Assessment of water quality: a case study of the Bouchegouf aquifer north east of Algeria

Nouar Tahar[1], Toumi Abdelouaheb [2]

[1]Civil Engineering Civil and Hydraulic Laboratory, PO Box 401, University 8 May 1945, Guelma, 24000, Algeria
Nouar.tahar@univ-guelma.dz

[2] Civil Engineering Civil and Hydraulic Laboratory, PO Box 401, University 8 May 1945, Guelma, 24000, Algeria
toumiouaheb@yahoo.fr

Abstract: The hydrochemistry of groundwater from alluvial aquifer located at Bouchegouf, north–east of Algeria was evaluated for drinking water and irrigation. Six boreholes and two wells were sampled. The physical parameters (pH), Electric Conductivity (EC), Total Dissolved Solids (TDS), TH as well as the concentrations in major ions Ca2+, Mg2+, Na+, K+, Cl -, SO42-, HCO-3, PO3-4 and NO-3 analyzed by standard methods. Two chemical facies are predominant in the study area Na-Cl and Ca-Mg-Cl). Water-rock interaction characterized by the dissolution of carbonates and silicates plays a primordial role in the chemical composition of the groundwater. The hydrochemical study of the area showed that the majority of cations and anions, electric conductivity, the TDS and the TH which characterize the chemical composition of the aquifer are above the limits allowed for the drinking water according to standards. Wilcox and Richards diagrams reveal that, barring a few locations, most of the groundwater samples are unsafe for irrigation purposes.

Keywords: Hydrochemistry, Groundwater, quality, Bouchegouf, Algeria

---

1. Introduction

Water is an essential and vital component for our life. In this region, ground water plays an important role in the context of fluctuation and increasing demand of water. Bouchegouf Groundwater forms the major source of water supply for drinking and irrigation purposes in most parts of the study area. There has been high increase in demand for fresh water due to population growth and agricultural activities. Quality of groundwater is equally important to its quantity owing to .

the suitability of water for various purposes. In this community, groundwater seems to be the only source of fresh water to meet domestic and agricultural needs because surface water is much contemned [1], [2], [3]. The main objective of the present study is to Knowledge on hydrochemistry is more important to access the quality of ground water for understanding its suitability for various needs.

2. Material and Methods

2.1. Study area

Bouchegouf basin is situated in the extreme North East of Algeria with a surface of about 100 km^2. It belongs to the middle Seybouse basin, with a population of about 50,000 inhabitants. The basin is limited by the Houara Massif in the North, by the N'bails in the South, by the Beni Saleh Mountain in West, and the Nador Mountain in the South-east and South. The basin is crossed by Seybouse River and its tributary Mellah River. These rivers constitute an important superficial water resource (Figure 1) which they contribute in the irrigation because the area is known by its intense agricultural activities.

The climate is of the Mediterranean type: moderate and characterized by a one soft wet season and a hot and dry summer. The average temperature is 12°C in winter and 25°C in summer, though summer high temperature can reach 40°C. Annual precipitation in the area is 667mm, and the average humidity is 68% to 75%. Annual total evaporation rises to 957 mm (ETR=460mm), and monthly evaporation is higher than monthly pluviometry during October and March [6].

Geologically, the area constitutes a basin of collapse full of plio-quaternary detritus deposits (rollers, gravels, and sands with clays standing on substratum constituted of Pliocen marls. All over the Seybouse watershed, the plio-quaternary is made of alluvia deposits with interspersions of gypsiferous formations [4], [5].

Aquifer parameter data of the study area are relatively sparse. Based on pump test data, the aquifer properties of aquifer namely transmissivity is ranged from 3.52 to 0.30 10^{-3} m^2/s; and 2.59 10^{-2} m^2/s at the borehole BS2 and permeability ranges between 7.70 10^{-5} to 1.14 10^{-4} m/s. The general direction of groundwater flow is from south-west to north-east [1], [3]. The alluvial aquifer is mainly recharged by precipitation by sandstones in North, by limestone in south west and by sandstone and triasic formations (gypsum, dolomite) of the located in the south–east and by return flow of water irrigation. The discharges of this aquifer are boreholes and wells. The Bouchegouf aquifer is exploited by boreholes and wells. Water from this aquifer is used unevenly by different economic activity sectors. However, drinking and irrigation water supply remains the primary purposes.

Bouchegouf

Figure 1: Location of the study area in Algerian Northeast

2.2. Sampling and Analyses

The hydro-chemical analysis was based on 6 boreholes and 2 wells (Figure 1).Samples were collected from the aquifer during April 2016. They were collected in to new polyethylene bottles that had been rinsed two or three times with the water to be analyzed. The bottles were filled until overflowing and closed underwater to minimize aeration. All bottles were carefully labeled and numbered prior to transport and kept at low temperature 4°C. Physico-chemical parameters TDS, pH, and EC) were measured in field using a multi-parameter WTW.

Alkalinity was determined using volumetric titration with sulfuric acid (0.1N). The cations (Na^+ and K^+) were carried up by flame spectrophotometric absorption. Ca^{2+} and Mg^{2+} were determined by the titrimetry method using EDTA. A spectrophotometer UV–visible spectral photolab WTW with compatible kits is used to analyze anions Cl^-, $SO^{2-}{}_4$, nutrients ($NO^-{}_3$, and $PO^{3-}{}_4$). Analyses have been accomplished at the laboratory of the Algerian Water Agency. To study the water quality for irrigation, odium adsorption ratio (SAR), the percentage of sodium and residual sodium carbonate (RSC) were calculated. The results of hydrochemical analysis were compared to WHO guidelines [7], [8] standards for the suitability evaluation of the groundwater for drinking and irrigation purposes.

3. Results and Discussion

The samples were collected from boreholes and wells tapping the deep and shallow aquifer during the stage periods (April 2016). The minimum, maximum, mean, and standard deviation and analytic results for each parameter are summarized in Tables 1 and 2.

Table 1: Chemical composition (in mg/L) of groundwater from Bouchegouf aquifer

ID	TDS	pH	EC	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	$HCO^-{}_3$	Cl^-	$SO^{2-}{}_4$	PO3-$_4$	NO-$_3$
BS1	1789	8.1	2700	595.50	135	62	334	10	317	536	316	0.26	23
BS2	2232	8.2	3500	650	120	84	468	13	323	720	430	0.15	28
BS3	2202	8	3341	541.15	140	46	487	24	275	675	475	0.21	22
BS4	1800	7.6	2800	628	188	38	350	10	305	500	384	0.10	25
B1	2339	7.82	3409	625	180	42	456	4	260	675	675	0.26	32
B2	2308	7.92	3508	566.50	140	52	570	8	268	635	581	0.10	21
P1	982	7.52	1397	400.50	102	35	107	8	292	275	106	0.42	39
P2	1003	7.1	1540	455	112	42	112	10	275	289	100	0.36	42

TDS total dissolved solids (mg/l), EC electrical conductivity (µS/cm and pH unit pH

Table 2: Descriptive statistics of the physico-chemical data

Variable	Min	Max	Mean	SD
TDS	982	2,339	1,831.87	559.73
pH	7.52	8.20	7.84	0.25
EC	1,3970	3,508	2,774.37	863.18
TH	400.50	650	557.70	88.66
Ca	102	188	139,62	30.60
Mg	35.	84	50.12	16.11
Na	107	570	360.50	172.12
K	4	24	10.87	5.89
HCO3	260	323	289.37	23.53
Cl	275	720	538.12	174.31
SO4	100	675	383.37	205.79
PO4	0.10	0.42	0.23	0.11
NO3	21	42	29	7.96

3.1. Suitability for Drinking Water

3.1.1 Physical Parameters

The pH indicates the degree of acidity or alkalinity of water. In this study, pH did not cross the permissible limit of 6.5–9.5. The mineralization of water varied with electrical conductivity. The values of EC vary between 982 and 2,339 µs/cm with an average of 1,831.87 ± 559.73µs/cm. The high values are attributed to the intense anthropogenic activities in this part of the basin. 100% of samples have a value above the maximum permissible limit (1,400µS/cm). The total dissolved solids (TDS) values of the Bouchegouf groundwater waters were above the WHO high permissible limit 1,500 mg/l. Hardness of water limits its use for industrial purposes; it causes scaling of pots and boilers, closure to irrigation pipes and may cause health problems to humans, such as kidney failure. *As* a water quality parameter, TH values can be used to classify water for domestic, agriculture and industrial uses. Total hardness (TH) ranges from 400.50 to 650 mg/l with an average value of 557.70 ± 88.66 mg/l. According to WHO standards, the maximum allowable limit of TH for drinking is 600 mg/l and the most desirable limit is 300 mg/l. The classification of groundwater based on TH shows that a majority of the groundwater samples of the study area falls in the hard to very hard water category [8]. Hence, classification of the groundwater of the study area based on hardness [9], has been carried out and is presented in Table 3. Based on TH in the study area all samples fall under very hard class. According to WHO guidelines, waters of boreholes BS2, BS4 and B1 are unsuitable for drinking and domestic purposes.

Table 3: Classification based on hardness (Sawyer and McCarthy 1967)

Total hardness (CaCO3 (mg/l)	Classification	Samples
<75	Soft	-
75–150	Moderately high	-
150–300	Hard	-
>300	Very hard	100%

3.2.2. Chemical Parameters

The tendency of the cation in all Boreholes is in the order of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ with sodium as a dominant cation and the tendency of anions is in the order of $Cl^{-} > SO^{2-} > HCO^{-}_{3} > NO^{-}_{3,}$ with chloride as the dominant anion. In contrast to this, the predominant anion trend is in the order Cl-> HCO3- > $SO^{2-}{}_{4}$>$NO^{-}{}_{3}$ and in cation Ca> Na>Mg>K in the well P1 and P2 (Figure 2).

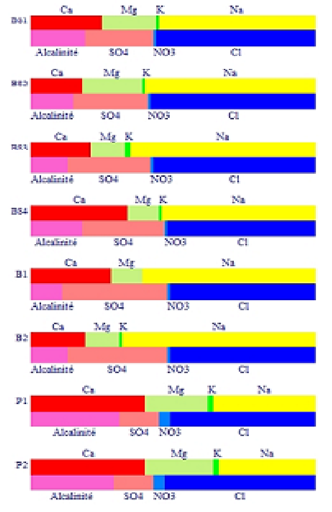

Figure 2: Stabler diagram illustrating major ionic dominance in the study area

The mean calcium concentration is about 139.62 ± 30.60 mg/l. It is apparent that BS4 showed higher calcium content compared to the other stations. The desirable for Ca^{2+} for drinking water is specified as 75 mg/l, However calcium in water did not exceed the permissible limit of 200 mg/l. The mean magnesium concentration is 50.12 ± 16.11 mg/l. It is evident that all samples water had a magnesium concentration within the permissible limit of 100 mg/l. The mean sodium concentration is 360 ± 172.12 mg/l. It is apparent that the water of the Bouchegouf aquifer showed generally sodium values over the permissible limit of 200 mg/l excepted for P1 and P2. The mean potassium concentration is 10 ± 5.89 mg/l; water indicates a low concentration of potassium compared to the permissible limit of 10 mg/l, excepted a few samples (BS2 and BS3) which have a concentration of 13 and 24 mg/l respectively.

The mean bicarbonate value is 289 ± 23.53 mg/l. Maximum permissible limit for $HCO^{2-}{}_{3}$ concentration is found to be 300 mg/l (10 WHO 2004), hence the groundwater from the study area is unsuitable for drinking purposes. The average chloride concentration in the Bouchegouf aquifer is 538.12 mg/ l. High chloride values are recorded in Boreholes compared to the wells (P1and P2) where chloride values are below the permissible limit of 250 mg/l and Bouchegouf groundwater are brackish for drinking purposes.

Sulfate contents vary between 100 and 675 mg/l with an average concentration of 383.37 ± 205.79 mg/l and 75 of samples are above the maximum permissible limit of 250 mg/l [8]. The mean nitrate concentration is 29 ± 7.94 mg/l. The groundwater showed nitrate values bellow the permissible limit of 50 mg/l for all samples. The concentration of nitrates in groundwater is the result of intensive agricultural activity or a contamination by irrigation water or animal wastes [10]. The mean concentration of orthophosphate in the study area is 0.23 ± 0.11 mg/l. It not exceeds the permissible limit of 0.3 mg/l, except for P1 and P2 where concentration of $PO^{3-}{}_{4}$ exceeded this limit (56 and 62 mg/l) respectively.

The major part of study area is overlain by a Plio-Quaternary cover of sand, gravel, and alluvium. The Triassic formation intruded the sedimentary cover as diapir and consists of evaporitic formations composed of gypsum-bearing marl, dolomite and salt, which explains the prevalence of sodium and chloride facies in the majority of samples. The Numidian formation of Oligocene age, composed mainly of thick and massive sandstone bedded on clay formation, may be explain the origin of chloride and calcium dominant in the Well P1 and P2.

3.3.3. Hydrochemical Facies

Hydrochemical facies of groundwater can be evaluated by plotting the major cations and anions on Piper's trilinear diagram [11. In Bouchegouf, two main groundwater types have been identified (Figure 3). Water was rich in chloride and sodium, producing a chlorinated sodium type representing the boreholes and water was rich in calcium, magnesium and chloride type representing the wells. The origins of chemical types of analyzed sampling are as follows:

i)- The sodium chlorinated type produced by the existence of evaporitic formations and by evaporation effect.

ii) -The calcium magnesium chlorinated type produced by the existence of sandstone, sand and gravels.

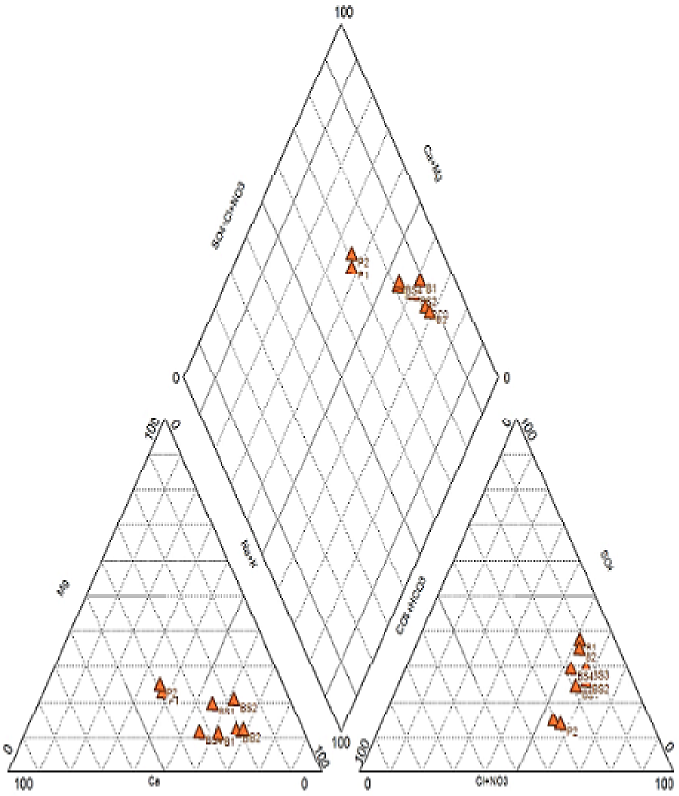

Figure 3: Piper diagram

3.3.4 .Suitability for Irrigation Purpose

The suitability of groundwater for agricultural purposes depends on the effect of mineral constituents of water on both plants and soil. Effects of salts on soils causing changes in soil structure, permeability and aeration indirectly affect plant growth. Richards [12] and Wilcox [13] proposed irrigational specifications for evaluating the suitability of water for irrigation use.
There is a significant relationship between sodium adsorption ratio (SAR) value for irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium, which can destroy the soil structure owing to dispersion of clay particles. SAR was computed using the equation given below:

$$SAR = Na^{+} + /\sqrt{Ca^{2+} + Mg^{2+}/2} \qquad (1)$$

Where all the concentrations are expressed in meq/l.

The SAR value varies from 17.0 to 12.56 with an average of 6.91(Table 4). In SAR classification Richards [12], 100 % of samples grouped in excellent category (SAR<10) and were suitable for irrigation purposes.
The values of electrical conductivity and SAR values, plotted on Richards diagram (Figure 4). Samples were clustered in three fields (C3-S1, C4-S2 and C4-S3). The class (C3-S1) indicating medium to high salinity hazard and low sodium hazard. These groundwaters can be used safely for irrigation on clay soil; however, selection of crops depending on salt tolerance should be carried out prior to cultivation. The classes C4-S2 and C4-S3 indicating very high salinity and medium sodium hazard and, high salinity and high alkalinity, Irrigation using groundwater from these samples should be assessed in terms of selection of salt-tolerant crops and good drainage especially on clay soils.

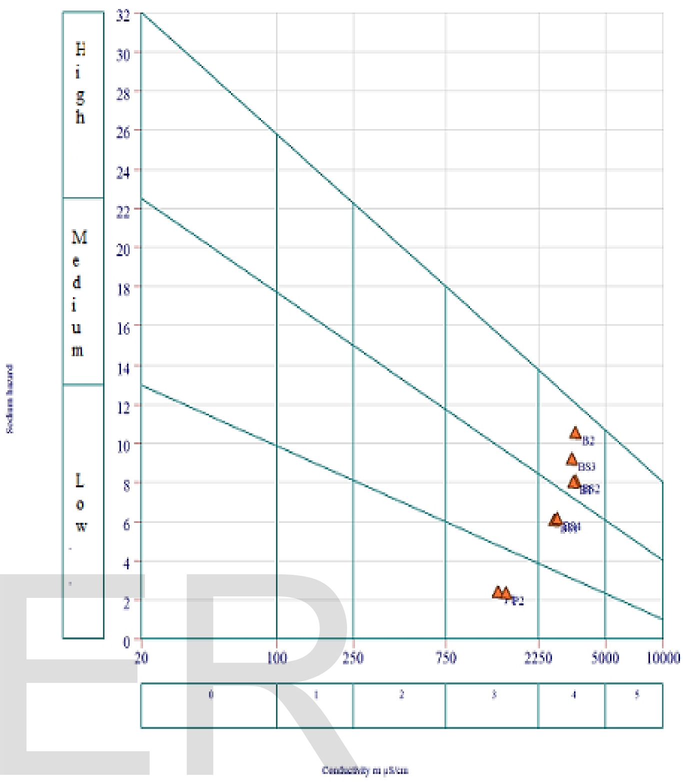

Figure 4: Richards diagram

Sodium percentage (Na %) was calculated by the following equation :

$$Na^{+}\,(\%) = 100.\,[(Na^{+}\,/\,(Na^{+} + Ca^{2+} + Mg^{2+})] \qquad (2)$$

Where all the concentrations are expressed in meq/l.
Sodium percentage (Na %) values ranged between 38.43 to 67. 22% with an average of 56.08% (table 4). In Wilcox [13] classification for Na percent, all the samples fall in unsafe range (Na% >26%).

The Wilcox diagram (Figure 5), relating sodium percentage and electrical conductivity, shows that the groundwater samples (257%) fall in the category of good, 25% fall in doubt category and 50 % of samples lie in the to unsuitable category, suggesting the contribution of anthropogenic sources to these ground waters.

Table 4: Results of the calculations of Na^+, SAR, Mg and RSC

ID	Na^+ %	SAR	Mg^{2+} %	RSC
BS1	55.65	6.12	43.32	-0.28
BS2	61.66	8.23	53.86	-2.25
BS3	67.22	9,57	35.36	-1.38
BS4	55.47	6.26	25.16	-2.41
B1	64.51	8.40	28.00	-3,85
B2	68.92	12.56	38.21	-2.68
P1	38.43	2.50	36.32	0.20
P2	36.80	1.70	38.46	1.14
Mean	56.08	6.91	37.33	-1.38

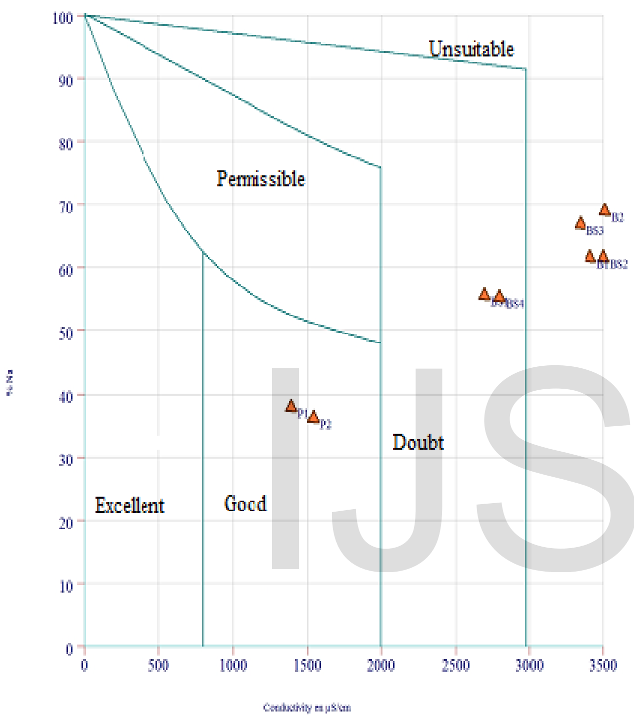

Figure 5. Wilcox Diagram

Magnesium Hazard

Magnesium hazard was calculated by following equation, developed by Paliwal [14]:

$$Mg^{2+} \text{ ratio} = 100.\,(Mg^{2+} + /\sqrt{Ca^{2+} + Mg{+}^{2+}/2})\,) \quad (3)$$

The concentration of $Ca^{2+}$and Mg^{2+} are in meq/l.
The magnesium hazard values range from 28.00 to 53.86% with a mean of 37.33%. 88 % of the samples falls below the permissible limit of 50 % indicating the favorable effect on crop yield and decrease in soil alkalinity and 2% falls above 50 % (Table 4). In the Bouchegouf area most of the samples are suitable for agricultural uses regarding magnesium hazard. The evaluation illustrates that one samples can cause adverse effect on the agricultural yield (BS2).

Residual Sodium Carbonate (RSC)

The high concentration of bicarbonate ions in water provokes the precipitation of calcium and magnesium as carbonates and then the proportion of sodium in the soil increases. The RSC is calculated using the following equation:

$$RSC= (HCO\text{-}3 \text{ x } \ 0,0333)\,(Ca^{2+} + Mg^{2+}) \quad (4)$$

The concentration of $Ca^{2+}$and Mg^{2+} are in milliequivalent/l and alkalinity values in mg/l.
Irrigation water having RSC values greater than 5 meq/l have been considered harmful to the growth of plants, while waters with RSC values above 2.5 meq/l are unsuitable for irrigation. An RSC value between 1.25 and 2.5 meq/l is considered as the marginal quality and value < 1.25 meq/l as the safe limit for irrigation (Richards 1954). The calculated RSC values in the groundwater samples of Bouchegouf aquifer are found to vary from -3,85 to 1.14 meq/l with an average of -1.38 meq/l (Table 4). Regarding to the RSC values all samples are suitable for agricultural purposes.

4. Conclusion

The present study dealt with the quality of the water of the Bouchegouf aquifer. According to the criteria of appreciation of groundwater quality (WHO), this aquifer can be classified as being extremely polluted. This pollution is due to excessive values of the physical and chemical elements in water were mainly related to the geological nature, to the precipitation salt by evaporation and anthropogenic activities. Wilcox and Richards diagrams reveal that, barring a few locations, most of the groundwater samples are unsuitable for irrigation purposes.

Acknowledgements: We would like to thank the reviews.

REFFERENCES

[1] L. Djabri, "Pollution mechanism and vulnerability of waters of Seybouse River: geological, industrial, agricultural and urban Origins," PhD Thesis, University Badji Mokhtar, Annaba, 176p, 1993.

[2] D. Fadel et al, " Aptitude des eaux de la vallée de la Seybouse à l'irrigation (Nord-Est algérien)," *Revue*

secheresse, 15: 350- 360, 2004.

[3] W.Chaoui, et al, “Study to the vulnerability of ground surface water in the Bouchegouf region (North-eastern Algeria,” *Journal of Nature & Technology, 08: 33-40, 2013.*

[4] J.M. Vila, “La chaîne alpine d’Algérie orientale et des confins Algéro-Tunisiens,” PhD of Science, University Pierre et Marie Curie, Paris VI, 1980.

[5] A. Chouabbi, “Geological study of the Hammam N'bails area (SE Guelma, Constantine region, Algeria,” PhD Thesis, University Paul Sabatier in Toulouse, 123p, 1987.

[6] L.Seing, “Hydrogeology and hydrochemistry of the middle basin of Seybouse in north -east of Algeria,” Master Degree, University 8 ma 1945, Guelma, Algeria, 102 P, 2016.

[7] WHO, “Guidelines for drinking-water quality,” World Health Organization, Geneva, Switzerland. Vol. 1, 3rd ed., Recommendations, 2004.

[8] WHO, “Guidelines for drinking water quality,” World Health Organization Geneva, 4th ed., Recommendations, 1-4, 2011.

[[9]] G.N. Sawyer, D.L. McCarthy, “Chemistry of sanitary engineers,” 2nd edn. McGraw Hill, New York, 1967.

[10] M. Guettaf, et al, “Assessment of water quality: a case study of the Seybouse River (North East of Algeria,” *Appied Water Sci. DOI 10.1007/s13201-014-0245-z Sci, 2014..*

[11] A.M. Piper, “A graphical procedure in the chemical interpretation of groundwater analysis,” *Trans. Amer. Geophy. Union, 25, 914-928, 1944*.

[12] L.A. Richards, Diagnosis and improvement of saline and alkaline soils,” U.S. department of Agriculture Hand Book, 1954.

[13] L.V.Wilcox, “Classification and use of irrigation waters,” US Dept. Argic. Circ, Washington, DC, p 969, 1953.

[14] K.V. Paliwal, “Irrigation with saline water,” *Monogram No. 2 (New series), IARI, New Delhi, p 198, 1972.*