

Full Length Research Paper

Characterization of groundwater quality in Oran Sebkhah basin

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Growing populations and increasing industrialization causes increase in living standard, which result in decrease in the quality of water and may put stresses on natural waters by impairing both the quality of the water and the hydrological budget. This research aimed at determining the origin of the chemical elements of groundwater from the Oran Sebkhah basin. It applied the inverse geochemical modeling to derive the sources of variation in the hydrochemistry. Fifty five (55) water samples were selected from different point in Oran Sebkhah basin for sampling purpose in July 2011. Physico-chemical parameters such as pH and electric conductivity were measured *in situ*. Moreover, chloride, sulfate, alkalinity, calcium, magnesium, sodium, potassium, were measured in the laboratory. Inverse geochemical models of the statistical groups were developed using PHREEQC to elucidate the chemical reactions controlling water chemistry. The inverse geochemical modeling demonstrated that relatively few phases are required to derive water chemistry in the area. In a broad sense, the reactions responsible for the hydrochemical evolution in the area fall into three categories: (1) dissolution of evaporite minerals; (2) precipitation of carbonate minerals; and (3) weathering reactions of silicate minerals. The high values of the physico-chemical parameters of water obtained in the present study sites indicate a variation in the physico-chemical parameters and demonstrated that relatively few phases are required to derive water chemistry in the area. Range of values were found as pH (5.1-7.6), conductivity (720-15820 $\mu\text{S cm}^{-1}$), chloride (994-7810 mg l^{-1}), sulfate (6.1-112.4 mg l^{-1}), alkalinity (421-19962 mg l^{-1}), calcium (80-680 mg l^{-1}), magnesium (212.4-4525 mg l^{-1}), sodium (124.2-4687.4 mg l^{-1}) and potassium (0.9-42.5 mg l^{-1}).

Key words: Physico-chemical parameters, water, Sebkhah.

INTRODUCTION

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life (Oluduro and Aderiyi, 2007). Natural water contains some types of impurities whose nature and amount vary with source of water (Drever, 1988).

Water quality characteristic of aquatic environment arise from a multitude of physical, chemical and biological interactions (Deuzane, 1979). The water bodies, rivers, lakes, dams and estuaries are continuously subject to dyna-

mic change with respect to the geological age, geochemical characteristics and anthropogenic influences.

This is demonstrated by continuous circulation, transformation and accumulation of energy and matter through the medium of living things and their activities. The dynamic balance in the aquatic ecosystem is upset by human activities, resulting in pollution which is manifested dramatically as fish kill, offensive taste, odor, color and unchecked aquatic weeds. The objective of the monitoring

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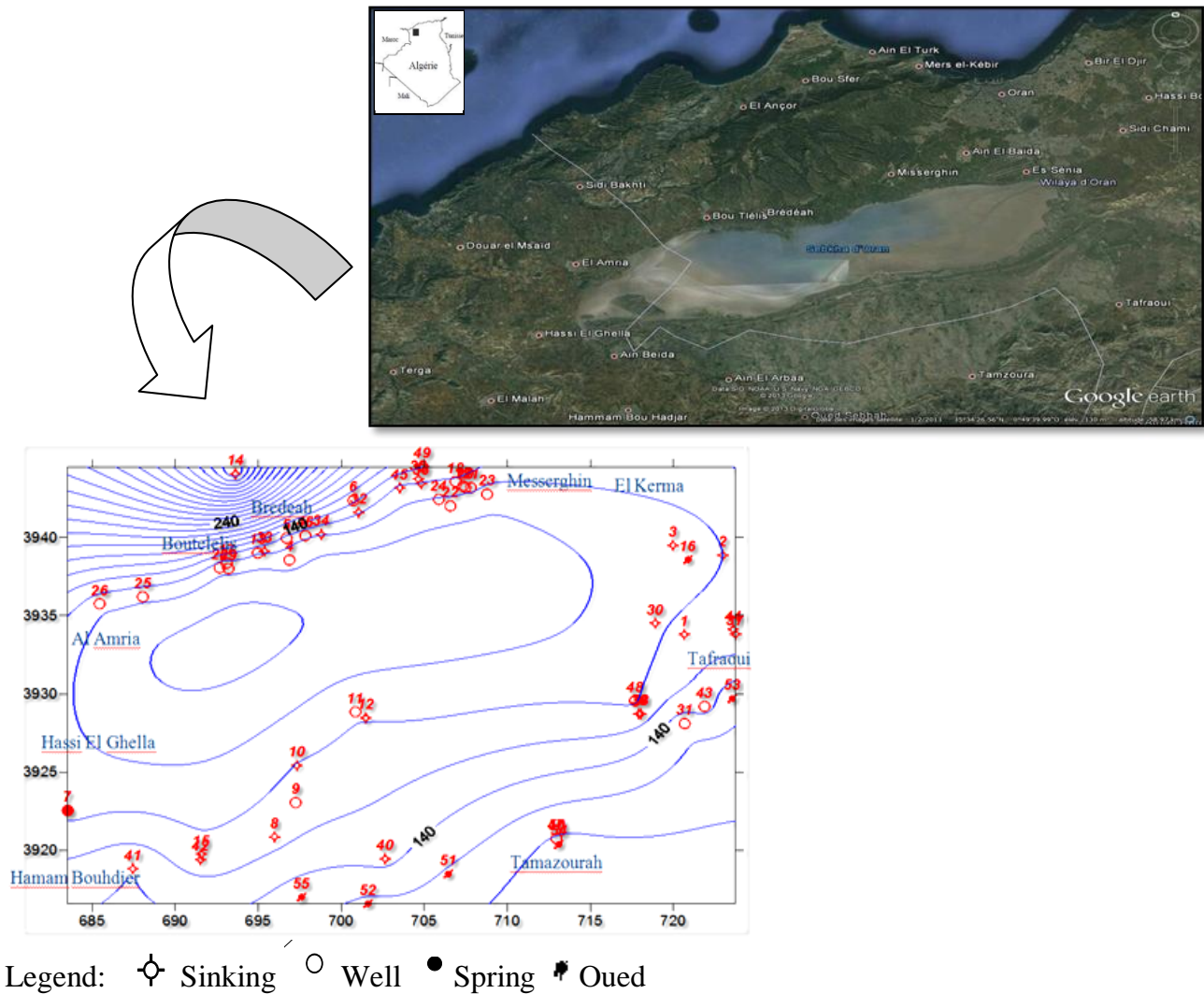


Figure 1. Localization of sampling points in the study area.

studies undertaken for water body is to assess variation in water quality.

The soundness or validity of the results in the inverse modeling depends on a valid conceptualization of the groundwater system, validity of the basic hydrochemical concepts and principles, accuracy of input data into the model, and level of understanding of the geochemical processes in the area (Güler and Thyne, 2004).

Variation in groundwater chemistry is mainly a function of the interaction between the groundwater and the mineral composition of the aquifer materials through which it moves. Hydrochemical processes, including dissolution, precipitation, ion exchange, sorption and desorption, together with the residence time occurring along the flow path, control the variation in chemical composition of groundwater (Apodaca et al., 2002). The zone of study covers: the great Oran Sebkhha basin (with an area of 1878 km²); the Sebkhha itself (with an area of 298 km²)

and the stretches (over 40 km long and 6 to 13 km wide). The zone is located in the Central Coastal Oran basin and is bounded by: the Djebel Murdjadjo (530 m) in the north, the Mount Tessala (1061 m) in the south, the plain oued Tlelat in the east, and oued Mellah in the west (Figure 1).

The integrated geological study (sedimentology, geomorphology, tectonic, hydrogeology) determined factors which conditioned its setting up, since the lower-middle Miocene (Burdigalian-Langhian-Serravallian); that emerged in the beginning of the Tortonian age, then it met, and until the Pleistocene under a marine regime that evolved toward a continental regime since the superior Pleistocene. The southward swing of the northern area (Murdjadjo south side) at the Soltanian age would have been the main reason of the Sebkhha of Oran endoreism and its subsequently closing (full) with the setting up of the wind accumulations.

Table 1. The physico-chemical parameters of water samples from Oran Sebkhah basin.

Parameter	Average	Minimum	Maximum	Standard deviation	Median
pH	6.9	5.1	7.6	0.4	6.9
EC ($\mu\text{S m}^{-1}$)	5905.3	720	15820	3303.7	5710
Cl ⁻ (mg L^{-1})	2472.7	994	7810	1180.8	2307.5
SO ₄ ⁻² (mg L^{-1})	26.1	6.1	112.4	20.3	22
HCO ₃ ⁻ (mg L^{-1})	4764	421	19962	4128	3288
Na ⁺ (mg L^{-1})	863.7	124.2	4687.4	717.7	733.7
K ⁺ (mg L^{-1})	8.6	0.9	42.5	8.4	6.2
Ca ²⁺ (mg L^{-1})	304.4	80	680	131.9	280
Mg ²⁺ (mg L^{-1})	1258.8	212.4	4525	920.2	956.4

MATERIALS AND METHODS

In order to characterize the groundwater quality in the dry season, a sampling network was chosen to allow the acquisition of representative data on the spatial and temporal variability (Figure 1). This network covers the entire basin upstream to downstream and consists of a set of points of water wells, boreholes and springs.

Water withdrawals were made at low waters. The samples were collected during the period of 04 to 20 July 2011 where comprehensive analyses were performed. The parameters that were measured are: pH and electrical conductivity (EC) measured in the field using a multi-parameter HANNA (pH meter HANNA instrument HI 9811).

Subsequently, the samples were analyzed in the laboratory for their chemical constituents such as calcium, magnesium, sodium, potassium, chloride, bicarbonate and sulfate. This was achieved using standard methods as suggested by Rodier (1996). Ca²⁺, Mg²⁺, HCO₃⁻ and Cl⁻ were analyzed by volumetric titrations. Concentrations of Ca²⁺ and Mg²⁺ were estimated titrimetrically using 0.05 N EDTA and those of HCO₃⁻ and Cl⁻ by H₂SO₄ and AgNO₃ titration, respectively. Concentrations of Na⁺ and K⁺ were measured using an Ionogram (Model: Ionogram Easy lyte Na/K/Cl, 800 ml, MEDICA 001384-001 R2 Analyser, 12160/12014-05) and that of sulfate by Spectrometer method (Model: Spectrometer UV Optizen 2120 UV). The results were tabled for interpretation.

In literature, many different methodologies have been applied to study, evaluate and characterize the sources of variation in groundwater geochemistry. Among these methods is the inverse geochemical modeling in PHREEQC (Parkhurst and Appelo, 1999) based on a geochemical mole-balance model, which calculates the phase mole transfers (the moles of minerals and gases that must enter or leave a solution).

RESULTS AND DISCUSSION

The physico-chemical parameters obtained from analysis of water samples from Oran sebkha basin are presented in Table 1. The groundwater samples of the study area have pH values ranging from 5.1 to 7.6, which indicate that the groundwater is slightly alkaline. The electrical conductivity (EC) values ranged from 720 to 15820 $\mu\text{S cm}^{-1}$ which is the characteristic of mixed water (Ca-Mg-Cl-HCO₃). The gradual increase of conductivity denotes a significantly lateral input of wastewater with higher conductivity (Trinh, 2003). The order of abundance of the

major cations is $\text{Mg} \geq \text{Na} \geq \text{Ca} \geq \text{K}$ and all samples exceeded the desirable limit of Ca, Mg and Cl for drinking water, respectively :75, 50 and 200 mg l^{-1} , but the sulfate concentrations are all below health guidelines (WHO, 1993) (Table 1).

In all water samples, a critical look at the results revealed that the values of these physico-chemical parameters are higher in the basin based on geological position; discharges of industrial wastewater and contamination of the groundwater by seawater were excluded as the source of high concentrations. The quantity of waste in different phases of a natural aquatic system is reflected by the level of hardness, alkalinity, and other physico-chemical parameters. Since the higher values of all these physico-chemical parameters than those obtained could be as a result of washing away of sulfate based fertilizers into the river (Ipinmoroti and Oshodi, 1993; Vogel, 1970).

Inferring the sources of solutes in groundwater using simple massbalance approaches does not provide unequivocal results, a reasonable way of constraining the processes that might influence the major-ion chemistry. The controls on the hydro chemical evolution of groundwater largely depend on the chemistry of the recharging water, water aquifer matrix interaction (cation exchange), or both, as well as groundwater residence time within the aquifer (Garrels and MacKenzie, 1971).

Three general processes that contribute to the generation of solutes in groundwater are: evaporate dissolution, carbonate dissolution and silicate weathering (Garrels and MacKenzie, 1971). The chemistry of the evolving water depends not only on the bulk chemistry of the matrix, but also on the rate of weathering. Meybeck (1987) reported that weathering rates of evaporates and carbonates are up to 80 and ~12 times, respectively, faster than silicate weathering rates. Hence, even relatively minor proportions of carbonates and evaporates can significantly influence water chemistry.

The study of the Ca²⁺/Mg²⁺ (mg L^{-1}) ratio of groundwater from the area of study suggests the dissolution dolomite present in the alluvium (Figure 2). That is, if the ratio $\text{Ca}^{2+}/\text{Mg}^{2+} = 1$, dissolution of dolomite should occur, whereas a higher ratio is indicative of greater calcite con-

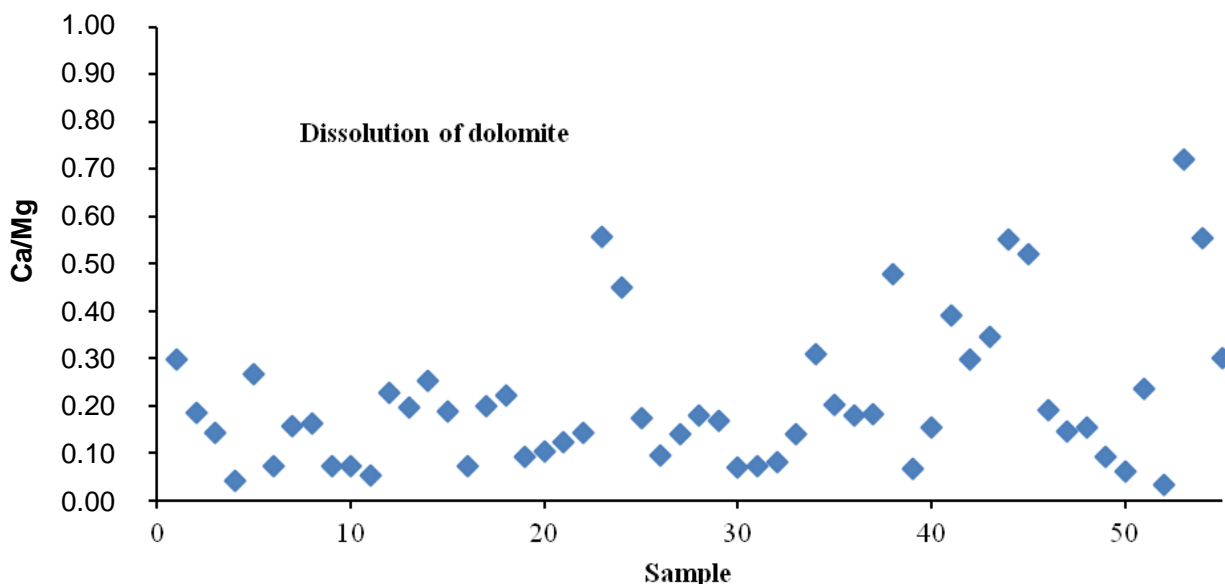
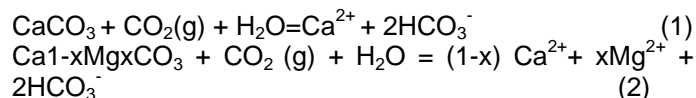


Figure 2. Sample number versus $\text{Ca}^{2+}/\text{Mg}^{2+}$.

Table 2. Saturation indices of the water samples from Oran Sebkhah basin calculated by PHREEQC.

Phase	Stoichiometry	Average
Anhydrite	CaSO_4	-2.19
Aragonite	CaCO_3	0.84
Calcite	CaCO_3	0.98
Dolomite	$\text{CaMg}(\text{CO}_3)_2$	2.87
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	-1.98

tribution (Maya and Loucks, 1995). The points are located below the line ($\text{Ca}^{2+}/\text{Mg}^{2+} = 1$) indicating the dissolution of dolomite. The samples have a ratio between 0.03 and 0.72 indicating the dissolution of dolomite. Dissolved carbonates (calcite and dolomite) occur predominantly in the form of HCO_3^- , due to the pH range. The solubility of calcite and dolomite is largely controlled by CO_2 fugacity and pH, according to the reactions:



The plot of $\text{Ca}^{2+} + \text{Mg}^{2+}$ versus $\text{SO}_4^{2-} + \text{HCO}_3^-$ will be above the 1:1 line if the dissolutions of calcite, dolomite, anhydrite and gypsum are the dominant reactions in a system (Maya and Loucks, 1995). Ion exchange tends to shift the points to left due to an excess of $\text{Ca}^{2+} + \text{Mg}^{2+}$ (Cerling et al., 1989; Fisher and Mulican, 1997; McLean and Jankowski, 2000). If reverse ion exchange is the

process, it will shift the points to the right due to a large excess of $\text{SO}_4^{2-} + \text{HCO}_3^-$ over $\text{Ca}^{2+} + \text{Mg}^{2+}$. The plot of $\text{Ca}^{2+} + \text{Mg}^{2+}$ versus $\text{SO}_4^{2-} + \text{HCO}_3^-$ (Figure 2) shows that the all samples are located in the right side due to an excess of $\text{SO}_4^{2-} + \text{HCO}_3^-$ (Belkhiri et al., 2010).

A Na ($\text{m}\text{e}\text{q L}^{-1}$)-normalized Ca^{2+} ($\text{m}\text{e}\text{q L}^{-1}$) versus HCO_3^- ($\text{m}\text{e}\text{q L}^{-1}$) and plot Mg^{2+} ($\text{m}\text{e}\text{q L}^{-1}$) (Figures 3, 4 and 5) (Gaillardet et al., 1999) shows that the three group samples range from being influenced by silicate weathering to carbonate dissolution. The relation between Na-normalized Ca^{2+} , HCO_3^- and Mg^{2+} shows that although most of the Mg may have been derived from carbonate dissolution, some have a silicate source (Belkhiri et al., 2010).

The saturation indices of some of the common mineral phases is presented in Table 2, which clearly shows that the groundwater is generally supersaturated with respect to most of the carbonate and silicate phases and is most probably responsible for the composition of the groundwater (Belkhiri et al., 2010). The results of saturation calculations show that all the points are under saturated with anhydrite and gypsum, halite mineral phases are minor or absent in the area, suggesting that their soluble components Na^+ , Cl^- , Ca^{2+} and SO_4^{2-} concentrations are not limited by mineral equilibrium. In contrast, aragonite, calcite and dolomite reach saturation as groundwater chemistry evolves along the groundwater flow paths. The groundwater in the studied area evolves from less saline Ca-g- HCO_3^- water to blended Mg-Ca- HCO_3^- -Cl water to brackish Mg-Ca-Cl- HCO_3^- water along the topographic flow path inverse geochemical modeling along groundwater flow paths indicating the dissolution of evaporite minerals, precipitation of carbonate minerals and weathering reactions of silicate minerals (Table 1 and Figure 6)

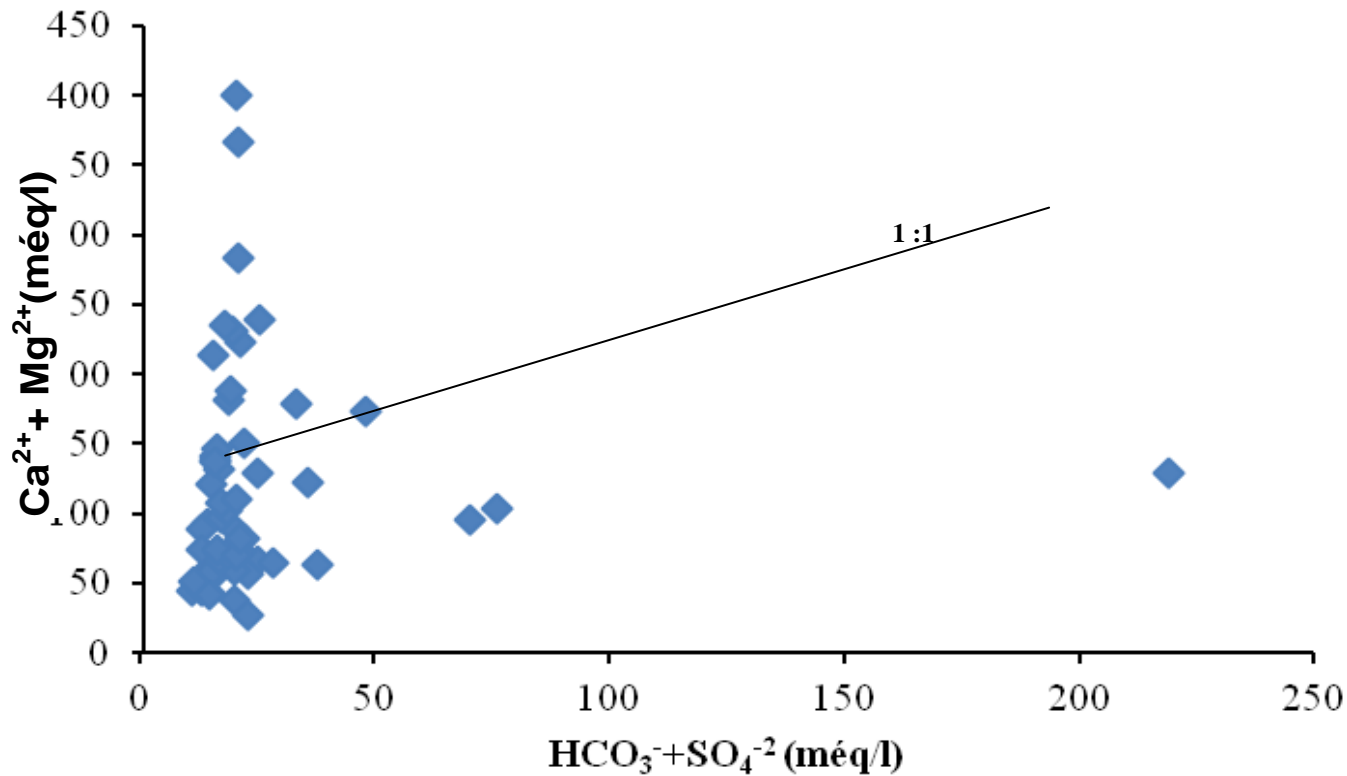


Figure 3. Ca²⁺ + Mg²⁺ versus SO₄⁻² + HCO₃⁻.

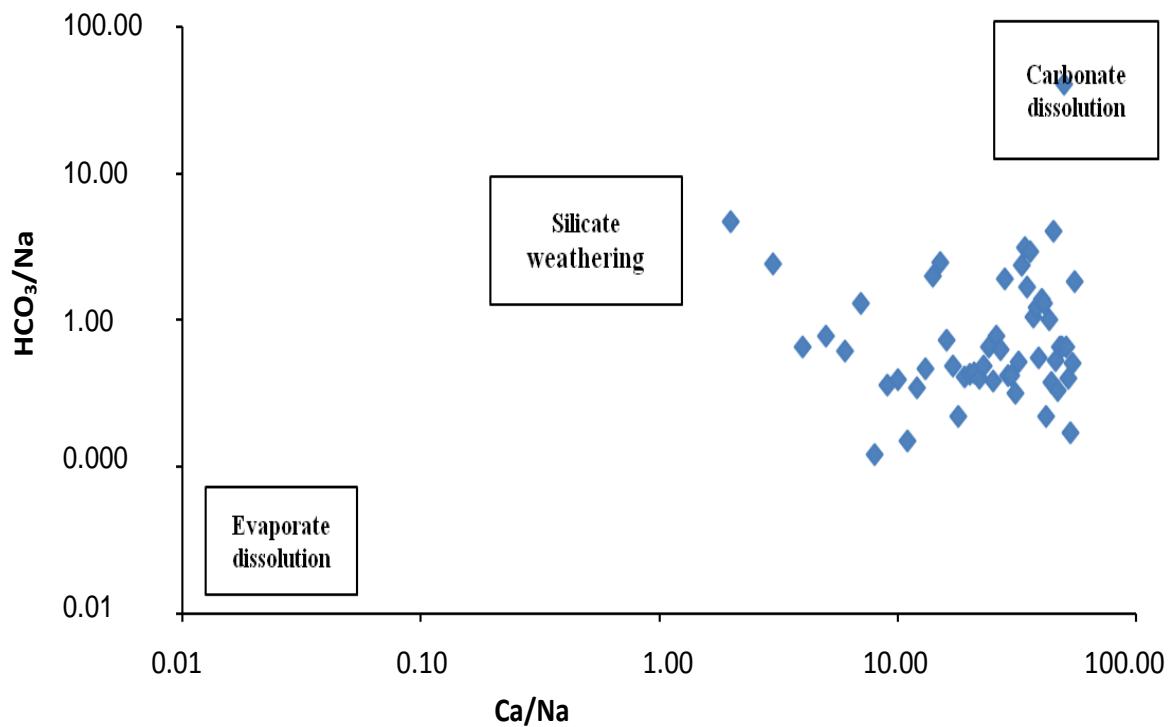


Figure 4. Na-normalized Ca²⁺ and HCO₃⁻ (HCO₃⁻/Na) (meq L⁻¹/ meq L⁻¹).

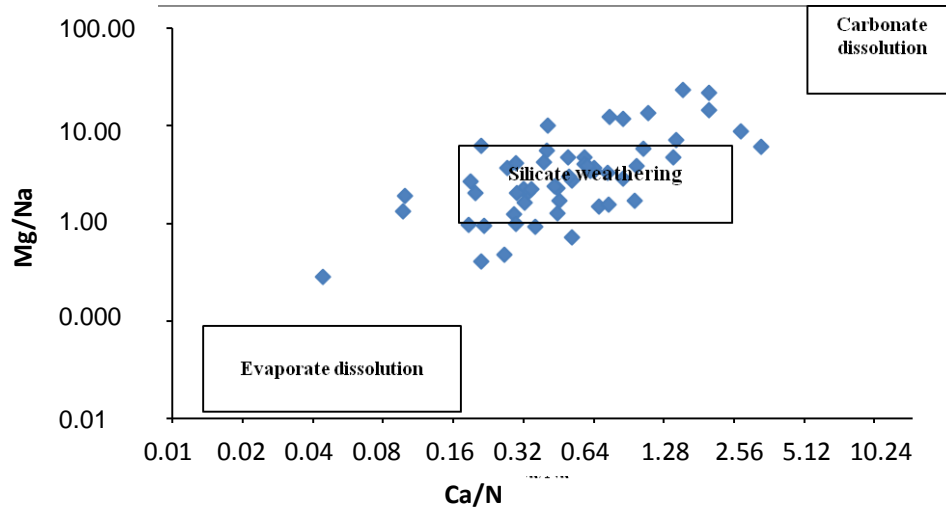


Figure 5. Na-normalized Ca²⁺ and Mg²⁺.

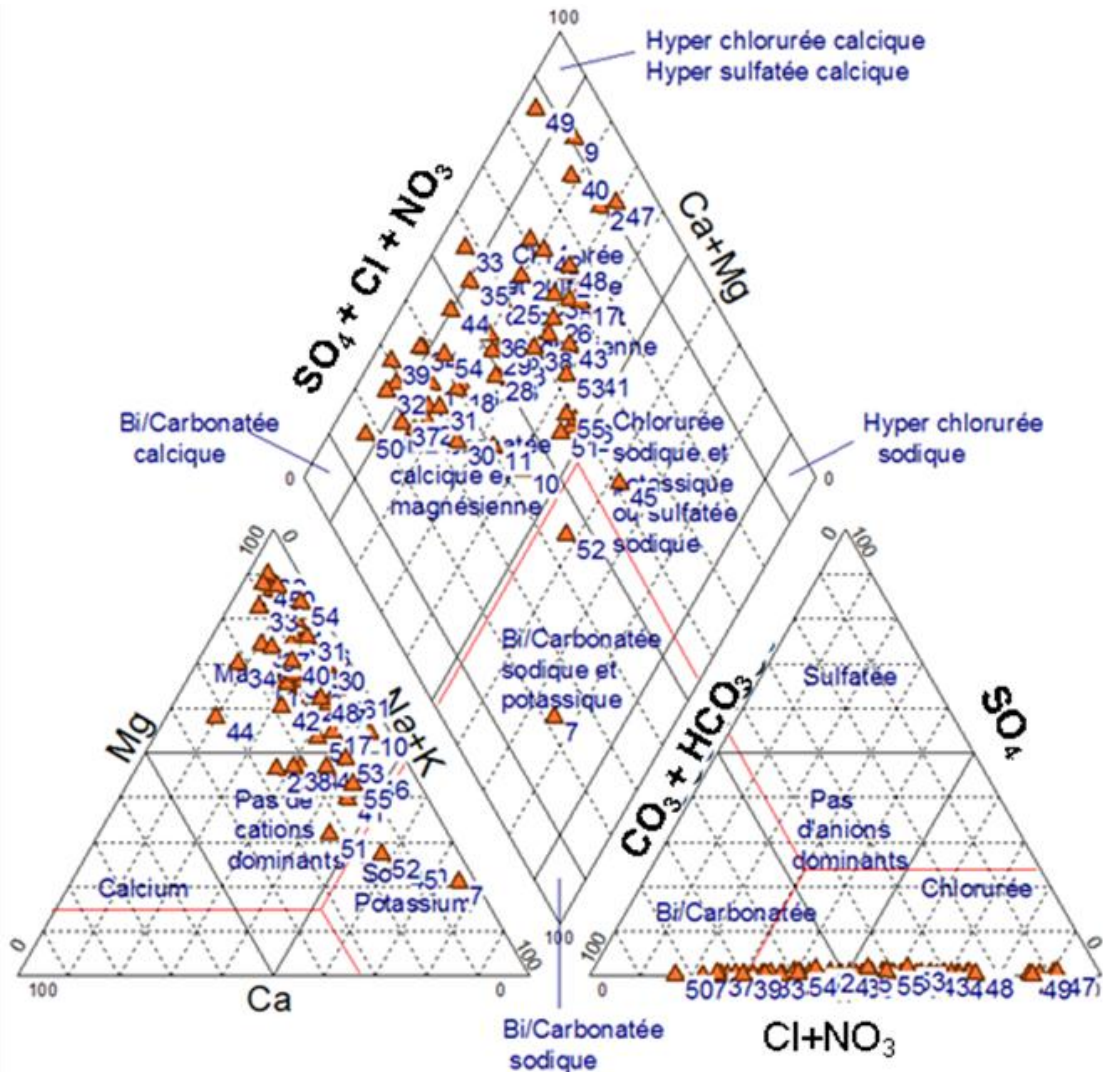


Figure 6. Piper diagram showing groundwater classification (Piper, 1994).

(Belkhiri et al., 2010).

Conclusion

In conclusion, the water quality is a significant aspect of determination of the water body status. The parameters examined in the scope of this thesis were subjected to variety of spatial trends. The results of this study show that the groundwater in the studied area evolves from less saline Ca-Mg-HCO₃ water to blended Mg-Ca-HCO₃-Cl water to brackish Mg-Ca-Cl-HCO₃ water along the topographic flow path. The analysis indicates that the water of Oran sebkha basin is characterized by moderate alkalinity in the investigated period.

In addition to this, it is important that bacteriological assessment of water from these different wells be carried out to be sure if the water is safe for drinking and other domestic applications.

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