Irrigation And Risk Of Saline Pollution. Example: Groundwater Of Annaba Plain (North East Of Algeria)

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Abstract

In the Annaba plain (Northeast of Algeria), the anthropogenic activities have imposed serious unfavorable impacts on hydraulic, hydrochemical and biological balances that influence the socio-economic future of this area. A hydrochemical analysis was performed in 29 wells distributed over the whole of the plain region during the period of high water (December 2013) to assess the quality of groundwater for its suitability for irrigation. Several parameters were analyzed such as pH, TDS, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-} and SO_4^{-}. Analysis of results suggests that groundwater in the study area has the same qualities; however the observed degradation reflects a change in the water quality, and the SAR values vary from 0.08 to 16 with an average of 1.3. The US salinity laboratory, Wilcox, and percentage Na+ it suggest that the majority of groundwater samples are not good for irrigation.

Keywords: Annaba Plain, Algeria, Groundwater, Irrigation, Salinization

Introduction:

In the wake of global warming and its associated changes in environmental conditions, the surface water availability becomes restricted and inadequate to meet all the water requirements for all purposes. Therefore, the demand for groundwater has increased over the years. However, the chemical composition of water is an important factor to be considered before it is used for domestic, irrigation or industrial purposes (Suresh et al., 1991).

In the low plain of Seybouse, the chemical composition of water is often influenced by the impact of the dissolution of geological formations, industrial discharges, and agricultural activities (Kherici 1993, Djabri 1996, Hani 2003, Zenati 2010, Habes 2013). Thus, it is required to periodically check the water quality changes over time and space depending on the variation of the physicochemical parameters of the water. To achieve these goals, it is important to make a monthly monitoring of water (surface and groundwater), with a comprehensive analysis of physicochemical parameters to explain the origin and evolution of each element (Rouabhia et al., 2010).

Geographic Location

The Annaba plain is situated in the northeastern part of Algeria (Fig.1).

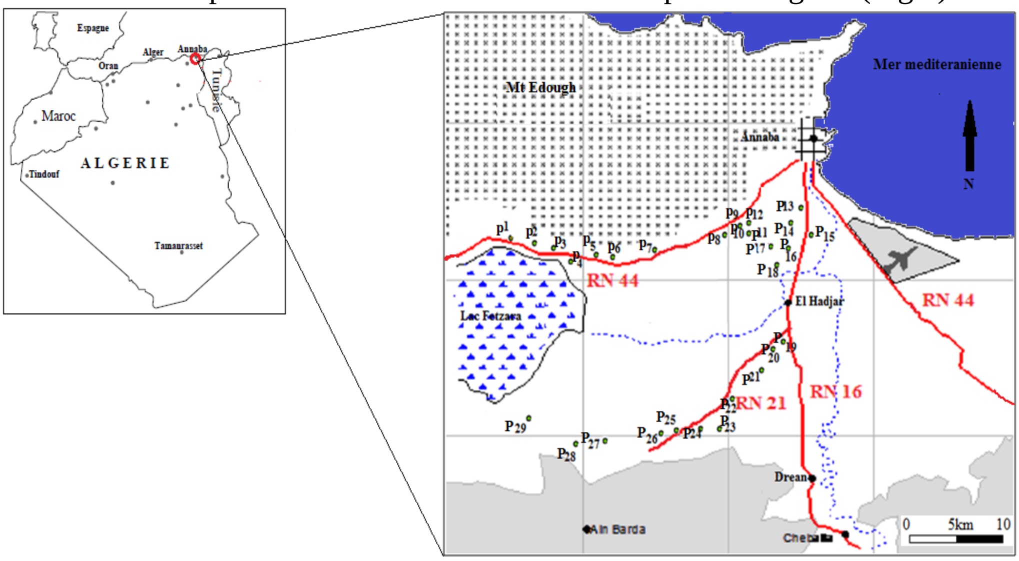


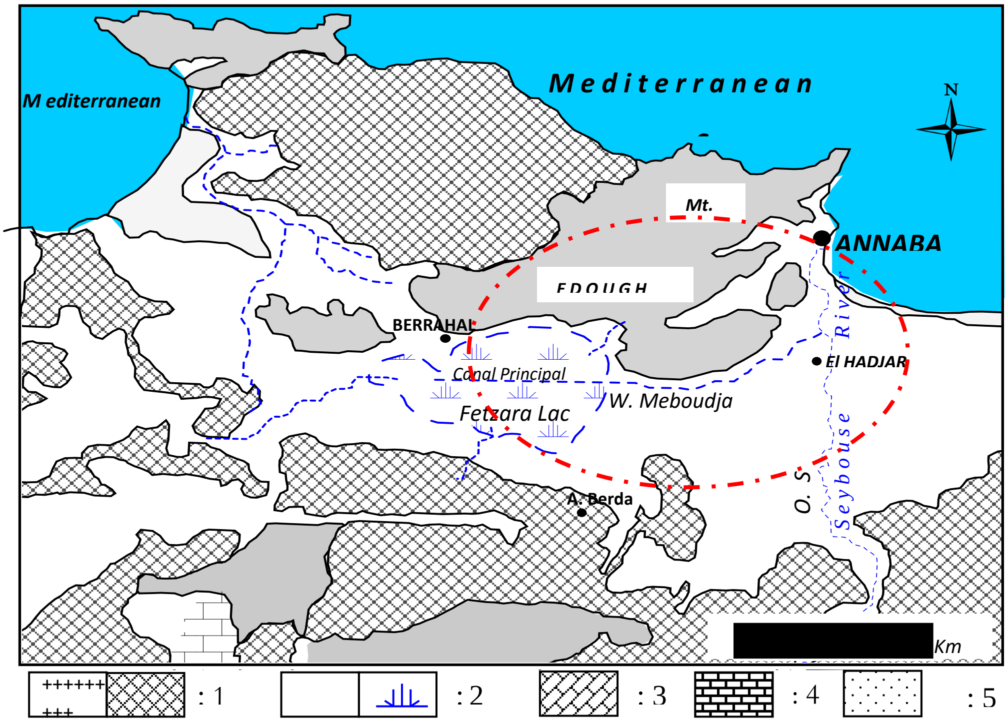
Fig. 1: Location map of the study area in Eastern Algeria

The area is subject to a Mediterranean climate defined by a cold and rainy winter and a hot, dry summer. The average annual rainfall, actual evapotranspiration and recharge are respectively 700, 500 and 80 mm.

Geological and hydro geological Framework

The region of Annaba has been the subject of several geological studies, including that of Joleaud (1936), Hilly (1936), Vila (1980), Lahondère (1987) and Laouar et al. (2002). These studies indicate the existence of two types of courses, one sedimentary and the other one metamorphic (Fig. 2). The stratigraphic column of this land is distributed from Primary to Quaternary:

1) Primary pedestal: is flush on the west in the Massif of Edough, Belelieta and Bouhamra, cristallophylliennes rocks formed by that are superimposed in three series:
   - Lower series: represented by wealthy biotite gneiss and sillimanite with an average thickness of 70 m, this training constitutes the heart of the anticline Edough Massif.
   - Intermediary Series: characterized by schists and mica-rich biotite, muscovite and garnet and sometimes with feldspaths often visible to the naked eye. This series contains Marble who intercalate into the formations of mica skarns form;
   - Upper series: constituted by a set of visible gneiss, satiny schist, mica schist and amphibolites garnet. These three series are the low viewpoint of the hydrogeological, except for the altered gneiss or fractured cipolin that can constitute the headquarters of an underground water table.
2) The secondary Plinth is flush apart from the study region, in the southern part, at the level of the region of Guelma and Bouchegouf, 20-50 km south of the study area. The three systems are constituted by:
   - The Triassic: formed by an association of dolomitic limestone and gypsum;
   - The Jurassic represented by black shale and limestone dolomite;
   - The Cretaceous includes dolomitic limestones rich in foraminifera and rudest debris.
3) The Tertiary Plinth presents an important thickness in the study area with three systems:
   - The Lower Eocene: transgressive series formed of solid limestone facies;
   - The oligocene include clay levels Numidian sandstones which form the relief of mountains of southern plain of Annaba, its thickness reaches 150 m;
   - The Mio-Pliocene constitutes gravelly and clayey sand filling in the basin of the Annaba plain. These trainings are of continental origin, they include gravel and travertine levels that constitute the gravel tablecloth



1: Metamorphic formation (Gneiss, Micaschists). 2: Undifferentiated Quaternary (Dunes and Ancient alluvium), lake or swamp. 3: Flyschs. 4: Numidian sandstone or clay. 5: dunes.

Fig. 2 : Geological map of the study area (Rouabhia, 1993).

4) The quaternary, three levels are dustings:

- The former Quaternary constituted by alluvial formations (clay, silt, sand, gravel and pebbles) constituting the high terrace, its altitude varies between 75 and 150 m;
- Average quaternary corresponds to the lower terrace 20 to 50 m, constituted by clays and sands. It supports the cultivated land. This terrace develops on the entire Area mainly at the level of the valley of Wadi Seybouse;
- The recent quaternary corresponding to sand dune ridges and alluvial silts of Seybouse.

Formations highlight two aquifers (Fig. 3) linked principally by the Wadi Meboudja, as well as by the superficial aquifer of Annaba (NSA) and by the alluvial aquifer of the higher terraces, the second aquifer is fed by the first using the connection of the Meboudja wadi (Habes, 2006). The saturated thickness of the unconfined aquifer can reach 18 m at the south of Annaba. This aquifer is tapped by drillings and wells.

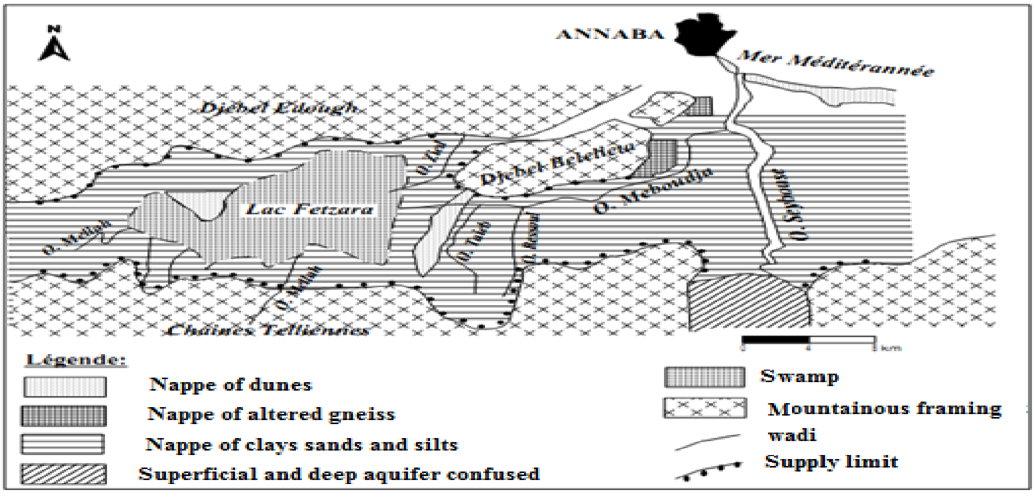


Fig. 3**:** Location of the superficial layers in the plain of Annaba (Habes, 2006)

The hydraulic head measurements taken between the 5th and 10th of February 2010 on 70 levelled domestic wells were plotted on an elaborate piezometric map by the kriging interpolation method using surfer 0.8. Flow follows the topographic form of the studied zone in a south–north direction. However, at the level of the Daghoussa hillock, there is a change of direction from the sea towards the continent.

The piezometric interpretations (Fig. 4) show the interaction between the lake, wadi, and aquifer systems. Excessive pumping (more than 100 installations) in the studied zone affects both the superficial and deep aquifers and generates a change of flow direction. The rate of flow of the extracted water is about (26.2 mm^3/year).

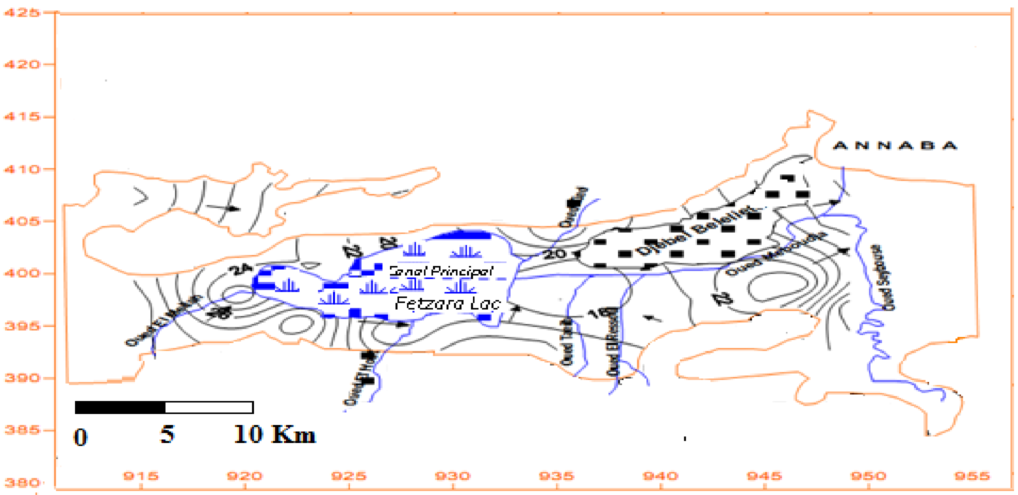


Fig. 4 : Potentiometric map of the study area (Zenati, 2010)

The water level of the superficial aquifer has lowered from 3 to 5 m. The recharge is dependent on precipitation (Djabri et al., 2003), (Zenati, 2010). Increased pumping and reduced recharge generates an imbalance of the salt–fresh water interface, resulting in increased salinity.

Materials and methods

The hydrochimical properties of groundwater samples collected from the quaternary aquifer system are shown in Table 1. The sites which samples were taken are show en in Fig 1. The physiochemical parameters (pH, T°C, and conductivity) were measured in situ using a WTW multi-parameter device (Multi-line P3 PH/LF-SET). The piezometric level was measured with a SEBA KLL probe for the measurement. The chemical analysis was carried out by flame atomic absorption (Perkin-Elmer 11005) for Cations. Anions Cl^-, SO_4^{2-}, HCO_3 were measured using a CPM. These elements were measured in the Hydrochimical Laboratory of University of Littoral Côte d'Opale, Dunkerque on (France).

Results and discussion

Identification of chemical facies water

Table.1 shows the variability and magnitude of different physicochemical parameters of groundwater across the whole sector studied.

Table.1 Basic statistics of the various physicochemical parameters measured (December 2013)

Parameters	Units	Min	Max	Average	Standard deviation
CE	(MS/cm)	2,07	9,68	5,87	3,81
T	(°C)	14	18,10	16,05	2,05
pH		6,53	6,95	6,740	0,21
Cl-	($mg.l^{-1}$)	5	350	177,50	1,30
SO_4^{-2}	($mg.l^{-1}$)	25	136	80,50	0,93
HCO_3^-	($mg.l^{-1}$)	2,20	52,40	27,30	0,77
Ca^{+2}	($mg.l^{-1}$)	0,40	30	15,20	1,28
Na^+	($mg.l^{-1}$)	15	200	107,50	1,17
K^+	($mg.l^{-1}$)	2	13,70	7,85	1,09
Mg^{+2}	($mg.l^{-1}$)	20	120	70,00	1,03
TDS	($mg.l^{-1}$)	192	854	523	331
Sal	($mg.l^{-1}$)	0,60	5,40	3,00	2,40
RS	($mg.l^{-1}$)	144,9	1391,6	383,12	264,41
NO_2^-	($mg.l^{-1}$)	30	130	80	91,92
NO_3^-	($mg.l^{-1}$)	11	94	52,5	58,68

The allocation of the anions for this period (December 2013) highlights a different dynamic from other periods. This reflects is the acquisition mode (dominant) of chemistry: chlorides and sulfates have relatively high levels (Fig. 5a, b). The cations are the same scenario, magnesium and sodium dominate. The Previous table also confirms the impact of geology on the water quality; bicarbonates derived boundary formations, while the sulfates and chlorides are related to human activities.

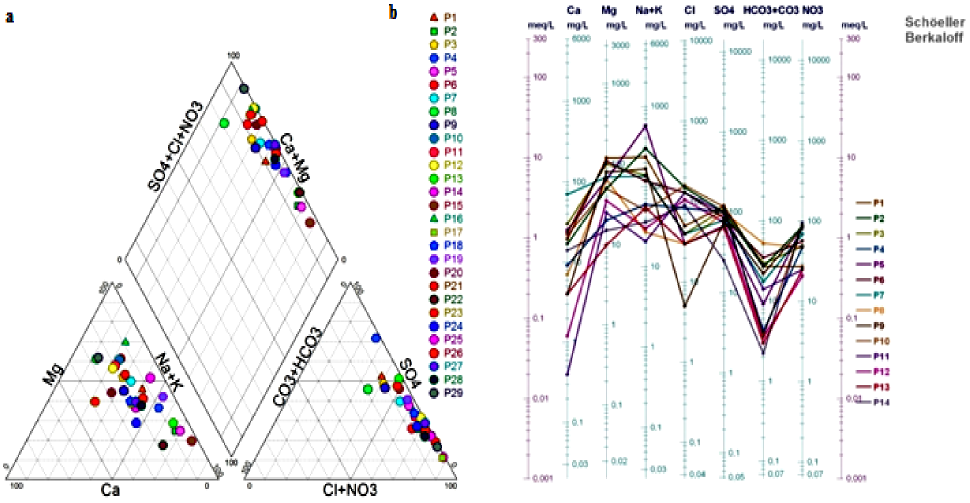


Fig.5 Identification of chemical facies water in the study area (a Piper, b Schoeller Berkallof)

Ionic relationship and sources of major components

The dissolved chemical species and their relationships with each other may reveal the origin of elements and the processes of the observed groundwater composition. The statistical analyzes indicate a positive correlation between some pairs of parameters shown in (Fig. 6).

The report of Na^+ - Cl^- shows an excess of chloride (Cl^-) can be explained by the existence of different origins that increase the concentration of the latter relative to that of sodium. These excess chlorides may come from the dissolution of salts, infiltration of wastewater and recycled water for irrigation. As the chloride excess is accompanied by a sodium deficiency, it can be explained by the Base Exchange associated with clay minerals, which fix Na^+ ion after the liberation of Ca^{2+} (Fig. 6a).

The relation between Mg^{2+} and Cl- shows an enrichment of approximately 50 % of the groundwater samples to the mixing line. Such enrichment may be due to the dissolution of the dolomite of reservoir rock (Fig. 6b).

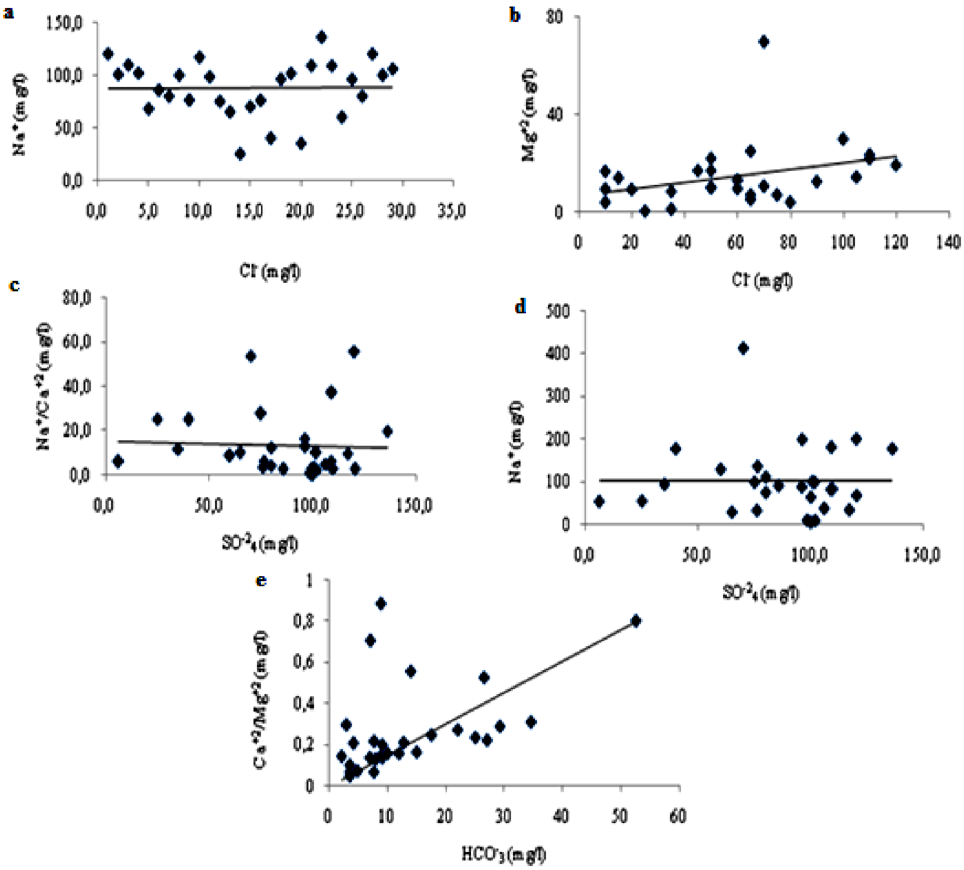


Fig. 6 Relation between elements: (a) Cl vs. Na, (b) Cl vs. Mg^{+2}, (c) SO_4^{-2} vs. Na^+/Ca^{+2}, (d) $SO4^{-2}$ vs. Na^+, (e) HCO_3^- vs. Ca^{+2}/Mg^{+2}.

The Graphics (Na^+/Ca^{+2} - SO_4^{-2} and Na^+ - SO_4^{-2}) show an excess of s sulphate mainly due to the alteration of calcium sulphate and magnesium (evaporates and pyrite) on one hand and human activities on the other hand (use of chemical fertilizers). Lower concentrations of Na^+ ions are due to the Base Exchange (Fig. 6c, 6d).

The relation between Ca^{+2}/Mg^{+2} versus HCO_3^- (Fig. 6e) shows an excess of bicarbonate, which can be explained either by feeding by waters rich in carbonates from the border or the drainage of water from the deep aquifer (long time stay ensures the dissolution of carbonate formations).

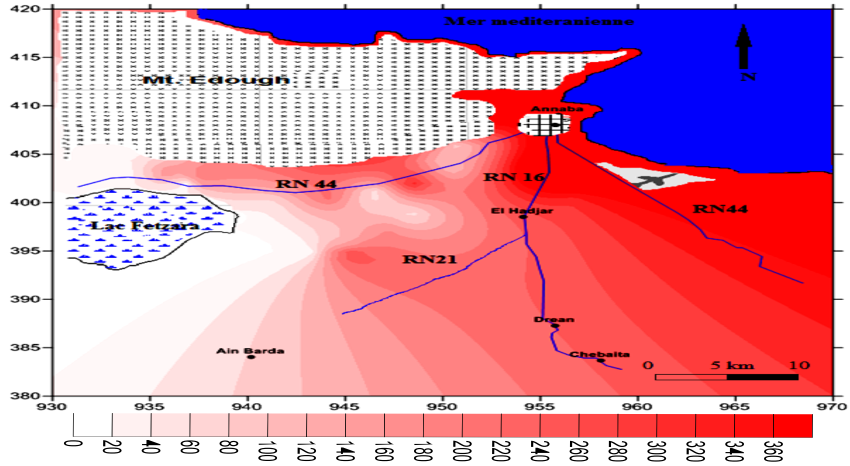


Fig.7 : Chloride distribution in the water plain of Annaba (December 2013)

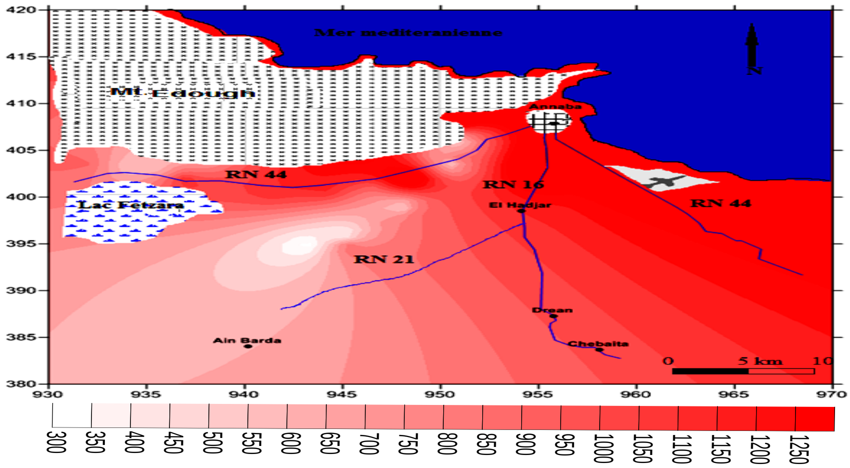


Fig.8 : TDS distribution in the water plain of Annaba (December 2013)

Saturation index

To assess the geochemical processes responsible for the mineralization of groundwater in the Annaba plain, particular attention is paid to the chemical composition, the saturation index (SI) of water with respect of certain minerals. The saturation index expresses the degree of balance between chemical and mineral water in the aquifer matrix considered a measure of the process of dissolution and/or precipitation on water-rock interaction (Drever, 1997). The use of geochemical program PHREEQC (Plummer et al., 1976), allowed us to calculate the saturation index with respect to anhydrite, aragonite, calcite, dolomite, gypsum (Fig. 9 and 10).

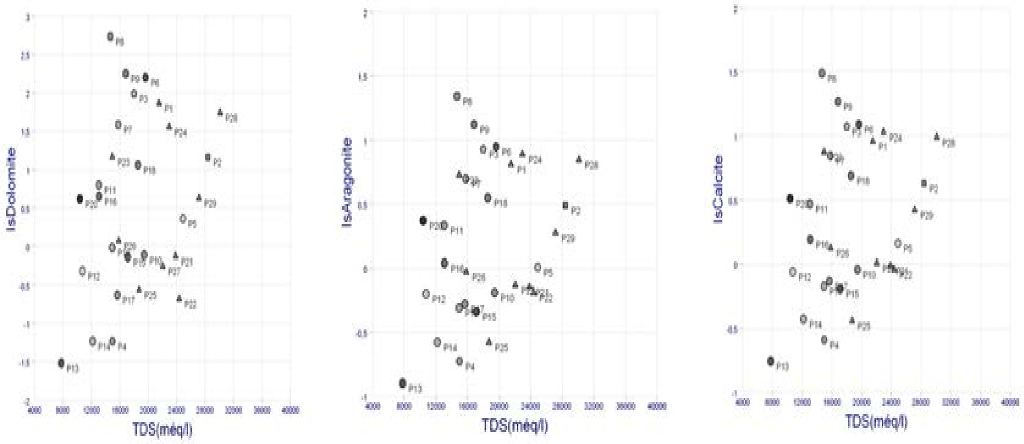


Fig. 9: Relationship saturation indices carbonate minerals with total meniralization groundwater in the plain of Annaba (December 2013).

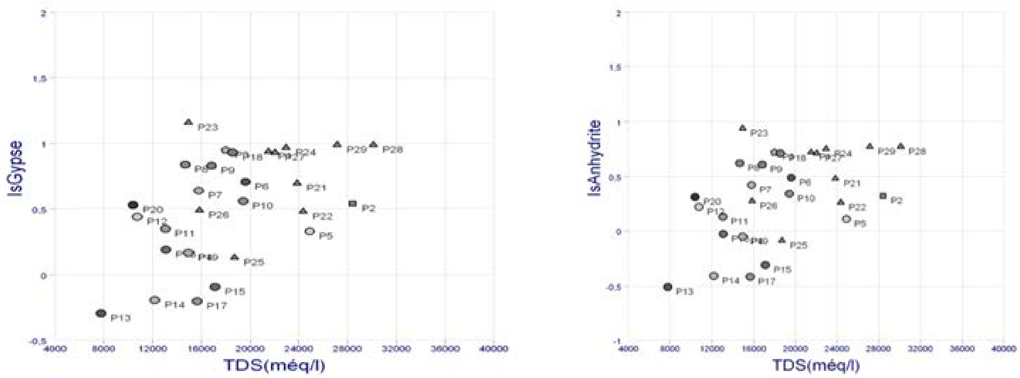


Fig.10 : Relationship saturation indices evaporate minerals with total meniralization groundwater in the plain of Annaba (December 2013).

The calculated index of minerals in water saturation indicates that only carbonate minerals tend to precipitate particularly in the form of dolomite.

The relationship between the saturation index and the carbonate minerals (Fig. 9) shows that most of the waters are over saturated with calcite, aragonite and dolomite. Indeed, the relationship between the saturation indices of evaporated minerals and the TDS shows that the waters of the plain are almost in balance with minerals evaporate : gypsum and anhydrite (Fig.10).

Irrigation water quality

In this study, we will highlight the use of water for irrigation of agricultural land in the Annaba plain (December 2013). The methods of Richards (1954) and Wilcox (1948) are still the most frequently used.

Risk of sodicity and salinity

The major factors that degrade the quality of water for irrigation are therefore summarized to the concentration of dissolved salts, expressed by the dry residue or the electrical conductivity, the potential salinity, the sodium concentration and the relating quantity of toxic elements (boron and chlorine) in the water. This is linked to the dry residue (RS) and the osmotic pressure π calculated by the following formulas:

$RS\ (mg/l) = 0.7\ CE\ (\mu S/cm)$

$\pi\ (atm) = 0.00036\ .CE$

The soil salinity is constituted by all the salts, particularly sodium chloride, magnesium and sulphates (Doneen, 1961). Therefore, the potential salinity (Sp) can be estimated by:

$$SP = Cl + {}^{1}/_{2}\ SO_4^{-2}$$

It was acknowledged that the concentration of sodium in the irrigation water has an influence on the permeability and infiltration of the soil (harmful effects on soil structure through the clay flocculating). This effect is interpreted by different authors by calculating several parameters such as the SAR previously mentioned:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

The sodium percentage (Na %) is calculated using the formula given below, were all the concentrations are expressed in miliequivalents per liter:

$$Na\ \% = \frac{Na+K}{(Ca+Mg+Na+K)} * 100$$

These parameters can act separately or combined to the classification of irrigation water, four classes appear excellent, good, poor and permissible.

The groundwater in the study area have the same qualities, the observed degradation reflects a change in the water quality.

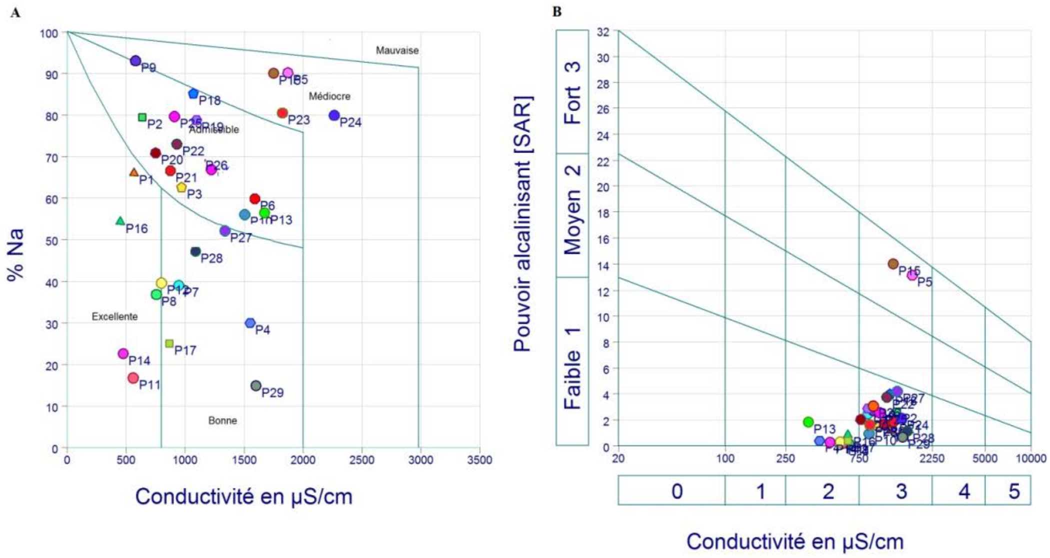


Fig. 11: Classification of irrigation water in the study area, (a) USA Salinity Laboratory diagram, (b) Wilcox (1948).

The representation of the conductivity and the SAR on a US salinity pattern (Fig. 11B) shows that the majority of samples are located in two classes of water: the categories C2S1 (medium salinity and low alkalinity) and C3S1 (high salinity and low alkalinity). Both categories fall in the suitable class for agriculture purposes. Two samples 5 and 15 fall in the poor zone of water quality (C3S3) so the water is unusable for agriculture.

The Wilcox diagram (Fig.11A), relating sodium percentage, and electrical conductivity, shows that most of the groundwater samples fall in the category of good to permissible. 50% of samples fall in permissible to the doubtful category, sample numbers: 5, 9, 15, 23, 24 and 25 are in the doubtful category improper for irrigation, suggesting the involvement of human activities.

Conclusion

The underground water of the aquifer of Annaba introduces important variations of the mineralization, which becomes more marked, with the sense of flow. Conductivity is generally high and wobbles between 2.07 mS/cm and 9.67 mS/cm. The most charged zones are in direct link with Sorted him Out sulfurous. This salinity is particularly controlled by chlorides and sodium. The use of major and minor chemical elements allowed us to understand the process of normalization of water. Therefore, this mineralization comes from the dissolution-precipitation of the aquifer rock, evaporation and the Base Exchange.

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