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Water resources and its quality in arid and semi arid areas: the case of the NW of Algeria

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Abstract

Hydrogeological and hydrochemical investigations were carried out to evaluate the groundwater resources and their quality in the North-west of Algeria. The studied aquifers are Maghnia and Zriga, Ain Sefra and Bechar-Abadla. The water types of these aquifers are dominated by sulphate and chloride. Climatic conditions and geological characteristics seem affecting the physico-chemical properties of ground waters. The concentrations of water in dissolved elements are controlled especially by evaporation and weathering of evaporitic and saline formations, the majority values of conductivity and hardness are higher than WHO drinking standards, as well as concentrations in certain ions as Na^+, Cl^- and SO_4^{2-}.

Keywords: Algeria, water resources, aridity, evaporitic formation, drinking water.

Introduction

This study deals with hydrogeological investigations and the evaluation of physical and chemical characteristics of some groundwater in some selected areas in the NW of Algeria taking in account the WHO

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standards for drinking water. Several of the inorganic elements found in drinking-water for which guideline values have been recommended are recognized to be essential elements in human nutrition and most of them are of health concern only after extended exposure of years, rather than months.

Some substances of health concern have effects on the taste, odour or appearance of drinking-water that would normally lead to rejection of water at concentrations significantly lower than those of concern for health. Such substances are not normally appropriate for routine monitoring (WHO 2004).

In countries located in arid and semi-arid zones, like Algeria, and known for their scanty annual rainfall and very high rates of evaporation, water resources are consequently extremely insufficient and water quality used for consumption are, in most cases, highly mineralized.

Only a portion of these water resources is demineralised by the reverse osmosis process before being distributed to Oran city. The production of the demineralised water (35000 m^3/day) represents only 20 % of the total consumption of this town (Dahmani et Bithorel 2001, Chabane 2008, Chabane et al. 2008).

General settings

Maghnia and Zriga plains

Maghnia and Zriga plains are located in the NW of Algeria (Figure 1). They cover a surface of more than 400 km². They are characterized by a climate of semi arid type with fresh winter (mean annual rainfall of 300mm and potential evaporation of more than 800 mm/year) (Zerrouki and Zenagui 2006).

Both plains are the result of a sediment filling of plioquaternary age with variable thickness and very heterogeneous content. It is represented by clays, fine and coarse sands, gravel, pebbles and lacustrine limestone.

These formations contain an unconfined aquifer resting on a marly substratum which appear on the surface at the edge of the plain and sank in the alluvial formations.

The water flows from North to South and the permeability values vary between 6×10^{-5} m/s North (Zriga plain) to South (Maghnia Plain) and 3.5×10^{-4} m/s (Zerrouki and Zenagui 2006).

Bredeah plain

Bredeah plain is located southwest of Oran city. Its climate is of semi arid type with a mean annual rainfall of 323 mm (Yebdri 2005). Two aquifers are encountered in the Miocene and the quaternary formations. Both aquifers are juxtaposed and their waters are in constant communication following complex hydrodynamic characteristics and multiple feeds.

The Miocene aquifer lays in the limestone formations of Murdjadjo (heterogeneous limestone, reef limestone, limestone with algae) which are based on marl or schist (Benziane 1984). It is unconfined in North and may become confined under Sebkha depression.

This aquifer provides a thickness of a hundred meters on average and is recharged directly by an impluvium with an area of about 135 km² (Benziane 1984), and extends from the Sebkha and its groundwater is contained in heterogeneous alluvia. The piezometric surface is of very shallow depth: it is situated between 2 and 3 meters.

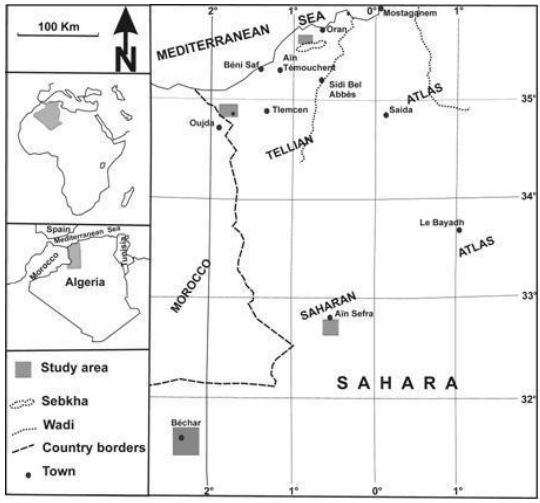

Figure1. Situation of studied aquifers

Aïn Sefra

Aïn Sefra area belongs to western part of the Saharan Atlas. Its climate has been identified as dominantly of arid nature. It is characterized by a climate of Saharan type with cold winter, a mean annual rainfall of 139 mm, a mean annual temperature of 21.3°C and a potential evapotranspiration of more than 590 mm/year. Rainfall distribution throughout the year and the months is quite uneven, and most of the precipitation is brought during spring season with 17 mm (39 % of annual precipitations) (Bensefia and Benali 2002, Benali and Alaoui 2002).

The most important aquifer, in this region, is situated in the barremo-albo-aptian formations which are represented, principally, by sandstones "Tiout formation" with a thickness of 1500 meters (Bassoulet 1973). This aquifer is characterized by a transmisivity of 7.6×10^{-4} m²/s.

Bechar-Abadla area

Bechar-Abadla area is located on the South side of the Saharan Atlas between latitudes 32°N and 30°30 N and longitudes 3°30W and 1°30W. The climate of this region is of Saharan nature and the mean annual rainfall vary, North to South, between 40 and 80. Rainfall distribution throughout the year is quite uneven, and most of the precipitation is brought during autumn (Hadji 2003).

Several aquifers have been identified in the Bechar-Abadla areas: they are contained in the limestone and sandstones formations of Carboniferous, limestone of Turonian and Eocene and alluvia of Guir, Bechar and Zousfana wadis and the quaternary calcareous covers (Schoeller 1945, Deleau 1955a, Deleau 1955b, Roche 1967, Roche 1968, Hadji 2003).

The lower aquifer of the Carboniferous is represented by limestone and has flows varying between 1.5 to 7 l/s and transmissivity values between 2×10^{-3} and 7×10^{-4} m²/s. The sandy aquifers of Upper Carboniferous are represented by the sandy and marly formations with rare limestone intercalations. The thickness of this formation is 3000 meters in the Abadla basin. The flow varies from 0.1 l/s in the Chebket-Mennouna

area to 5 l/s in the Bechar one. These water-table depths do not exceed 10 meters in Bechar zone and less in the North and particularly in Kenadsa zone.

The aquifer of Turonian limestone has flows varying between 2 and 35 L/s and transmissivity between 10^{-3} and 10^{-2} m²/s.This calcareous aquifer, of a thickness varying from 25 to 45 m, rests on a marly substratum (45 to 50 m) of Cenomanian age and is limited in his upper part by Senonian sandy marls (700-800 m) containing evaporitic formations (gypsum, anhydrite and salts).

The limestone aquifer of the Upper Eocene ($T = 2.5 \times 10^{-4}$ m²/s) has flow values ranging between 2.6 and 5 l/s. Its extension is of 800 km^2 and its maximum thickness is approximately of 60m. Aquifers of Guir, Bechar and Zousfana wadis and quaternary calcareous covers are related to the wadis alluvia and quaternary limestone.

Materials and Methods

This study deals with the physical and chemical characteristics and the spatial variability of some groundwater in selected areas in the NW of Algeria taking in account the WHO standards for drinking water. Analysis of Na^+, K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-} Cl^- and HCO_3^- was carried out on at more than 200 wells distributed in different aquifers.

Four areas were selected according to a NS transect in NW of Algeria. The data comes from works carried out during the 2001-2006 period during which groundwater samples from areas cited above were collected (Benali and Alaoui 2002, Bensefia and Benali 2002, Hadji 2003, Yebdri 2005). In the field, analysis of water samples included temperature, electrical conductuvity, TDS and pH. Major anions (Cl^-, SO_4^{2-}, HCO_3^-), major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and nitrate were analyzed.

Results and Discussions

Tables 1 and 2 illustrate minimum and maximum values of analyzed parameters obtained at the sampling points and Table 3 summarizes the percentages of wells where ions contents are above the standards of drinking water.

Maghnia and Zriga plains

The results of the water analyses, on the totality of the zone, allowed us to emphasize two principal types of chemical facies represented by the chloride-sodic and the chloride-magnesian one. The conductivity, whose values range between 800 and 9200 µS/cm, is influenced especially by the strong sodium, chloride and sulphate contents. The values of the total dissolved salts (TDS) are higher than 1g/l and exceed 4 g/l and the highest concentrations in sodium and chloride ions were localised in the western area (Plain of Zriga). For the majority of the waterholes, the values of conductivity are higher than the standards recommended by the World Health Organization (WHO), as well as the concentrations in certain ions, in particular Na^+, Cl^-, $SO4_2^-$ and NO_3^- for which the contents reach respectively 1432 mg/l, 2382 mg/l, 835mg/l and 70 mg/l (Table 2). Two types of hydrochemical facies have been identified in these groundwater plains: the NaCl (55 %) and $MgCl_2$ (42 %) (Figure 2). In the totality of the wells, chloride ions are above the drinking standards (Table 3).

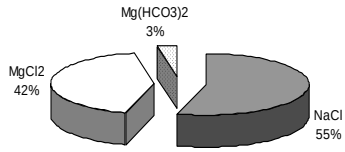

Figure 2. Percentages of hydrochemical facies in Maghnia and Zriga plains

Bredeah Plain

Groundwater of Bredeah Plain flows in two superimposed formations (Benziane 1984, Benlekhal 1985, Djebbari and Madani 1994) and whose waters are of different qualities. These are the brackish waters of the Plio-Quaternary aquifer and freshwater from the Miocene limestone. This water is demineralised by the reverse osmosis process to feed Ain-Temouchent and Oran cities (the daily production is of 35 000m^3) with drinking water (Dahmani and Bithorel 2001, Chabane 2008). However, in others cities, this groundwater is used for human consumption without prior treatment. Groundwater salinity (which reaches 7370 mg/L) and

conductivity of the Quaternary aquifer are very high unlike to those of waters flowing through the Miocene limestone. Groundwater is harsh, of poor quality and with taste.

Table 1. Minimum and maximum values of physico-chemical parameters

Areas	**EC (µS/cm)**	**pH**	**T (^{0}C)**	**TH (mg/L)**	**TDS (mg/L)**
Maghnia and Zriga	800-9200	6.8-8.2	19-22.5	390-1630	1050-3720
Bredeah	987-14440	5.2-7.01	18-25.5	168-1120	530-6788
Ain Sefra	-	06.09.1930	18.05.2029	267.5-1690	496-4259
Bechar-Abadla	525-7556	-	17-33	-	345-4849
Standards	333-833	6.5-8.5	-	500	-

In Bredeah plain the minimal value of conductivity is of 987 µS/cm in a well tapping groundwater of the Miocene limestone. The maximal value is of 14440 µS/cm. 100 % of the wells groundwater has an electrical conductivity above WHO standards and 58 % of them have a ph below 6.5.10.5 % of the water sampled have a hardness below the WHO standards which is of 500 mg/l. Contents of some ions, including chlorides (95 %), sulphates (95 %) and nitrates (35 %) are generally higher and exceed the standards prescribed by the World Health for human consumption (Table 3).

Table 2. Minimum and maximum of ions contents

Areas	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}
Maghnia and Zriga	70 -288	37-231	35-1432	1-20	237-642	5-835	136-2382	6-70
Bredeah Plain	64-712	104-568	-	4-20.9	64-573	140-1695	120-2769	13-68.6
Ain Sefra	10-832	24-560	14-1145	-	149-309	175-2255	27-2477	8-70
Bechar-Abadla	6-409	4-333	6-900	-	49-445	7-1465	14-1496	-

Table 3. Percentages of wells above the standards of drinking water for each ion

Areas	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}
Maghnia and Zriga	0	16	54.5	12.1	12.1	36.4	100	31
Bredeah	79	74	-	60	31.6	95	95	35
Ain Sefra	12.7	6,3	16.7	-	34	8	53.2	28
Bechar-Abadla	1	5	16	34	0	25	30	-
Standards	400	150	200	12	400	250	250	50

Ain Sefra plain

Various types of water were individualized in this zone. The chemical facies of the Ca-SO_4 and Ca $(HCO_3)_2$ types dominate in this aquifer with respectively 31 % and 23 % (Figure 3). These groundwater are characterized by a salinity ranging between 0.65 and 7.2g/L. The sulphate and chloride ions contribute significantly to the anion composition of this water and reach respectively the 2.25 and 2.45 g/L (Table 2).

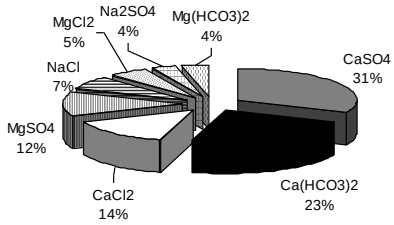

Figure 3. Percentages of hydrochemical facies in Aïn Sefra area

Contents of chloride (53.2 %), bicarbonate (34 %) and nitrates (28 %) and the hardness (64.5 %) are generally higher and exceed the standards prescribed by the World Health for human consumption (Table 3).

Bechar-Abadla plain

Values of conductivity are very high and respectively reach 3489, 4492, 2212 and 7556 µS/cm in aquifers of carboniferous limestone, turonian limestone, Eocene and those of the underflows of wadis. The contents of cations vary between 6 and 900 mg/l for sodium, 6 and 409 mg/l for calcium and 4 and 333 mg/l for magnesium. The lowest sodium contents are those of water of the underflow of the Bechar wadi and those of the quaternary covers of the basin of Bechar-Kenadsa.

For this same cation, the highest concentrations were observed in water of carboniferous and Turonian limestones with the maximum respectively of 695 and 806 mg/l, the under flows of Guir (900 mg/l) and of Zousfana (545 mg/l).

The content of anions follows that of the cations roughly; it varies between 14 and 1796 mg/l for chlorides, 7 and 1465 mg/l for sulphates

and 49 and 445 mg/l for bicarbonates. Very important concentrations in chloride ions were observed in groundwater of the carboniferous sandstones (1028 mg/l), and Turonian limestones (1340 mg/l) and in those of Guir and Zousfana underflows with the maximum respectively of 1796 mg/l and 780mg/l.

With regard to sulphates, the highest contents were localised in Turonian groundwater with a concentration of 997 mg/l and in those of Guir and Zousfana underflows with the maximum respectively of 1300 mg/l and 1465 mg/l.

Various hydrochemical facies characterize this groundwater area with dominance of the NaCl type (Figure 4). Apart bicarbonate, concentrations of other elements are above the WHO standards of drinking water (Table 3).

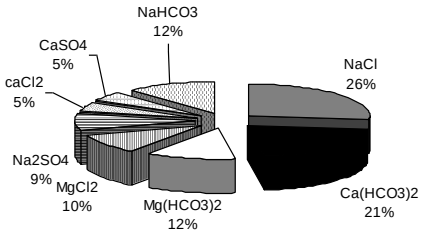

Figure 4. Percentages of hydrochemical facies in Bechar - Abadla area

Conclusion

In the studied semi-arid and arid areas, groundwater quality is influenced by many different environmental factors (high annual temperature, low precipitations, intense potential evapotranspiration and the lithological nature of the formations).

The climate conditions and the geological characteristics of the host formations appear to have affected the physico-chemical properties of these groundwaters in different ways. Groundwater salinity in some parts high and results indicate that the water types are dominated by sulphate and chloride hydrochemical facies.

In these zones where ions contents are controlled especially by the evaporation and the weathering of the evaporitic and saline formations, the majority values of conductivity and hardness are higher than the WHO drinking standards, as well as the concentrations in some ions, in particular, Na^+, Cl^-, SO_4^{2-} and NO_3^-.

Acknowledgments

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