an oxidation of ferrous ions to ferric ions in the presence of the oxygen in the air.

Indeed, the presence of hydrogen carbonate ions in groundwater is related to CO_2 dissolution. The presence of CO_2 in water, with no oxygen, results in the formation of the ions H^+, HCO_3^- and CO_3^{2-}.

The appearance of H^+ ions lowers the pH, and the water becomes more acidic. These H^+ ions form a proton pump which subsequently triggers an acceleration of the phenomenon of corrosion.

Like the H^+ ions, the Fe^{2+} ions in water react with the HCO_3^- and CO_3^{2-} to form soluble ferrous bicarbonate and ferrous carbonate which, when the solubility limit is reached, precipitates according to the reactions (equations 3 and 4):

$$Fe^{2+} + 2HCO_3^- \rightarrow Fe(HCO_3)_2 \quad (3)$$
$$Fe^{2+} + CO_3^{2-} \rightarrow FeCO_3 \quad (4)$$

For calcium bicarbonate waters, a significant diffusion of oxygen could lead the ferrous hydroxide to be oxidized to ferric hydroxide. The phenomenon may have been exacerbated by the fact that the boreholes D1 and D3 have been deserted for a long time with stagnant water in contact with the rock rich in iron oxides as indicated by Kam[5]. It is important to note some elements which are essential for aquaticorganisms, plants as well as human beings must be within limits. Their high concentrations are toxic[10]. The immediate observable effects concern the alteration of the organoleptic quality of water[4,11].

Conclusion

In concluding this study, it emerges that the waters of the village of Djirwal has an acidic pH in general, with values of 4.3 and 6 for 90% of the samples. The mineralization of the waters of the area remains negligible for the majority of the sources. The waters of boreholes D1, D3 and that of the wells W1, W6 have turbidity values higher than the accepted standard. An excess of iron was noted for 50% of the water sources (boreholes and wells), with corollaries of exacerbated unfavourable organoleptic characteristics.

If the excess of iron which reaches 20 times the accepted limit may result from the degradation of the piping materials due to the corrosity of the water, it is not excluded however that the rock and the layers of soil which see the water flowing through altered the quality of the groundwater by the dissolution of the minerals present, all the more that the boreholes and the wells are concerned. With this in view, the population of Djirwal must collect and store drinking-water in plastic containers on the one hand and aerate them to raise the pH before consumption.

Upstream, the boreholes must be equipped with PVC piping to avoid the risk of corrosion with potential transfer of mineral pollutants in the water.

References

1. WHO (2010). Progress on sanitation and drinking-water. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. pp 1-56. ISBN 978 92 4 156395 6.

2. Derouane J. (2004). Rapport de Modélisation des eaux souterraines de la série sédimentaire dans la zone d'intervention du Programme VREO au Burkina Faso. Assistance Technique Sofreco-Sawes-partie 1. MAHRH/ DGAEP /Programme VREO. Burkina Faso, 1-58.

3. Soubeiga M., Guiguemde I., Diendere F., Kone M., Diarra and Bary A. (2013). Quality of Drilling well water: Case of six drilling wells in the municipality of sapone, Burkina Faso. *Int. Res. J. Environment Sci.,* 2(2), 15-24. ISSN 2319–1414

4. Gbohaida V., Agbangnan D.C. Pascal, Ngossanga M.B., Medoatinsa S.E., Dovonon L.F.C., Wotto D.V., Avlessi F., Sohounhloue D.C.K. (2016). Etude de la qualité physico-chimique de l'eau de boisson dans deux localités du Bénin : Cotonou et Dassa-Zoumè. *Int. J. Biol. Chem. Sci*., 10(1), 422-434.DOI : http://dx.doi.org/10.4314/ijbcs.v10i1.32. http://ajol.info/index.php/ijbcs**.**

5. Kam M.A. (2007). Caractérisation des sources de pollution agricoles dans le bassin du Kou et première ébauche de cartographie de la vulnérabilité des aquifères. *Rapport. Burkina Faso*., 1-68.

6. Lorenzini G. (2008). Etude du bassin d'alimentation des sources de Nasso (Bobo-Dioulasso, Burkina Faso) Etat des lieux des ressources en eaux souterraines du bassin du Kou. *Mémoire Ingénieur Civil Géologue*, Université de Liège. Belgique, 1-96.

7. Eblin S.G., Sombo A.P., Soro G.M., Aka N., Kambiré O., Soro N. (2014). Hydrochimie des eaux de surface de la region d'Adiaké (Sud-est côtier de la Côte d'ivoire). *J. Appl. Biosci*., 75, 6259-6271. http://dx.doi.org/ 10.4314/ jab.v75i1.10

8. Adekunle I.M., Adetunji M.T., Gbadebo A.M. and Banjoko O.B. (2007). Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria. *Int. J. Environ. Res. Public Health,* 4(4), 307-318. Doi:10.3390/ijerph200704040007

9. Hwang J.Y., Park S., Kim H.K., Kim M.S., Jo H.J., Kim J.I., Lee G.M., Shin I.K. and Kim T.S. (2017). Hydrochemistry for the Assessment of Groundwater Quality in Korea. *Journal of Agricultural Chemistry and Environment*, 6(1), 1-29. https://doi.org/ 10.4236/ jacen.2017.61001.

10. Arbind K. and Seema (2016). Fluoride Analysis of GroundwaterAround Tea-Gardens in Kishanganj Block, Bihar, India: Correlation with Physicochemical Parameters. *American Journal of Environmental Engineering and Science,* 3(2), 48-61. ISSN: 2381-1153. http://www.aascit.org/journal/ajees.

11. Dougna A.A., Gnazou M.D.T., Kodom T., Djaneye-Boundjou G. and Bawam L. (2015). Physical chemistry and water quality of rural water supplydrilling in Central region in Togo. *Int. J. Biol. Chem. Sci*., 9(4), 2249-2262. DOI : http://dx.doi.org/10.4314/ijbcs.v9i4.42.