ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 11(20), DOI: 10.17485/ijst/2018/v11i20/120750, May 2018*

Hydrochemical Study of the Groundwater of the Maâmora Aquifer: Case of the Sidi Taibi-Morocco

N. Bentoutou[1,2]*, K. Momayiz[3], M. Najy[1], D. Belghyti[1], A. El Yahyaoui[2], G. Acil[2] , H. Ech-Chafay[1] and A. Chaouch[1]

[1]Department of Chemistry, Faculty of Science, Laboratory of Agrophysiology, Biotechnology, Environment and Quality, University Ibn Tofail P.B : 133, 14000 Kenitra-Morocco
naimabentoutou@gmail.com, belghyti@hotmail.com, hamman.mohamed9@gmail.com, hassanfes98@gmail.com, achaouch61@gmail.com
[2]National Center of Energy, Science and Nuclear Techniques, B.P.1382 R. P. 10001- Rabat, Morocco; naimabentoutou@gmail.com adilelyahyaoui@gmail.com, acil.ghassan@gmail.com
[3]Hassan Premier University, FST Settat, Morocco
momayizigt@gmail.com

Abstract

Objectives: To evaluate the physic-chemical quality status of the groundwater of SIDI TAIBI in Morocco and to identify the sources of the pollution. **Methods/Analysis:** The study covered 21 observation sites while the quality parameters selected and analyzed are physic-chemical parameters such as temperature, electrical conductivity and hydrogen potential. These were measured in situ using portable probes. The analysis of the major elements (cations and anions) was carried out by ion chromatography and bicarbonates by titration in the laboratories of the National Energy Center for Nuclear Science and Technology in Rabat-Morocco. **Findings**: The results obtained show that most of the physicochemical parameters involved in determining the quality of these waters comply with the standards of Morocco and those of the World Health Organization. However, we obtained non-conformance values for ammonium analysis, nitrates and the hydrotimetictitle. These parameters can be considered as indicators of the degree of pollution of this groundwater originating from the domestic and agricultural activities of the population of the region. **Novelty/ Improvement:** In the light of these results, as well as those described above, we advocate continuous monitoring of the parameters studied for wells with abnormal values, until the competent authorities connect the villages Region of SIDI TAIBI to the drinking water network and the sewerage network. Also, a campaign to sensitize the population on the basic means and techniques of treatment of water intended for human consumption for the protection the health human.

Keywords: Groundwater, Hydrochemistry, Irrigation, Quality, SIDI TAIBI

1. Introduction

Groundwater constitutes an important part of the hydraulic heritage of Agency of the hydraulic basin of Sebou[1], in Morocco in which The SIDI TAIBI region is part of the SEBOU basin in the north-west of the country. The groundwater of the MAAMORA water table is the primary water resource for the drinking water supply of the local population and irrigation of agricultural lands. The study area is equipped with drinking water installations like all regions of Morocco but these do not supply all the districts and DOUARS of the region especially those

*Author for correspondence

in peri-urban environment and the cubic meter of water becomes expensive because of the distribution conditions. Thus, many parts of the population in peripheral or even urban areas uses well water, as drinking water and/or for domestic activities without any worry about the quality of the water whose regional importance as a potential resource for the drinking water supply of the neighboring centers of the commune of SIDI TAIBI and for agricultural development in this region. Given its negative influences on the water quality of this aquifer in relation to domestic and agricultural activities in the region, with reference to portability or irrigation standards, a hydro chemical study proves useful and necessary to determine the state of quality and to detect areas of contamination.

2. Material and Methods

2.1 Environmental Study

Since it is bounded to the north by the town of KENITRA, to the east by the rural commune HADDADA, the west by the Atlantic Ocean and the rural town BOUKNADEL to the south, the rural commune of SIDI TAIBI is located within the region of RABAT-SALE and KENITRA and it covers an area of 145 km^2. The area which is richly watered

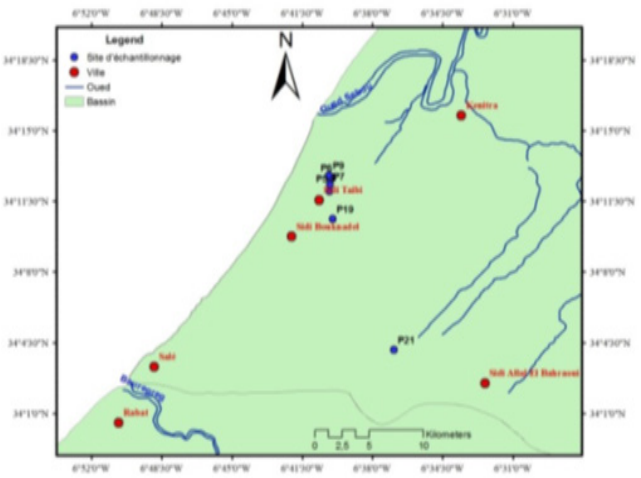

Figure 1. Geographical location of the studied sites in SIDITAIBI-Morocco region[19].

(558 mm/year) and its average temperature is 18 °C, is part of the MAAMORA aquifer which represents a very important hydraulic potential throughout the country and contributes to the development of economic, industrial and agricultural activities. Similarly, the SIDI TAIBI catchment area, whose the dominant crops in the region are nurseries, contributes to the production of drinking water for the KENITRA, MEHDIA, BOUKNADEL AND SALE[1] (Figure 1).

3. Methods of Water Analysis

The study covered 21 observation sites while the quality parameters selected and analyzed are the physic-chemical parameters, in particular the temperature, electrical conductivity and hydrogen potential. The latter were measured *in situ* by means of portable conductormeter WTW 3310 integrated by a thermometer and a Portable pH-meter type WTW3310. The sampling, transport and storage of water samples were carried out according to the protocol which is defined by the French Agency for Standardization[3,4]. The analysis of the major elements (cations and anions) was carried out by using a DIONEX ion chromatography system and bicarbonates by volumetric determination by using 0.02 N sulfuric acid in the presence of a green colored Bromocresol indicator[5] in the physicochemical analysis laboratories of the National Energy Center for Nuclear Science and Technology in Rabat-Morocco.

4. Results and Discussion

The results in study are discussed by discussing the parameters' average values of the measured throughout the observation period, including *in situ* and laboratory measurements. The summary of the results of measurements of the physical parameters of the waters of the SIDI TAIBI aquifer are given in Table 1.

In order to define the portability of the studied waters, we were based on the standards established by the World Health Organization and Morocco.

Table 1. Descriptive statistics of the physicochemical parameters of the waters of the SIDI TAIBI aquifer

Variables	Observations	Minimum	Maximum	Average	Standard deviation
pH	21	7,18	7,59	7,34	0,14
T (°C)	21	23,6	25,9	24,34	0,69
CE (µS/cm)	21	627	951	753,70	85,02
HCO_3^-(mg/L)	21	261,1	403,8	339,38	40,06
F^-(mg/L)	21	0,23	0,8	0,40	0,19
Cl^-(mg/L)	21	51,41	96,94	72,37	22,99
NO_2^-(mg/L)	21	0,00	2,83	0,25	13,57
NO_3^-(mg/L)	21	12,77	100,86	54,97	21,36
SO_4^{2-}(mg/L)	21	7,17	39,71	23,58	9,31
Na^+(mg/L)	21	39,46	95,23	53,16	14,73
NH_4^+(mg/L)	21	0,44	3,09	1,42	0,77
K^+(mg/L)	21	1,84	4,11	2,8	0,58
Mg^{2+}(mg/L)	21	6,23	10,87	8,25	1,33
Ca^{2+}(mg/L)	21	80,82	149,09	119,62	16,93
TH (mg/L)	21	241,6	415,2	334,9	44,04

5. Study of Physicals Parameters

The results of analyzes showed that the average values of the electrical conductivity (750.33µS/cm), temperature (24.9 °C and pH (7.34) are compatible with the Moroccan portability standards[6], which are set at 2700µS/cm, 25 °C and [6-8,5] (Figure 2). They can be considered consequently to be permissible and have no impact on the water quality of the water Table.

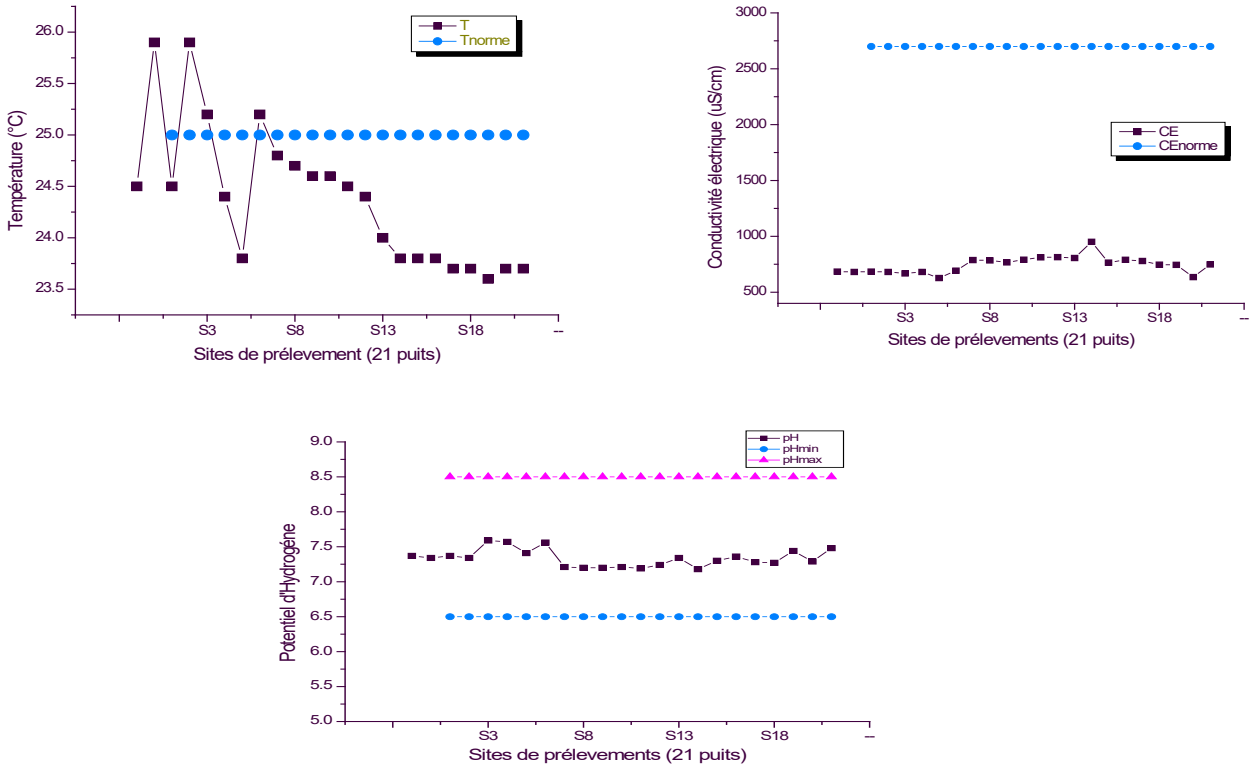

Figure 2. Spatial variation of the physicoparameters (T°C, CE, pH) of the studied grounds water.

6. Study of Chemicals Parameters

6.1 Anions

The results of hydrochemical analysis of groundwater in the SIDI TAIBI region have shown that the average contents of major elements (anions and cations) such as HCO_3^-, Cl^-, F^-, SO_4^{2-}, Na^+, K^+ and Mg^{2+} conform to the standards recommended by Morocco for the water which is intended for human consumption with the exception

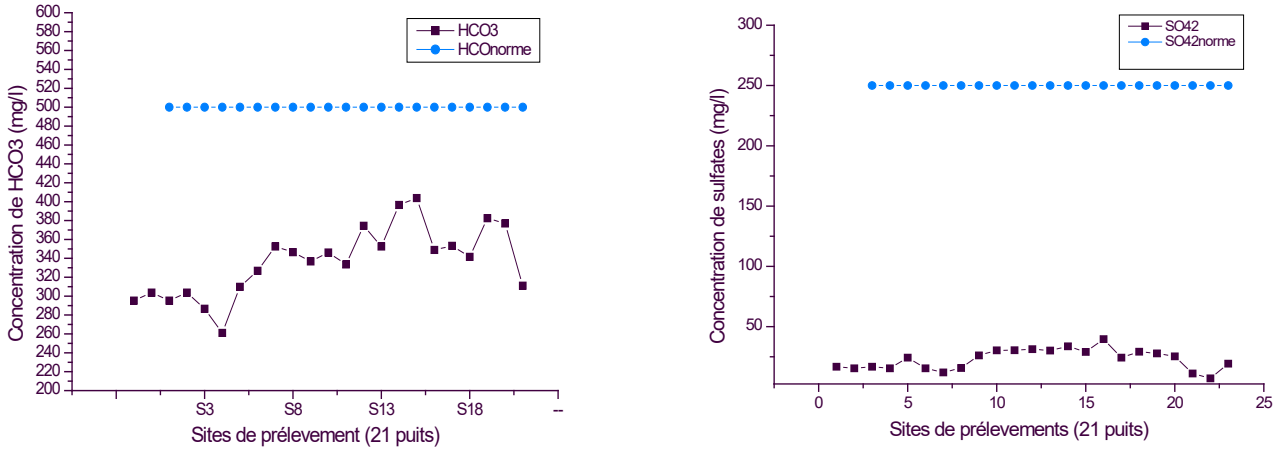

Figure 3. Spatial evolution of bicarbonates and sulfates in the studied groundwater.

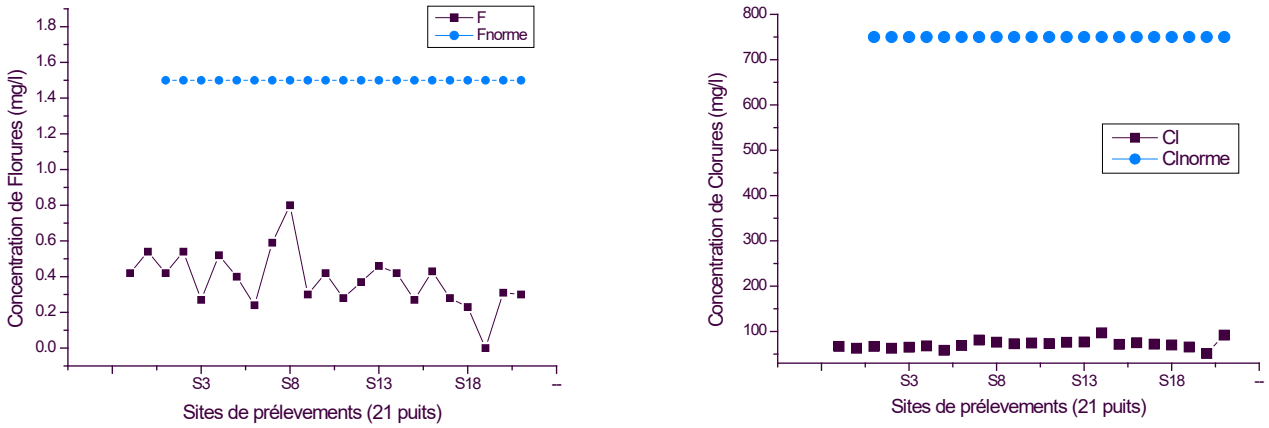

Figure 4. Spatial evolution of fluorides and chlorides in the studied groundwater.

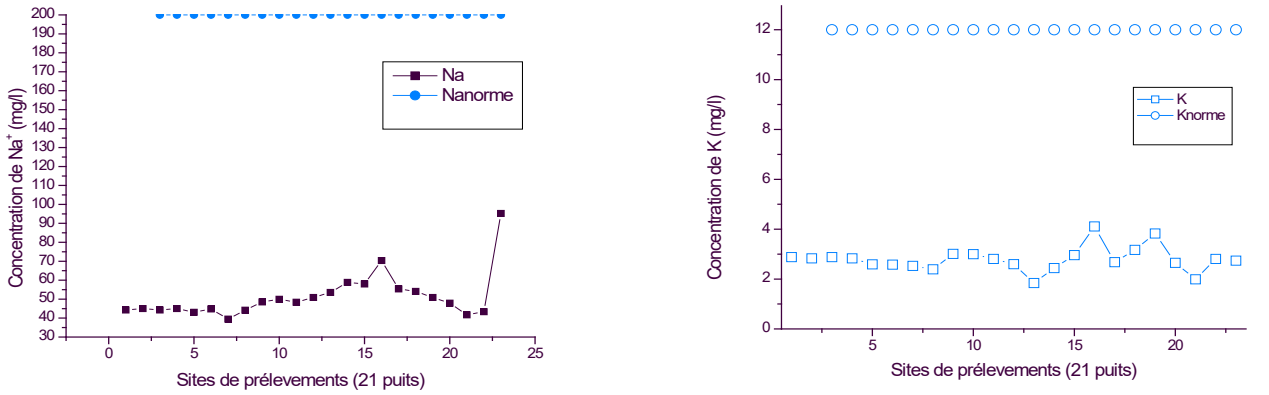

Figure 5. Spatial evolution of sodium and potassium in the studied groundwater.

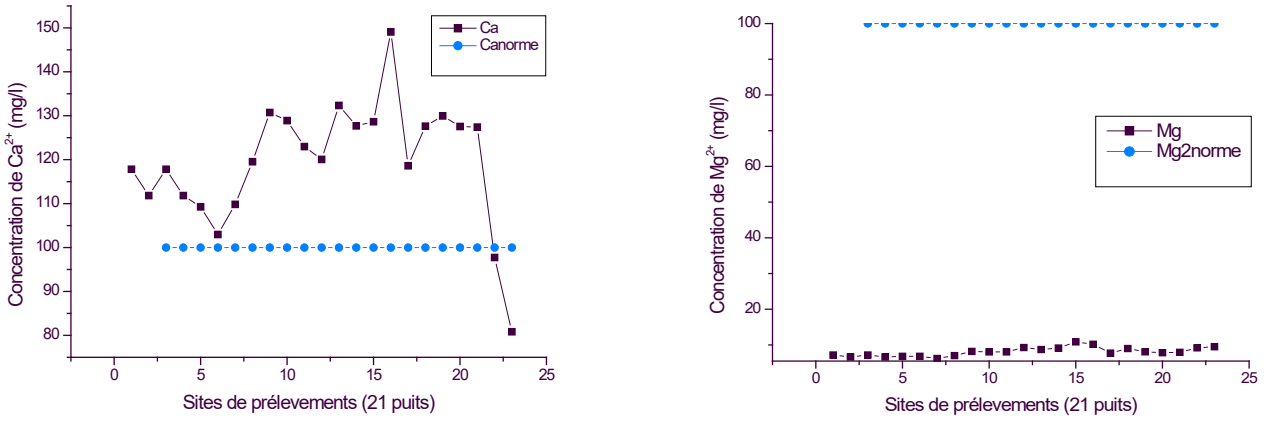

Figure 6. Spatial evolution of calcium and magnésium in the studied groundwater.

that the Ca^{2+} content is greater than the maximum value allowed by the current standard (Figure 3 & 6).

7. Nitrogen Compounds

The nitrate levels in the groundwater analyzed in this study indicate that approximately 62% of the water withdrawals are above the World Health Organization[7]/ Morocco maximum permitted value (AMV) of 50 mg /L. The obtained results are similar to the findings in the case of Moulouya basin confirming the anthropogenic origin of nitrates[8]. The state of pollution by nitrates is very alarming as a result (Figure 7).

Similarly, the ammonium standard enacted by Morocco for human consumption is in the order of 0.5 mg/L while in the study area, about 91% of the total inventoried wells exceed this standard (Figure 7), thus signaling contamination of these waters.

Similarly, the total hardness value of the studied water ranges from 241.6 mg/L to 415.2 mg/L with an average value of 334.33 mg/L, thus exceeding the guideline value of 200 mg/L recommended by the World Health Organization[9] and 81% of the sampled water drops present fairly high values at this standard (Figure 8). Therefore, groundwater is considered hard to very hard.

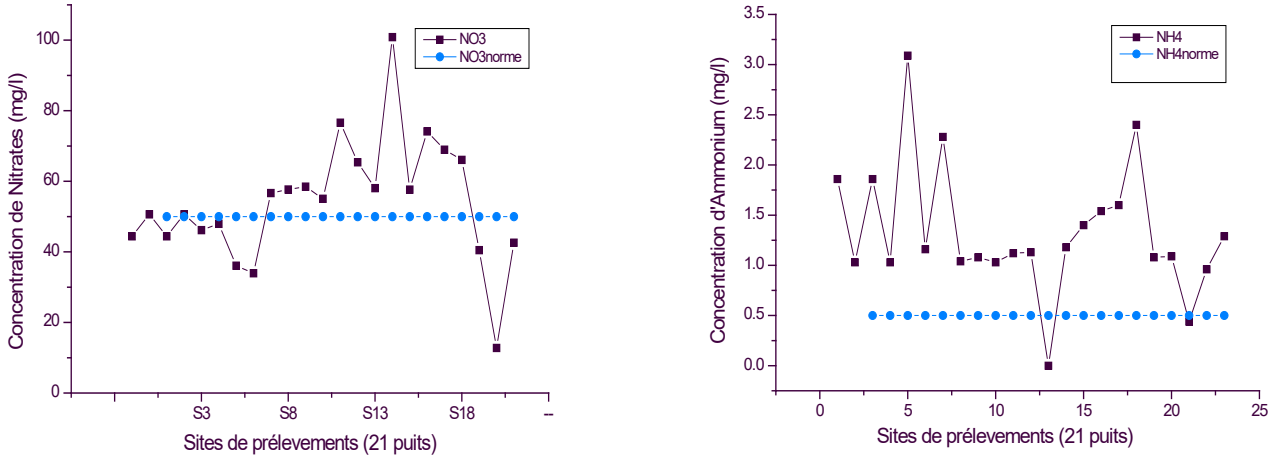

Figure 7. Spatial evolution of nitrates and ammonium in the studied groundwater.

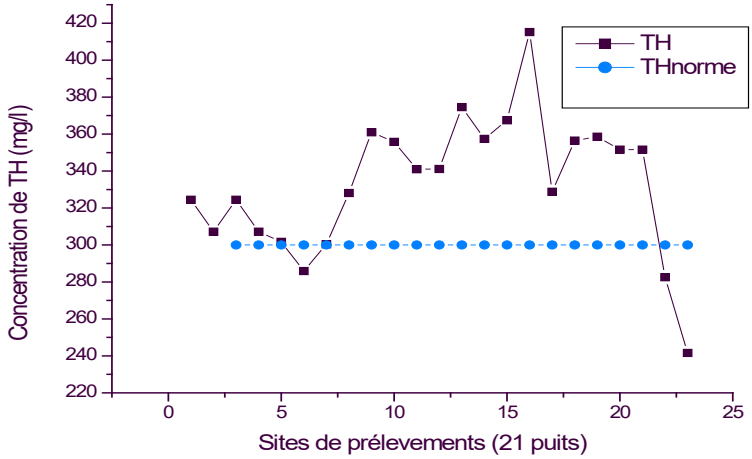

Figure 8. Spatial evolution of total durability in the studied groundwater.

8. Status of Water Quality for Agricultural Usage

8.1 The Risk of Nitrates (NO3-) Pollution

Those which are obtained by Laafou[10] in the spring waters of El HAJEB region and also those reported by El Kharmouz[11] in the groundwater of the city of Oujda (Morocco) and by Chofqui[12] in the groundwater of EL JADIDA (Morocco) are similar to the abnormal nitrate contents which are obtained in these waters. The presence of nitrates is an evidence of recent contamination which results from the sewage infiltration and the early oxygen deficiency[13,14], as well as the excessive nitrogen fertilization of agricultural areas of adjacent sites. The majority of the studied groundwater is of poor quality for agricultural use consequently (Table 2).

9. Hydro Chemical Fancies of Groundwater in the Area of SIDI TAIBI

The chemical quality of water directly affects the yield of agricultural land and the preservation of soils. Therefore, a chemical study of water for irrigation is essential to highlight the danger that certain chemical elements may present to the plant and to the soil which are used for agricultural purposes. We used the Piper and Stable diagrams for the determination of chemical facies[15,16] in order to evaluate the groundwater quality of SIDI TAIBI aquifer for agricultural use and to understand the risk of soil Stalinization.

10. Classification of Groundwater Studied by Piper

The representation of the water drops on Piper's triangular diagram throughout the observation period shows the

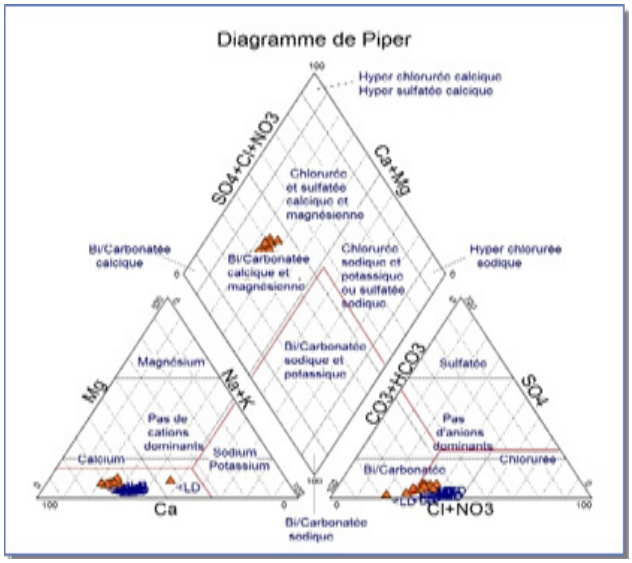

Figure 9. Evolution of the chemical facies of the studied waters (Piper Diagram).

Table 2. Distribution of nitrate classes in irrigation waters of SIDI TAIBI according to DIAEA/DRHA/SEEN standards

Class	Nitrate Concentration (PPM)	Class of sites in percentage (%)
Excellent	$[NO_3^-]<5$	0,01
Good	$5< [NO_3^-] <25$	4,76
Average	$25< [NO_3^-] <50$	33,33
Bad	$[NO_3^-]>50$	61,90

tendency towards the calcium pole in the sub-triangle of the cations while the anions show bicarbonate dominance for some drops. The other drops show the trend towards chloride enrichment while the global diagram shows a single chemical fancies: calcium and magnesium bicarbonate (Figure 9).

10.1 Classification of Waters According to Stabler

This classification makes allows for the different chemical fancies of the waters where we have converted the weights of each element into (meq/L), and then the latter are reduced in percentage (%) of the total number of meq/L. The anions followed by the cations are classified in order of magnitude.

The obtained results show that there are two dominant chemical fancies which are chloride-calcium representing

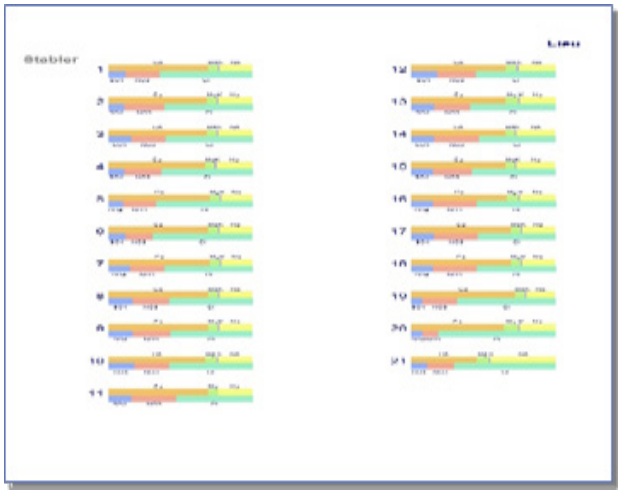

Figure 10. Stabler Diagram.

95.24% of the water points studied and chloride-calcium and sodium which does not exceed 4.76% of these points. This confirms the influence of litho logy on the chemistry of water (Figure 10).

10.2 Water Classification by the Wilcox Method

Plants do not tolerate soil saturated with sodium in general. The Wilcox classification based on electrical

Conductivity and sodium content in water is expressed in the percentage figured in formula:

$$\% \text{ Na} = \frac{[Na^+]+ [K^+]}{[Ca^{2+}] + [Mg^{2+}] + [Na^+] + [K^+]} \text{ x } 100$$

The physicochemical analyzes of the waters of the SIDI TAIBI aquifer (Table 1) allowed us to acquire a number of parameters usually used for estimating the quality of irrigation water: salinity (translated by conductivity (Sodium per cent), sodium Na^+ (percentage of sodium relative to the sum of basic cations, concentrations expressed in meq/L) and Sodium Adsorption Ratio (SAR), also known as alkalizing power. Their parameters are reported in Table 3. The Na^+ ions can replace the Ca^{2+} ions in the absorbent complex (base exchange) when they are very abundant in the dissolved state in the soil and the combination of electrical conductivity and Sodium Ratio Adsorption (SAR) allows for discerning this risk: the higher is risk, the higher the conductivity and the SAR are (Table 3). The representation of the different samples on this diagram allows water characterization for their irrigation capability (Figure 11).

This approach has shown that the groundwater of the SIDI TAIBI aquifer belongs to both classes (Figure 11a) according to the Wilcox classification:

Class C2S1: It contains good quality waters which are weakly mineralized and have a low alkalizing power (SAR). Therefore, they are acceptable quality for watering.

Class C3S1: Refers to waters of acceptable quality which are more mineralized than those of the previous class. They are characterized by a low risk of alkalinization and medium Stalinization.

These waters are generally suitable for salt-tolerant crop irrigation on well-drained soils, and the evolution of salinity must be controlled.

In The Wilcox classification (Figure 11, b), the studied water drops give very close results to the two following classes:

The "excellent" class is more dominant, with 95.24% of the analyzed water drops in this class, While,

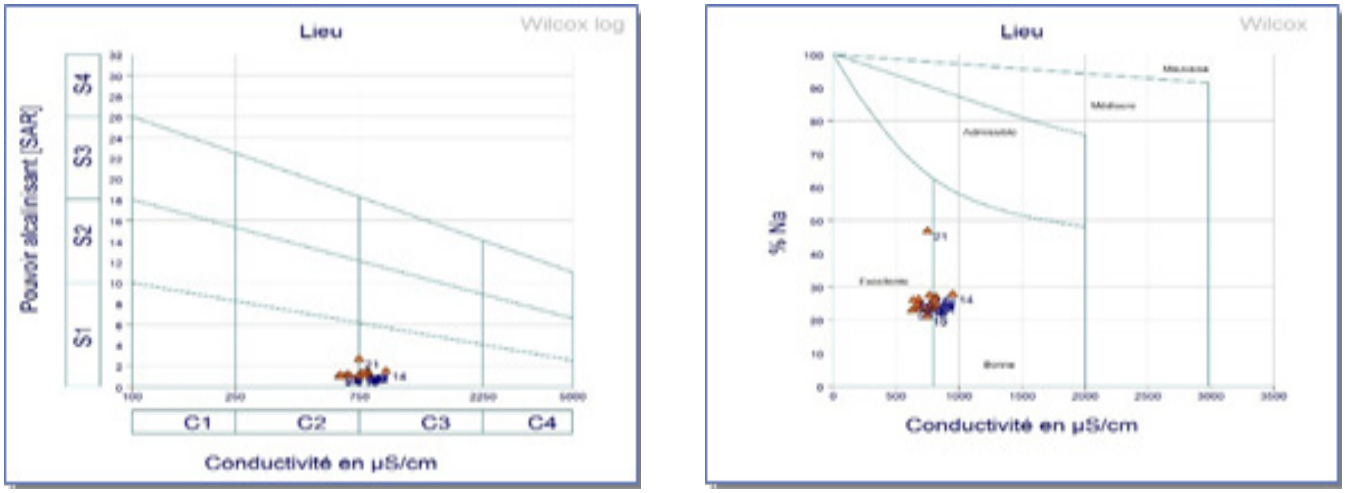

Figure 11. Diagram of classification of the studied irrigation water (WILCOX method).

Table 3. Statistics of some variables of groundwater in the area of SIDI TAIBI (2016)

Variables	Minimum	Maximum	Average
Electrical conductivity(µS/cm)	627	24,40	753,70
SAR (méq/L)	0,97	2,00	0,72
% Na^+	24,40	51,51	30,45

The "good" class only has 4.76% of these drops.

Indeed, the electrical conductivity and the sodium content have no impact on the quality of these groundwaters and these waters can consequently be used in agriculture without any precaution.

10.3 Water Classification by the Richards Method

The study area is characterized by a warm Mediterranean climate with dry summer, where Stalinization and alkalization of water are the main risks that can incur water intended for irrigation.

The results of the physicochemical analyzes were projected on the Riversides diagram[17,18] (U.S. salinity laboratory staff, 1954 In Hem, 1985) in order to evaluate these two risks. On this graphic representation, the risk of salinity is estimated by the conductivity which is expressed in µS/cm while the risk of soil alkalization is quantified by S.A.R (sodium Adsorption Ratio). This coefficient is given by formula:

$$SAR = [Ca2+] / [\sqrt{([Ca2+] + [Mg2+]) / 2]}$$

Two classes are highlighted after deferring all the water points on the Richards diagram (Figure 12):

The first class is predominant and it is characterized by water of good quality, having a low alkalizing power

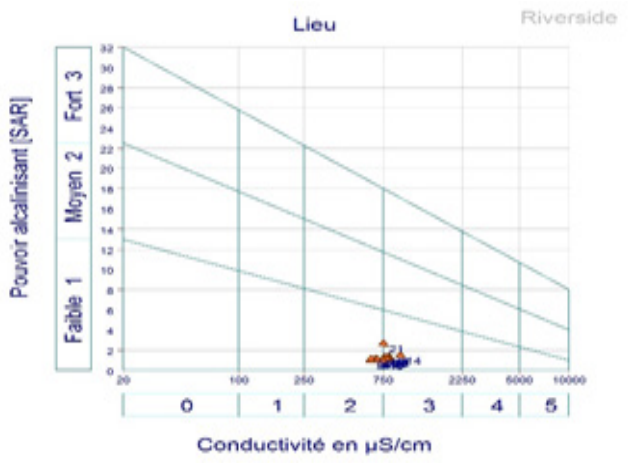

Figure 12. Suitability of the groundwater studied for irrigation (Richards method).

(SAR) and a relatively low mineralization. This can be used without special control for the irrigation of plants with medium tolerance to salts.

Other class means mediocre and moderately mineralized waters with medium salinity and low alkalization risk. That is used only for irrigation of salt-tolerant crops.

11. Conclusion

The results of the physicochemical analysis of groundwater in rural areas in the SIDI TAIBI region which is obtained during the observation period in 2016 may be considered admissible and it presents no danger for consumption. However, non-compliance values were obtained for the nitrate, ammonium and total hardness hydrochemical analysis, which is likely to be a threat to the people the World Health Organization obtains all or most of their needs from the water from these underground aquifers. This requires a reduction in the use of chemicals in agriculture and requires treatment with regard to hardness.

The SAR in this region is less than 5 meq/L); while, the water can not cause a risk of soil alkalization[4,5] and could therefore be used in irrigation. We advocate, in the light of these results and those described above, a continuous monitoring of the parameters studied for the wells with abnormal values and a campaign to sensitize the population on basic means and techniques for the treatment of water intended for human consumption, until the competent authorities link villages in the SIDI TAIBI region for the drinking water system and the sewerage network.

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