ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Earth and Planetary Science 7 (2013) 44 – 48
Procedia Earth and Planetary Science

Water Rock Interaction [WRI 14]

Preliminary study of the groundwater geochemistry in the sub-desert area in Morocco: case of the Ziz-Ghris basins

T. Bahaj[a*], I. Kacimi, M. Hilali[b], N. Kassou[a], A. Mahboub[b]

[a]*University Med V, Faculty of Sciences Rabat-Agdal, Earth Sciences Department, Morocco*
[b]*University Mly Ismail, Morocco*

Abstract

The Tafilalet region has very significant economic advantages based on tourism and agriculture. This sub-desert area faces several challenges: water scarcity, intense evaporation, limited water resources, and intense agricultural development. The topic of this work is to study the non-exploited water resources in the study area and to try to understand their geochemistry. Water samples were collected from exploited shallow aquifers and the khettara system, and from thermal waters in order to explore for possible links between the different water systems.

Keywords: Tafilalet, groundwater geochemistry, thermal waters, fossil waters, heavy metals.

1. Introduction

Tafilalet lies in the southeastern Moroccan Atlas between latitudes 29°30 'and 32°30'. It occupies approximately 8.44% of the surface of Morocco and located in arid and semi-arid regions. It is bounded to the south and east by the Atlas Mountains, and by the Morocco-Algerian frontiers in the north. Like under every arid and sub-desert system, water is the precious matter that the local inhabitant does preserve and use carefully. In fact, since antiquity, the water is mainly managed by traditional water laws. It became distributed within traditional canals that are perpendicular to the superficial oueds direction (oueds Ziz and ghriss). The shallow aquifer was mostly exploited by an ancient water system distribution called *khattara* [1]. Using this system, every land owner receives a precise number of time units for the irrigation. The area of study does have other large non-exploited water resources, including surface fresh water sources, and thermal waters in the great complex of Tizi'n Test faults. The studied waters have high salinity and still unusual for any exploitation. The aim of this work is to understand the geochemistry of those waters, their extension, and the possible links existing by different aquifers, and finally to give an

* Corresponding author. Tel.: +21-266-109-0510;
E-mail address: tarikbahaj@yahoo.fr

Selection and/or peer-review under responsibility of the Organizing and Scientific Committee of WRI 14 – 2013
doi:10.1016/j.proeps.2013.03.162

idea about the water quality. Two important hydrological Basins Ziz and Rheris and occupying 27,500 km² were studied in the Tafilalet.

2. Geological data

The study area extends from the High Atlas in the north to the Anti-Atlas to the south. Its center is a part of the pre-African foredeep between the High Atlas and Anti-Atlas. The Cretaceous basin contains the Errachidia area [2]. The outcropping formations are mainly Cretaceous, they overlie the Jurassic. The stratigraphy ranges from Precambrian to Quaternary. Precambrian constitutes the eastern extension of the anti-atlas and is covered by folded layers formed during Hercynian phases. The Precambrian crops in other small areas and comprises shale, Precambrian rhyolites associated with conglomerates and sandstones assigned to the Precmbrian. The Paleozoic comprises basal schists, quartzites and some intrusive rocks. It is reduced under large anticlines or some buttonholes. The Mesozoic in the High Atlas, basalts, Triasic marls and Clay licks levels, plays an important role as substratum. The Jurassic rocks form the major representative of the lithology in the High Atlas and crops out in the northern part the of the Errachidia-Boudnib basin. The Lower Lias is calcareous and dolomitic and forms the dominant rock constituent in the High Atlas Mountains [3]. The Upper Lias sedimentation is predominantly marly limestone with alternating green marls with inter-bedded marly limestone. The Dogger has neritic facies in the Sahara becoming limestone in the area. At the end, the Dogger becomes detrital. The Jurassic is continental and detrital; it starts with heterogeneous conglomerates and sandstones. During the Cretaceous, a major transgression invaded the South Moroccan region and covers the current path south reaching the Atlas Tafilalet. It presents variations in thickness and facies. In the Upper Atlas, the Cretaceous is represented by red marls of the Cenomanian, and the Turonian comprises limestones, and ends with Cretaceous continental facies (Fig. 1).

3. Water Resources

Both oued ziz and oued ghriss basins are the most important hydrological basins in the area, they take their origin in the High Atlas mountains, they have an irregular flow. In the last decades, the Moroccan authorities built several dams in the area in order to guarantee permanent water supply for drinking and agriculture, and to preserve the oasis system and its neighbourhood from spectacular floods that occur during winter and spring [1]. Groundwater in the province of Errachidia is used by the authorities and population to ensure a permanent water supply (Fig. 1). These aquifers are located along valleys and characterized by their small size and their direct dependence on the variation of the climate and exploitation [4]. The deep aquifers that are divided from north to south into three hydrogeological units well separated: The High Atlas, the Cretaceous basin of Boudnib-Errachidia-Tinghir and the Anti-Atlas. High Atlas contains a set of hydrogeological units communicating with each other (Lias and Dogger). These aquifers give rise to several sources. The Cretaceous basin of Errachidia includes two aquifers that are from top to the bottom: The Senonian aquifer, it's artesian between Bouanane Boudnib; The Turonian limestones aquifer of which gives rise to Tifounassine sources, and Meski Tarda .Water table from the Infracenomanien (ex.Ain El Ati) is locally artesian it is drained by a complex khettaras in south of the area Goulmima Tinjdad. This water resource is not exploited due to its salinity .The layers of the Anti-Atlas are exploited by khettaras and wells [5].

4. Groundwater chemistry

4.1 Materials and methods

The distribution of the water sampled was as strategic as possible. Different physical parameters were measured during sampling: pH, electrical conductivity and the redox potential. Major elements were performed by ion chromatography, heavy and trace elements were performed by ICP-AES.

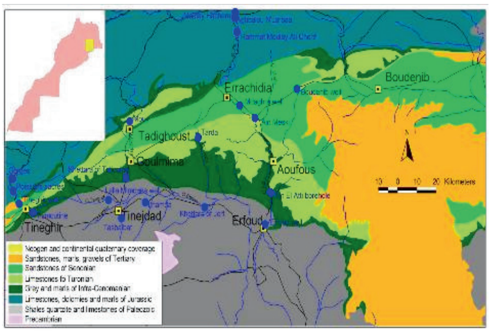

Fig. 1 geological map of the area of study with principal aquifers and the localization of the water samples situation

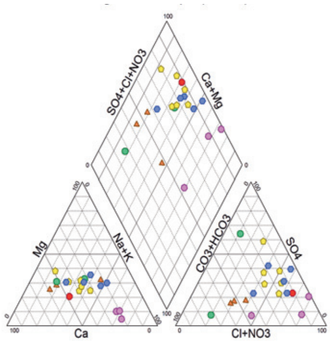

Fig. 2: Piper diagram showing the different water families.

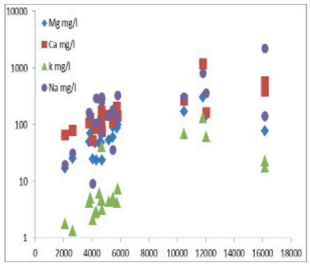

Fig. 3a: plot of TDS vs cations

4.2 Water families

The water sources in the study area have different origin and evolution in different lithologies (Fig. 2). The waters from Paleozoic and Jurassic (triangles in the Piper plot) aquifers are of HCO_3^- Ca^{2+} facies, they become richer in sulfate as they get closer to the Anti-Atlas formations, where the geological formation has intense hydrothermal activity. In some areas, mineralization on baryte, galena, and gypsum are identified on surface, the Tismoumine and Tasblbat sources flow through this mineralization. (green circles below). These waters are in equilibrium with respect to calcite, aragonite and anhydrite. The waters from the Infracenomanien, the Senonian and the quaternary aquifers show a mixed facies (yellow lozenge in the plot, except for the Ain El Ati which is in red color). They are richer in sulfate due to the lithology of the reservoir made of marls and clay. For the first aquifers, the quaternary reservoir is made by a mixture of detritus and locally by limestone. These waters are in equilibrium with respect to gypsum and dolomite. Ain El Ati is an artesian well; it flows on the surface with an average flow of 15 l/s, with a very high salinity (above 21 g/l). Both Ain El Ati and Tasblbat, show at their immediate emergence important mineral neo-formation, essentially ferromagnesian. The quaternary aquifer contains waters in equilibrium with respect to calcite, dolomite, aragonite, gypsum and anhydrite. These waters constitute the shallow aquifers, and they are mostly exploited by the inhabitants for drinking and irrigation purposes. In fact, before the construction of the Hassan Addakhil Dam, this shallow aquifer was the only water resource in the area, it was distributed by the khattara system, and used in dry season for irrigation and water supply. The last water family concerns the thermal springs in the area, they belong to the great fault system of Tizi N'firest, their temperature is between 40 °C at Hammat Moulay Ali Cherif, to 30°C in the Hammat Moulay Hachem and the Aghbalou N'Larba. These waters have a sodium-potassium and chloride facies, and they are also in equilibrium with respect to calcite, dolomite and aragonite. In this area the water's TDS is higher than the World Health Organization (WHO) recommendations for the drinking waters; it exceeds 4 grams per liter on all over the study area. (Fig. 3 a, b), the lithology of the aquifers, the residence time of the waters in subsurface and the mixture of waters with thermal waters is probably responsible of this high salinity. The long period of residence time in the study area could be responsible for the water salinity. In fact the SiO_2 weathering is a very slow process in this area, its levels are ranging from 2 and up to 16 g/l, those high levels could testimony of probable long residence time of the waters and/or an important mixture with thermal waters (Fig. 4).

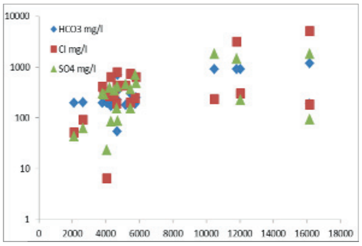

Fig. 3b: plot of TDS vs anions

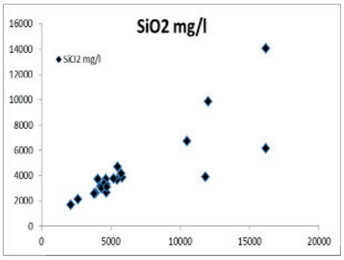

Fig. 4: plot of TDS vs SiO_2

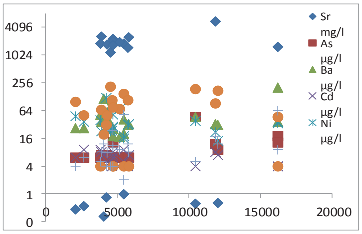

Fig. 5: plot of TDS vs trace elements and heavy metals

4.3 Heavy metals and trace elements

Iron, aluminum and magnesium have low concentrations in the waters, except for the Moulay ali cherif thermal water, the Ain El Ati artesian well and the Ain Tasblbat. For these two localities, the iron reaches very high concentrations. The redox potential for these two sources is above 0.3 V, and pH is below 6.6, the iron comes maybe form the oxidation of iron minerals at depth. Sulfate for this sample is very high and reaching for Ain El Ati 9.7 g/l. Analyses of some trace elements have been performed. Their distribution depends on their location; the most charged in heavy metals are the waters collected from areas showing traces of hydrothermal activity, except for lead, the waters do not show any diffuse mineralization (Fig. 5).

5. Water quality

The inorganic quality of the studied water is in generally bad to very bad; the natural high salinity of this water is principally responsible. Some major cations and anions exceed the recommended OMS daily value for drinking waters. Except for the thermal waters and the Ain El Ati and Tasblbat source, they could be very toxic for the biota. The presence of heavy and trace elements in these waters contribute to their poor quality (high Pb, Zn, Ba and As). The high salinity of this water will surely contribute to the soil salinization, where agriculture is the unique source of income for almost one million inhabitants. Indicators of an anthropic contamination were not found in the area except for two water samples taken from the quaternary aquifer that contained high concentrations of nitrates.

6. Conclusion

The Moroccan authorities must be careful with the water quality used for drinking and agricultural purposes, and have to elaborate programs destined to help the population to use low cost technologies that are able to reduce the salinity of the waters and optimize the water exploitation. Waters sources, like Ain El Ati from the Infracenomanian aquifer are not exploited due to bad quality, and important water volumes are lost due to the absence of water desalinization implants.

References

[1] DRH-GRZ. Etude de synthèse hydrogéologique du Haut Atlas faisant partie des bassins du Guir, Rhéris et Ziz (province d'Errachidia, Ouarzazate et Figuig). *Rapport de synthèse,* 2009; 94p.
[2] DRH-GRZ. Etude de synthèse hydrogéologique du bassin Crétacé d'Errachidia. *Rapport final,* 2006; 210 p.
[3] MICHARD A. Eléments de géologie marocaine. *Notes & Mém Serv Géo Maroc n°252* 1976: 408 p.
[4] DRH GRZ. Elaboration du bilan hydrologique des bassins de Guir, Rhéris, Ziz et Maïder, *Rapport final,* 2007.

[5] Abddelfadel F., Rachid, L., et Takhis R. Contribution à l'étude hydrogéologique de la nappe quaternaire de la région Maâdid-Erfoud (bassin de Tafilalet, Sud d'Errachidia). *Projet de fin d'étude, Faculté des Sciences et Techniques d'Errachidia,* 2011.