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Impacts of morphological factors on the marine intrusion in Annaba region (east of Algeria)

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ABSTRACT

Annaba is famous as an agricultural region. The main crops are water melon and tomatoes. These crops grow in the summer, thus need intensive irrigation that requires an overexploitation of water, which leads to an imbalance of freshwater–saltwater interface. To explain the marine intrusion and its extension, we examined the information given by geomorphologic, hydrochemistric and hydrodynamic studies. The studied area is characterized by horst and graben structures. The effects well localized of those faults allow to explain the presence of preferential areas of flow. The calculated ratio values were compared to critical level values ($Mg/Ca = 4.5$, $SO_4/Cl = 0.1$ and $Cl^-/\text{conductivity} < 0.30$). The obtained results show that the ratio values are over the limits, presenting a possible marine intrusion. This intrusion could particularly be from the Salines, regions in the North to Besbes in the South, which explains the water's salinity in this region, despite its distance from the sea.

Keywords: Salinity; Water; Fresh water–salted water interface; Bromine

1. Introduction

Although the marine intrusion is linked to the overexploitation of the coastal groundwater aquifers, we must recognize that other factors could contribute directly or indirectly to the increase of salt wedge [1]. The work done in the studied area showed that the local morphology could lead to marine intrusion in the zones far from the littoral.

The present work is based on collecting and combining specific data or information in order to explain the mechanisms controlling marine intrusion in this zone.

The plain of Annaba is bordered from the north by the Mediterranean Sea. It contains two groundwater aquifers of unequal extensions: The first, called superficial and in which implanted domestic wells, is located at few meters of the surface. The second, called deep, is reached by drillings of over 100 meters deep. The studied region has an agricultural vocation. The cultivated summer crops are mainly tomatoes, melon and water melon. These crops need intense irrigation

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that causes an increased request for groundwater. To satisfy water demand, particularly in summer, farmers intensify water pumping from wells and drillings which imbalances freshwater–saltwater interface. In this work, we attempt to prove the existence of marine intrusion and to determine its preferential directions.

2. Geological and geomorphological settings

The studied region is located in the North-East of Algeria (Fig. 1). It is bordered by the Mediterranean Sea from the North, by Drean town from the South, by Mafragh River from the East and by Fetzara Lake from the West. The plain is supplied from the West by the river coming from the Edough mount, and from the South by the upstreams coming from Ain Berda and Guelma mounts.

The studied area is characterized by the outcrop of a sedimentary and a metamorphic formations (Fig. 1). These formations date from the Paleozoic to the Quaternary. The metamorphic formations which crop out in the western part date from the Paleozoic. They form the Edough, Belilieta and Boukhadra massif, constituted mainly of gneiss. The sedimentary formations age go from the Mesozoic to the Quaternary. This latter is constituted of alluvial sediments forming the reservoir rock. We distinguish the old Quaternary (high terraces) containing the alluvial aquifer, where the material is made of sand, clay and gravels. The recent Quaternary correspond to the low and the average terraces. The actual Quaternary: the alluvial fans are actual bed deposits of the river; they are formed of sand and gravels.

The results of the geophysical studies carried out show a succession of horsts and garbens in the studied zone. That alternation leads to the establishment of preferential sectors of underground flows. Thus, on both sides of the Daroussa mount settle plains which could reseal aquifers that extend to the sea (Fig. 2). The obtained results from the observations coming from the tectonics and the geophysics prove the existence of a hydraulic link between the sea and the water layers [2]. We notice that the Daroussa mount functions as a barrier between two plains and consequently blocks the

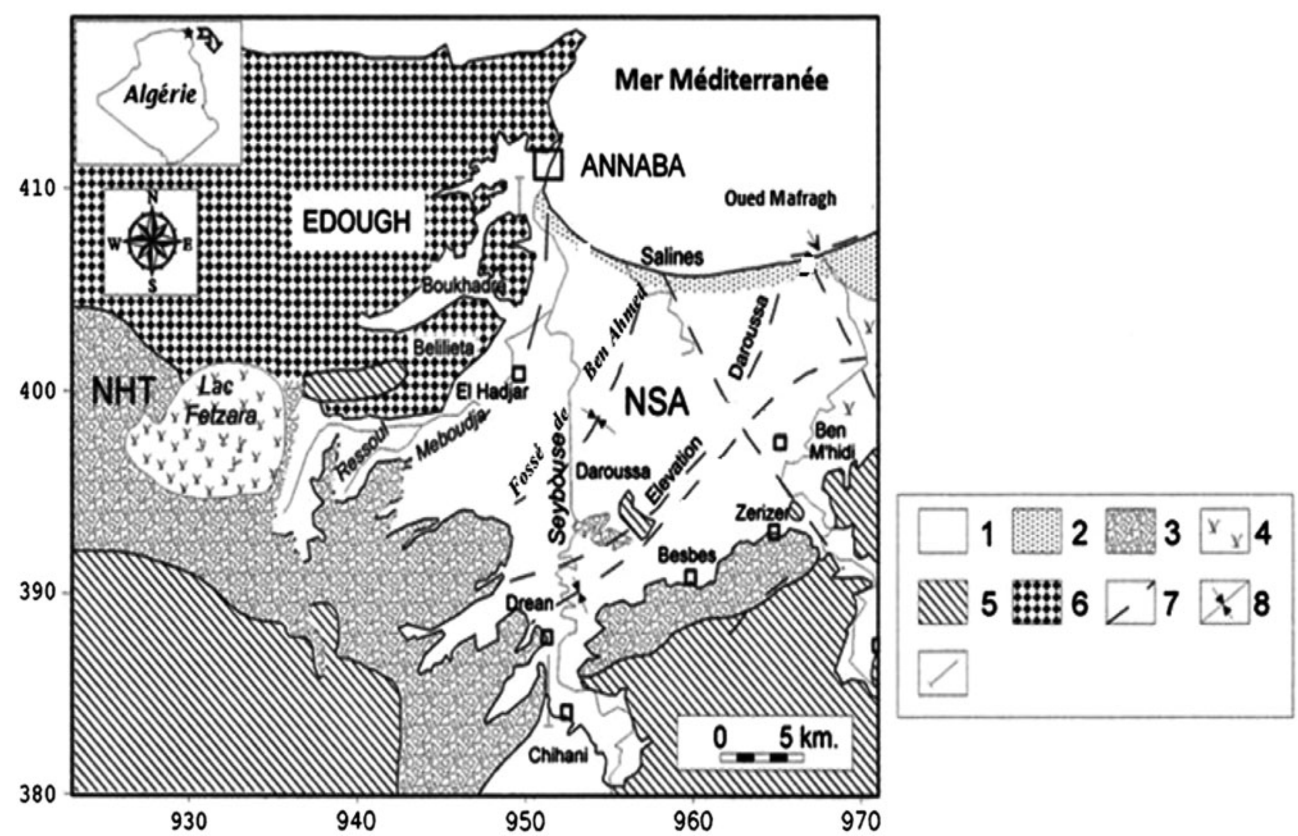

Fig. 1. Geographic location and geologic characteristics of the studied zone. **1**: Recent and actual Quaternary; **2**: sandhills; **3**: old Quaternary; **4**: swamp or lake; **5**: sandstone and Numidian clay; **6**: Metamorphic formations; **7**: faults; **8**: trenches axis.

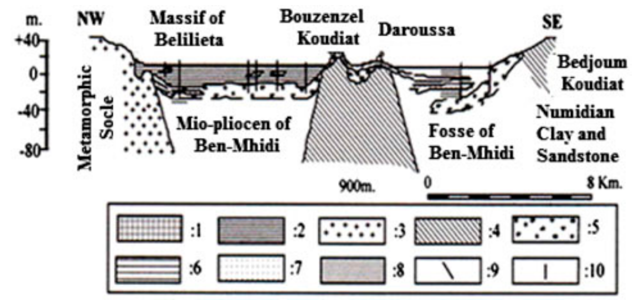

Fig. 2. Geologic cross section of the studied area. **1**: Clay loam with sand past (groundwater); **2**: Plio-Quaternary detrital clay; **3**: metamorphic Socle (micashiste, gneisses, marbles); **4**: Numidian sandstone; **5**: peeble and gravel (deep tablecloth); **6**: Numidian or Paleocene clay; **7**: sand; **8**: Dunes; **9**: faults; **10**: drilling.

lateral exchanges East-West and allows the water from the sea to flow towards the southern zones and vice versa.

3. Hydrogeology

Two hydrogeologic layers are superposed. The first one, called free, in which the wells are implanted; and the second one is captive becomes free in its southern part (Drean region).

4. Superficial aquifer

Fig. 3(a) shows that there is a south–north flow. However, at the Daroussa mount we notice a change of the flow direction. This latter is from the sea to the continent. This tendency is localized on the northern part of the map; pointing out probably a penetration of sea water. The map shows also an interlink between the sea, the rivers and the aquifers. These elements certainly affect the water chemistry.

5. Deep aquifer

The piezometric map (Fig. 3(b)) by S. Aoun [3] shows two flows. The first one from the south to the north and the second one more important because it shows the supply of the aquifer by the sea water. This could generate a marine intrusion caused by the over-exploitation of the water layer in the salines area which lead to the appearance of a depression due to continuing pumping in that area.

The transmissivity values are important along the Seybouse valley and in the oriental of the dunar massif. The very low values of transmissivity are located at the east of Ben M'hidi and extend all over the littoral part of the dunar massif [4].

6. Hydrochemistry

The values of some characteristic ratios show the marine influence on water's salinity. Granted, for the sea water, the Mg^{2+}/Ca^{2+} and SO_4^{2-}/Cl^- ionic ratios are, respectively 4.5 and 0.1. To prove a possible marine intrusion, we used the results of the chemical analysis carried out on samples collected from the studied area.

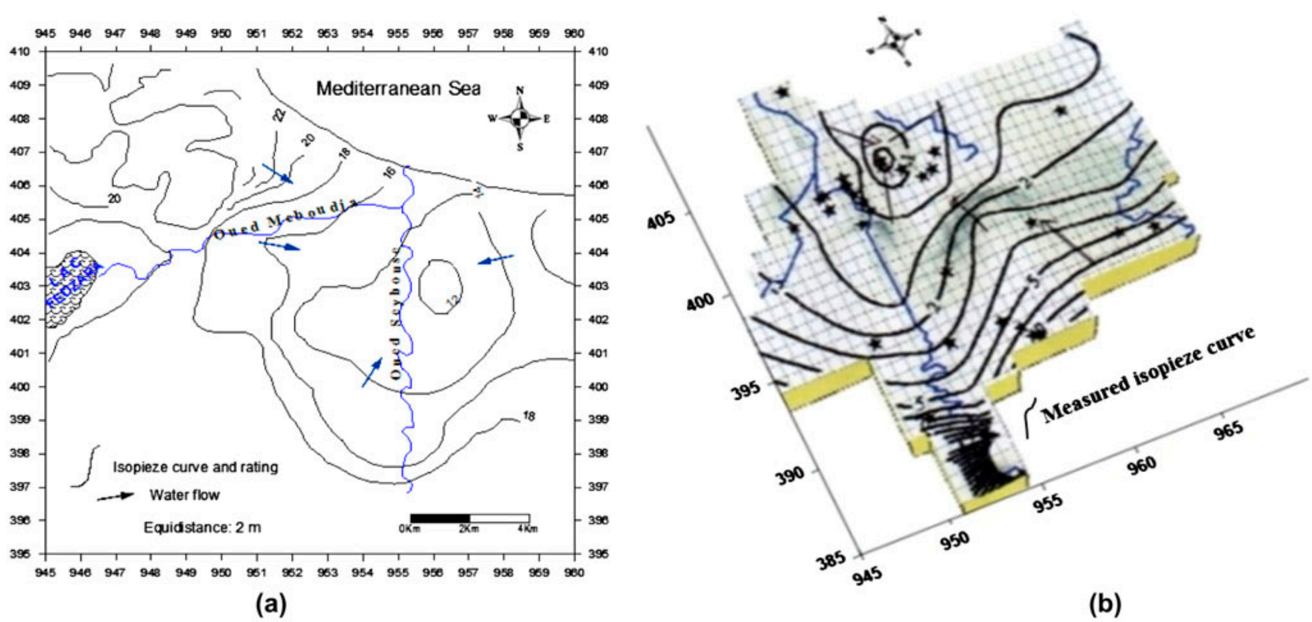

Fig. 3. Piezometric map (a) superficial aquifer and (b) deep aquifer [3].

Table 1
Values of the characteristic ratios (2009)

Wells	Distance/sea (km)	Mg/Ca	SO_4/Cl	Cl/CE	Wells	Distance/sea (km)	Mg/Ca	SO_4/Cl	Cl/CE
Alalig	4.0	0.85	0.02	*0.7*	*Trad*	7	1.22	0.5	0.65
Seybouse	2	0.5	0.75	*0.4*	*Jenen Sidi Mbarek2*	4	0.24	1.6	0.14
Nedjara	6	0.6	0.22	*0.4*	*Jenen Fayed*	5	0.7	0.1	0.8
Hamani	7	2.3	0.1	*0.6*	*F2ZIPB*	3.5	1.6	0.1	0.4
Besbes	25	0.8	0.4	*0.2*	*P1*	22	0.6	0.7	0.19
Bellahmers	6	0.5	0.47	*0.26*	*P2*	19.7	1.2	0.6	0.07
Saline	2	0.8	0.38	*0.34*	*P6*	11.9	0.4	0.2	0.16
Rachrach	14	0.75	0.6	*0.33*	*P12*	1.25	0.6	0.6	0.21
Zerizer	20	1	0.1	*0.28*	*P13*	0.6	0.4	0.3	0.15
ZIBP Kaboe	3.5	0.8	0.10	*0.39*	*SF1*	22.5	0.9	1.1	0.09
Ferkous	3	0.92	0.1	0.6	*SF2*	17.5	0.3	1.0	0.13
Sidi Abd	20	0.88	0.52	0.26	*SF5*	12.4	1.2	2.0	0.09
Ghod el Bordj	7	0.89	0.17	0.5	*SF6*	12	1.3	0.4	0.05
F525	5	0.4	0.001	0.8	*SF12*	2.65	0.7	0.3	0.08
Jenen Sidi Mbarek1	4	0.2	0.3	0.13					

Table 1 allows us to deduce that the ratio-values of Mg^{2+}/Ca^{2+} vary between 2.3 and 0.2. However, the SO_4/Cl ratios vary between 0.02 and 1.6. Compared to the limit values, the anionic ratios are greater than the limit values. On the other hand, the ratio-values of cations do not show the same tendencies. It may due to the cationic exchange [5]. This leads us to be interested in the Cl/conductivity ratio. When Cl/conductivity ratio is < 0.37, the chlorides have a marine origin, but if it is >0.37, the chlorides do not have a marine origin. For this last ratio, we notice that 60% of the samples (i.e. 18/29), show values less than 0.37, which allow to suppose that there is a marine contamination. To better visualize the relations between the aquifer and the sea, we carried out the Br/Cl vs. distance to the sea graph (Fig. 4).

Fig. 4 shows that the value of Br/Cl ratio is high in the wells near the sea; that is the case of wells in Sidi M'Barek region. In this region, the value of Br/Cl ratio reaches 33.3‰ and the sea is at less than one kilometer. So, the marine influence is evident (family 1). In other places, the ratio-value is low but the sea is close, at less than 4 km, the research establishment case (family 3). The value of the Br/Cl ratio is about 0.13 ‰. It does not give an indication about the existence of a marine influence. In the mean time, the ratio-value is very high in the lands far from the littoral. It is the case of water taken from Besbes at

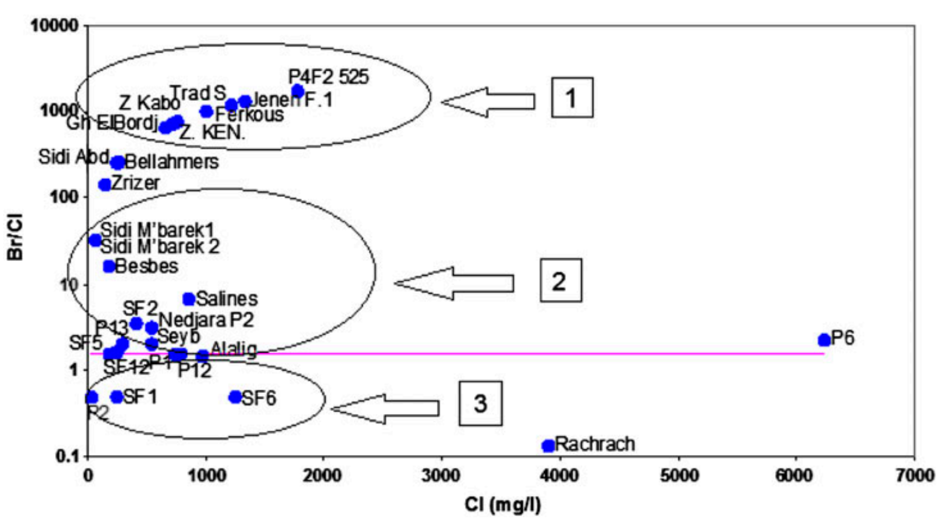

Fig. 4. Variation of Br^-/Cl^- vs. the distance to the sea.

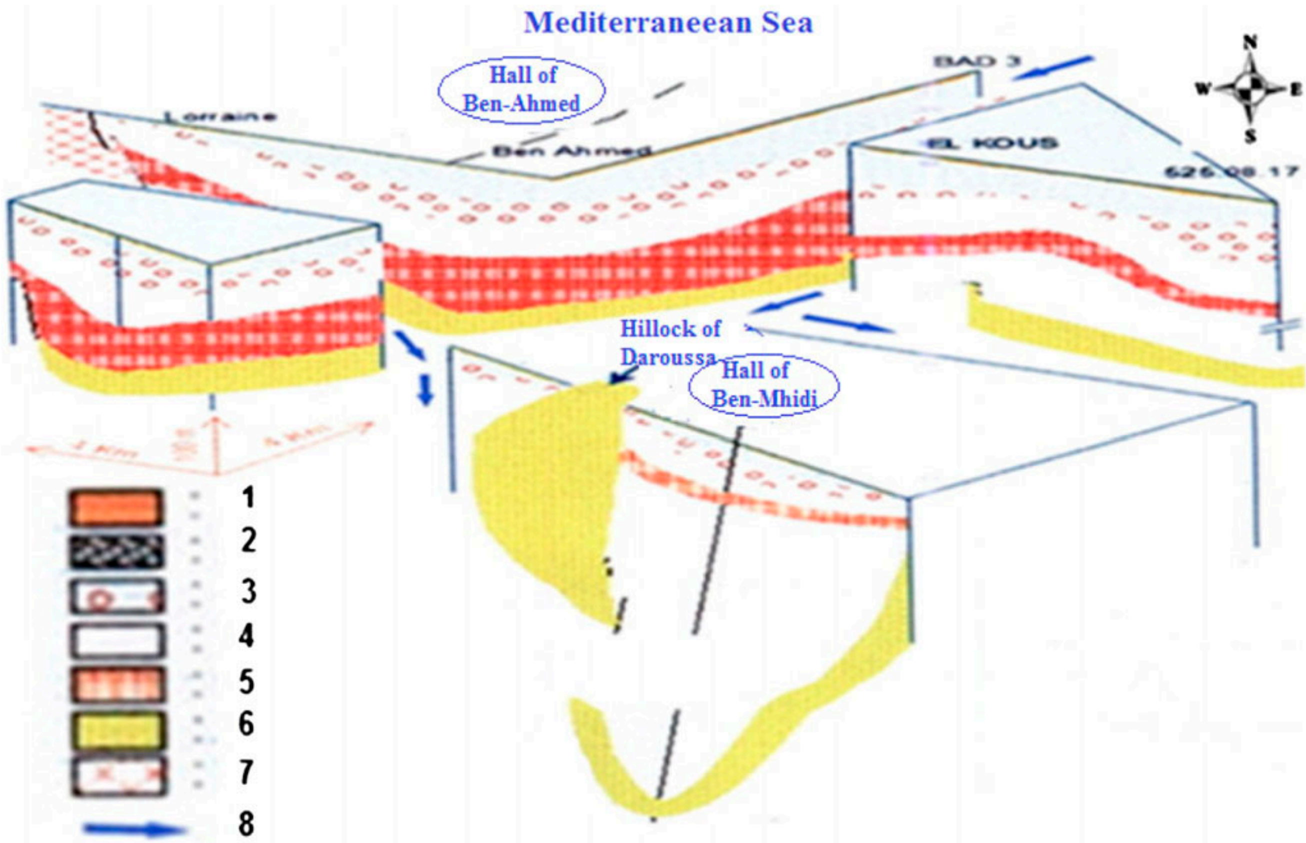

Fig. 5. The intrusion mechanisms in the studied area. **1**: Clayey sands (surface table cloth); **2**: sandy clay (semipermeable layer); **3**: pebbles and gravel (deep tablecloth); **4**: clay substratum (Plio-Quaternary); **5**: Marl (Miocene); **6**: clay and sandstone (Numidian); **7**: metamorphic formations; **8**: arrival and movement of marine waters.

25 km from the littoral. This water gives a ratio of about 16.3 ‰ putting in evidence a marine influence (family 2). The observation made shows that the marine intrusion happens according to preferential zones [6]. These latters are in the extension of the tectonic accidents described previously.

7. Marine intrusion mechanisms

To well understand the marine intrusion problem, we used different methods. The results achieved during different stages allowed us to have a good approach to the marine intrusion problem in a zone where the water resource is overexploited. The combination of the results obtained from the tectonics, the hydrodynamics, and the water chemistry shows that the local faults that generated the horsts and the grabens are at the origin of the marine intrusion, particularly at the far lands such as the Besbes region [7]. Fig. 5 locates the faults and shows their contribution to the marine water flows. This leads us to say that if at the Annaba bay the marine intrusion seems to be evident, at the eastern zone, the marine intrusion is caused by the natural factors as the elevation of Daroussa and Oued Mafragh. This could favour the saltwater penetration towards the far zones [8].

8. Conclusion

The present work is achieved in a coastal agricultural zone, characterized by the interference of two aquifers: one is superficial and the other is deep. The exploitation of these aquifers is more important during the summer period. During this period, the irrigation becomes more important which can cause a marine intrusion in some places. The followed approach, based on the use of several tools, allowed us to put in evidence some preferential zones of the marine intrusion [9]. We noticed that the intrusion is favoured by the natural factors, such as the horsts and the grabens existing in the region. For information, the Besbes region, which is 20 km far from the littoral, remains the more vulnerable to the marine intrusion. This is due to the fact that the openings of the faults that favour the intrusion of marine waters. On the other hand, the transmissivity in this part is very important.

References

[1] Y. Hsissou et al., Dynamic coastal aquifer salinity of Agadir (Morocco): Influence of salt bevel and evaporitic facies. Hydrochemistry, IAHS Publ. 1997, N° 244.

[2] L. Djabri, Mechanism of pollution and vulnerability of the waters of the Seybouse geological, industrial, agricultural and urban Origins. State Thesis, University of Annaba, 1996.

[3] B. Aoun Sebaïti, Quantitative and qualitative modeling for integrated management of water resources: Application to the plain of Annaba, PhD thesis, University of Annaba, 2010, p. 140.

[4] T.H. Debieche, Evolution of the quality of water (salinity, nitrogen and heavy metals) due to salt pollution, agricultural and industrial: Application to the lowland Seybouse, NE Algeria, PhD thesis, University of Franche-Comté, 2002.

[5] L. Djabri, A. Rouabhia, A. Hani, Ch. Lamouroux, A. Pulido-Bosch, Origin of water salinity in a lake and coastal aquifer system, Environ. Geol. 54 (2008) 565–573.

[6] P. Pulido-Leboeuf et al., Strontium and SO_4^{2-} /Cl^- and Mg^{2+}/Ca^{2+}, ratios as tracers for the evolution of sea water into coastal aquifers, The Example of Castell de Ferro aquifer 2003 (S.E Spain), CRASP.

[7] A. Hani, Methodological analysis of the structure and anthropic processes: Application to water resources in the Mediterranean coastal basin, State Thesis, University of Annaba, 2002.

[8] J. Mania, Salt pollution of the coastal aquifer in east of Algiers, Hydrogeology 3 (1985) 213–226.

[9] F. Sánchez-Martos, A. Pulido-Bosch, L. Molina-Sánchez, A. Vallejos-Izquierdo, Identification of the origin of salinization grounwater using minor ions (Lower Andras, Southeast Spain), Sci. Total Environ. 297 (2002) 43–58.