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Hydrochemical study of Drean–Annaba aquifer system (NE Algeria)

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Abstract

Water quality is subject to frequent changes in the Drean–Annaba alluvium aquifer. Water-rock interaction can not be the only process that produces the observed modification, but dryness that the country knew during the last two decades has highly contributed to the water quality changes. During this period, irregularities in the distribution of rainfalls, in time and space, have been observed. As a result, a periodicity in hydrochemical changes in water of wells and rivers is noticed. Statistical, the principals components analysis (PCA) tools and Tickel diagram have been used to show, through chemical presentation, these effects. The results show, indeed, seasonal changes of water quality for the period 1999–2000. From a cationic point of view, a competition between alkaline and alkaline earths is shown. On the other hand, from an anionic point of view, there is a transition from chlorides to sulphates and may be to bicarbonates.

The present work was carried out in a relatively small area and this was useful to show the relationship that existed between dryness and water quality of both the aquifer system and surface water.

Key words: *Algeria, Annaba, aquifer, Drean, hydrochemical parameters, water quality*

INTRODUCTION

Some countries bordering the Mediterranean had many problems with water quantity and quality [BARKAT *et al.* 2013; BENRABAH *et al.* 2016]. This situation has constrained the scientists to look at this problem). In Algeria, the work carried out by DJABRI *et al.* [2014] highlights the salinity of water in two aquifers with different climates and geology: alluvial aquifer of Tebessa (semi-arid zone) and superficial aquifer of Annaba–Boucheougouf–Guelma. ZENATI

[2010] and HABES [2013] showed that the presence of highly salted water lake (Lake Fetzara) could influence the salinity of groundwater by brought in mineralised waters. The water flows from the lake towards the aquifer passing Wadi Meboudja. BOUGHERIRA *et al.* [2014], DEBIECHE [2002], HANI [2003] and AOUN SEBAÏTI [2010] underline a salinity of Annaba deep aquifer waters, which its origin is not well defined. AOUN SEBAÏTI [2010] demonstrated the existence of seawater intrusion through the South-North oriented periphery. We presented the influence of the seasonal

climate on groundwater. The physicochemical analyses of the aquifer system confirmed again this relationship. This work is based on the above mentioned research studies.

The objectives of this research were to identify and describe the impact of the seasonal climate on the water quality and its distribution among different hydraulically linked zones.

GEOGRAPHIC LOCATION AND GEOLOGICAL FRAMEWORK OF THE STUDIED ZONE

The studied region is in the North-East of Algeria (Fig. 1). It is bound by the Mediterranean Sea to the north, by Dréan town to the South, by Wadi Mafragh to the East and by Fetzara Lake to the West. The plain is supplied at the West by the streams water coming from the Edough mount, and at the South by the up-stream supplies.

The studies realized in the region show that there were two types of formations: metamorphic and sedimentary (Fig. 2). The geological formation dates back from the Palaeozoic to the Quaternary period.

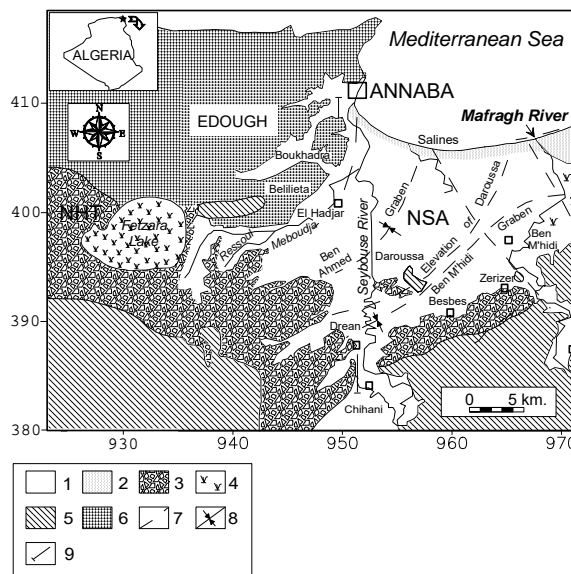


Fig. 1. Geographic location and geological frame of the studied zone; 1 = undifferentiated Quaternary, 2 = dunes, 3 = ancient alluvium, 4 = lake or swamp, 5 = Numidian sandstone or clay, 6 = metamorphic formation, 7 = border of the graben, 8 = graben axis, 9 = cross section, NSA = Superficial aquifer, NHT = Ancient alluvium aquifer; source: own elaboration

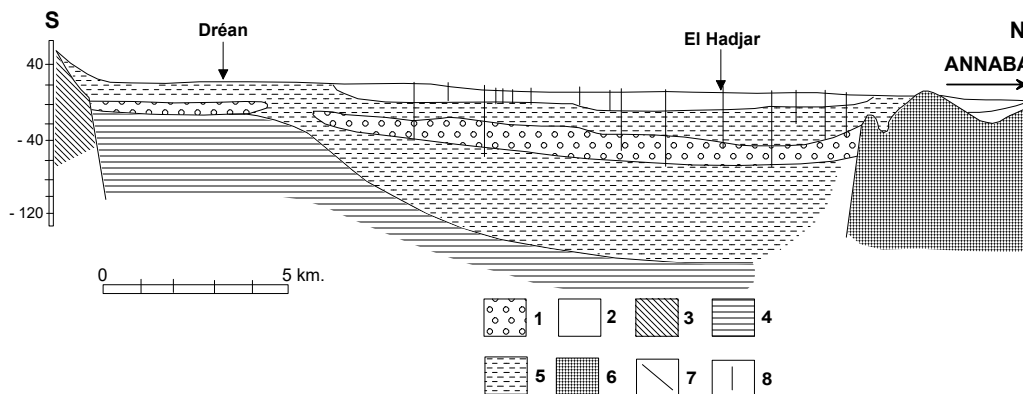


Fig. 2. Cross-section through the plain of Annaba and Aquifers dispositions; 1 = pebbles and gravels, 2 = sand, 3 = Numidian clay, 4 = Cenomanian marl and marly limestone, 5 = Plio-Quaternary detrital clays, 6 = metamorphic formations, 7 = fault, 8 = drilling; source: own elaboration

The Quaternary is represented by dune sands and alluvial formations. We distinguish Old Quaternary (high terraces) containing the alluvia aquifer of which the material is composed of sands, clays and gravels; Recent Quaternary corresponding to low and medium terraces; and Current Quaternary including the alluvia of the current riverbeds, constituted by sands and gravels.

LOCAL CLIMATE

The average annual precipitation overall Seybouse basin varied between 400 to 700 mm, with a monthly maximum between 90–120 mm, in December–January. As far as the temperatures were concerned, the extremes are observed in winter and summer. The minima were observed in December–Janu-

ary (less than 10°C, and the maxima in July or August (between 25 and 30°C). The contrast between winter and summer is highly important far from the Mediterranean Sea. The potential evapotranspiration was closely linked to the temperatures. The annual average of the evapotranspiration range from 1000 to 2000 mm. The Seybouse climate is Mediterranean but changing from the north to the south. Along the coast, the annual rainfall varies between 700–900 mm.

HYDROGEOLOGY

The disposal of these formations highlighted two aquifers (Fig. 2) communicating between them principally by Wadi Meboudja, the superficial aquifer of Annaba and Alluvial aquifer of high terraces.

The piezometric map realized (Fig. 3) shows, in general, that the flow follows the topographic form of the studied zone in the South-North direction. However, at the level of the Daroussa elevation, we notice a change of the flow direction, which is from the sea towards the continent [ZENATI 2010].

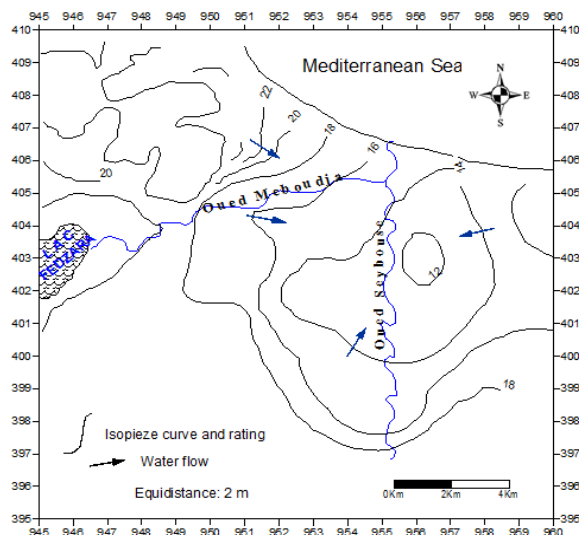


Fig. 3. Piezometric map of superficial aquifer of Annaba; source: own elaboration

This predisposition sited on the Northern part of the map indicates a possible supply of the aquifer by the sea. Furthermore, the presence of depression highlights the influence of pumping which can contribute to the advance of saltwater wedge.

The second aquifer is the alluvial aquifer of high terraces (NHT).

The piezometric map shown the existence of an interaction between the various elements of the system (lake, wadi, aquifer) AOUN SEBAÏTI [2010]. The excessive number of pumping (more than 150 installations between well and drillings) in the studied zone affected the two aquifers (superficial and deep) and generates a disturbance of the direction of the water flow.

This results in an imbalance of the salt-fresh water interface. This state deteriorated the quality of water (increase in the salinity). The water chemistry indicated the state of the aquifer according to other constituent parameters of the system.

MATERIALS AND METHODS

To realize this work, water samples were collected each month. 148 samples were taken through the zone of study. The withdrawal concerned the domestic wells of the unconfined groundwater located in Annaba–Dreaan zone (65), the groundwater surrounding Lake Fetzara (42), the Seybouse (25) and Mebou-dja stream (16).

The physicochemical parameters (pH, T in °C and conductivity) were measured in-situ using a Wissen-

sschaftlich-Technisch Werkstätten (WTW) multi-parameter device (multi-line P3 PH/LF-SET) and a SEBA KLL type probe for the measurement of the piezometric level. The chemical analysis was carried out by flame atomic absorption (PerkinElmer 11005) for cations. Anions and trace elements were measured using a spectrophotometer “PhotoLab WTW”.

RESULTS

The chemical analyses carried out had enabled us to highlight the cause and effect relationship, which exist between the sea and the aquifer, between the lake and the aquifer, and between the wadi and the aquifer. Relying on the representations, the following tools will be developed: analyses in principal components, Piper diagrams and Tichel diagrams HABES [2013].

A PRINCIPALS COMPONENTS ANALYSIS

The PCA realized refers to the four seasonal periods. The number of samples considered were 148, and 9 chemical elements were analysed.

The global data are considered in the PCA and the axes F1, F2 and F3 provide 68% of the total information (from 2010 to 2012).

The observation of the circle (Fig. 4) formed by F1 and F2 shows, along the axis F1, an opposition between strongly mineral bearing water and water slightly mineral bearing.

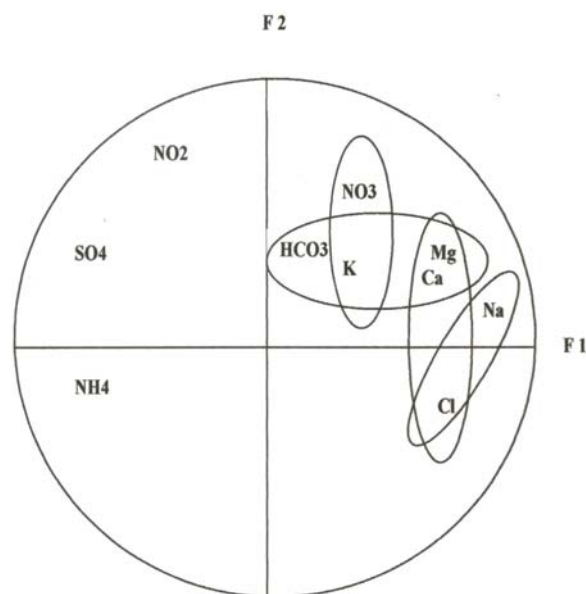


Fig. 4. PCA Circle of superficial aquifer (2010–2012); source: own elaboration

The axis F2 indicated an opposition between chloride water and the remainder of water. While looking on a seasonal scale we noticed a variation of the quality of water. This variation remains dependent on the following parameters:

- piezometric proximity of the level compared to the surface of the ground,
- lithologic formation (change rather frequent of the quality),
- effective infiltration which conditions the refill of the aquifer [HANI 2003].

This interpretation given some idea for the variation of water quality but do not explain the variation observed. So, now we use the second method using the Tichel diagrams.

THE PIPER DIAGRAMS FOR ALL DATA (FROM 2010 TO 2012)

The Piper diagram of the superficial aquifer of Annaba and Lake Fetzara (Fig. 5a, 5b) shows that, in general, the samples concentrate on the sodic and chlorinated poles showing a sodic chlorinated facies domination. We notice that some samples are rich in calcium and chlorides showing the presence of a second calcic chloride water type. In the aquifer of the Lake Fetzara, three families water seem to exist (Fig. 5a, 5b): a calcic chloride type; the calcic sulphated

type; and a hydro carbonated calcic type. The presence of these three facies is related [DEBIECHE 2002] to the sources of supply of the lake (Wadi Mellah, Wadi El Hout and Wadi Zied).

The Piper diagrams show a variability of the chemical facies of the distributed water on three principal poles (3 cations and 3 anions).

1. A salt pole characterizing the sodic chloride facies produced either by marine water or by the presence of evaporated formations, in deep geological layers.

2. A gypsum pole at the origin of the calcic sulphate facies, generated by the gypsum formations which undergo dissolution.

3. A carbonated pole at the origin of the calcic bicarbonate facies due to the scrubbing and the dissolution of metamorphic limestone (cipolin marbles) of the near Edough complex. The interpretation of the Piper diagrams shows the presence of two poles. This enables us to seek the origin of these elements and their contribution to the gain of water salinity.

To assess the element evolution between two periods, we used the Tichel diagram and we compared the results obtained.

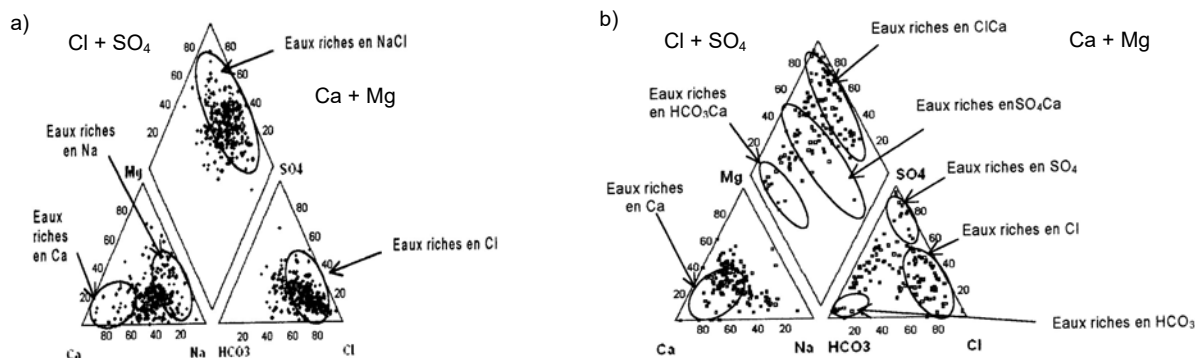


Fig. 5. Piper diagram of the superficial aquifer a) of Annaba (2010–2012), b) of Lake Fetzara (2010–2012); source: own study

TICKEL DIAGRAMS

We notice some variations between chemical analyses. The Tichel diagram (Fig. 6) confirms the result obtained by Piper diagram. So, we notice a seasonal variation of water quality between summer and winter at 2012. In summer, the salinity is very high because the evaporation is more important. In winter, we observe the contrary because the precipitations are important and the dilutions generate low salinity DJABRI [2013]. In the last years, we observed a decrease of the precipitation in winter. This situation emphasizes the salinity of water because the exchange between rocks and water is weak and the dilution is not important. The dominant facies are chloride and sodium. This repartition is caused by geological formations. The dilution is the principal factor causing this quality.

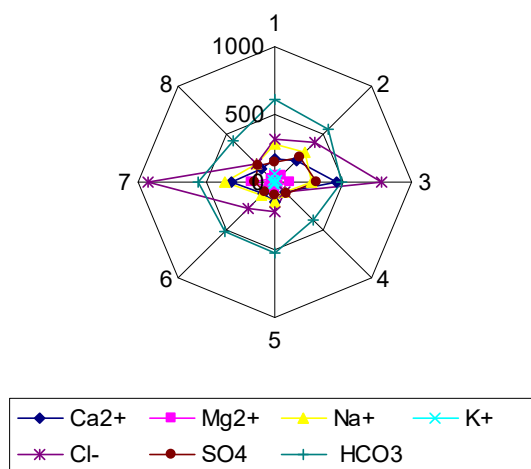


Fig. 6. Tichel diagram between summer and winter 2012; source: own study

CONCLUSIONS

This work is realised in a region characterized by a Mediterranean climate. In the last ten years, we noticed an elevation of the temperatures which caused a salinity of water. In the superficial aquifer, the salinity is more important because of the low water depth. Between two seasons, the water quality changes: in the first season, the sodium and chloride are present; in the second one, the calcium and carbonate dominate. The heterogeneity of the formations explains the variations of water quality in the deep aquifer.

REFERENCES

- AOUN SEBAÏTI B. 2010. Study of the water's salinity and modelization of the aquifer system of Annaba. PhD thesis. Annaba University pp. 185.
- BARAKAT A., EL BAGHDADI M., MEDDAH R., RAIS J., NADDEM S., AFDALI M. 2013. Evaluation of water quality in open channels flowing through Beni-Mellal City (Morocco). *Journal of Water and Land Development*. No. 19 p. 3–11.
- BENRABAH S., ATTOUI B., HANNOUCH M. 2016. Characterization of groundwater quality destined for drinking water supply of Khenchela City (eastern Algeria). *Journal of Water and Land Development*. No. 30 p. 13–20. DOI 10.1515/jwld-2016-0016.
- BOUGHERIRA N., HANI A., DJABRI L., TOUMI F., CHAFFAI H., HAIED N., NECHEMA D., SEDRATI N. 2014. Impact of the urban and industrial waste water on surface and groundwater, in the region of Annaba (Algeria). *Energy Procedia*. Vol. 50 p. 692–701.
- DEBIECHE H. 2002. Evolution of the water's quality (salt levels, azotes and heavy metals) influenced by industrial, agricultural and salt pollution: Application for the lower plains of Seybouse, Algerian NE. PhD thesis. Franche-Comte University pp. 200.
- DJABRI L., BOUHSINA S., HANI A., BOSCH A.P., MUDRY J., DJOUAMAA M.C. 2014. Impacts of drought on water quality: The case of aquifers in eastern Algeria. *Evolving Water Resources Systems: Understanding, Predicting and Managing Water–Society Interactions Proceedings of ICWRS2014*, Bologna, Italy, IAHS Publ. pp. 364. *Proceedings of the International Association of Hydrological Sciences*. Vol. 364 p. 357–362.
- DJABRI L. 2013. Mechanism of Seybouse water pollution and vulnerability – geological, industrial, agricultural and urban origins. PhD thesis. Annaba University pp. 176.
- HABES S. 2013. Chemical characteristics of a lake belonging to wetland ecosystems in northern Algeria; Case: Lake Fetzara, North-East Algerian. PhD thesis. Annaba University pp. 211.
- HANI A. 2003. Methodological examination of anthropological structure and process, application for Mediterranean coastal basin water sources. PhD thesis. Annaba University pp. 213.
- ZENATI N. 2010. Groundwater–lake relationship, confirmed by hydrochemistry. Case of the surface groundwater of the West Plain of El-Hadjar–Fetzara Lake, NE Algerian. PhD thesis. Annaba University pp. 165.

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Badania hydrochemiczne systemu poziomów wodonośnych Drean–Annaba (północnowschodnia Algieria)

STRESZCZENIE

W systemie aluwialnych poziomów wodonośnych Drean–Annaba jakość wody podlega częstym zmianom. Oddziaływania woda–podłoże skalne nie mogą być jedynymi procesami odpowiedzialnymi za obserwowane zmiany, natomiast susze, jakich kraj doświadczał w ciągu minionych dwóch dziesięcioleciach znacząco przyczyniły się do zmian jakości wody. W tym okresie obserwowano nieregularny rozkład opadów w czasie i przestrzeni. W konsekwencji zanotowano okresowość zmian hydrochemicznych właściwości wody w studniach i rzekach. Użyto statystycznych narzędzi, takich jak analiza składników głównych (PCA) i diagram Tickela do prezentacji wymienionych efektów. Uzyskane wyniki dowodzą sezonowych zmian jakości wody w okresie 1999–2000. W odniesieniu do kationów wykazano konkurencję pomiędzy pierwiastkami alkalicznymi i pierwiastkami ziem alkalicznych. W grupie anionów stwierdzono przejście od chlorków do siarczanów i prawdopodobnie do wodorowęglanów.

Przedstawione badania prowadzono na stosunkowo małym obszarze, co okazało się korzystne dla wykazania zależności pomiędzy suszą a jakością wody zarówno w systemie poziomów wodonośnych, jak i w wodach powierzchniowych.

Słowa kluczowe: *Algieria, Annaba, Drean, jakość wody, parametry hydrochemiczne, poziom wodonośny*