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Preliminary Interpretation of Environmental Isotope Data in the Ain El Atti Area (Tafilalt)

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Abstract

Present study on the sustainable use of saline land and saline groundwater for agricultural production has been conducted in the pre-Saharian area of Ain El Atti through the application of environmental isotopes supported by the hydrochemistry. In the study area, a network of 20 water points has been the focus of the isotope analysis ($\delta^{18}O$, $\delta^{2}H$, ^{3}H and ^{14}C) and physical chemistry. The samples were collected once every 3 months from artesian groundwater of "the Infracenomanian" (4), the Turonian (4), the Senonian (1) and the Quaternary aquifer (5) and from the precipitation of the years 2001, 2002 and 2003. The results show that (i) the stable isotope from the Infracenomanian is very poor and they are without tritium, confirming the fact that this aquifer is confined and it is not evaporated. Its strong salinity is due to the dissolution and the lixiviation of the geological formation; (ii) the Turonian, the Senonian and the Quaternary aquifers are not confined, and their stable isotope contents more or less as important as the tritium, signifying that they receive recent recharge. The first one is affected by the artesian well and it is not evaporated and it has high salinity. The second and the third one are not affected by the artesian well, but the influence of the precipitation and the flood is clear. Their groundwater is not evaporated and their salinity is moderate; (iii) however, the Ziz surface water isotopic elements are rich, signifying an actual recharge. Its water is highly evaporated and its salinity is variable.

Keywords: Agricultural production; Ain El Atti area; Environmental isotope data; Saline groundwater; Saline land

Introduction

The groundwater quality, its availability and its variations in intensive farming are still a concern for many users and researchers. The age and origin of these aquifers is an additional difficulty for solving scientific problems and sensitive issues of hydrogeology including current trends, development and management of water resources. Over the past 10 years, the use of isotope techniques is of economic interest with regard to the conditions of overexploitation of groundwater and identification of areas likely to provide the groundwater quality and quantity. These isotopic techniques relate to methods for determining the isotopic data subject, the residence time of groundwater and the forecast arrival of pollutants to the aquifer horizons. The resolution of these problems by hydrogeological investigations can improve the effectiveness of their implementation and accuracy of the estimated recoverable reserves of groundwater. They also increased measures to protect these reserves against pollution and overexploitation.

Geography, hydrology and hydrogeology

The region of Ain El Atti is located immediately upstream of the plain Tafilalt, about 60 km south of the city of Errachidia and 10 km north of Erfoud, in the southeastern Morocco (Figure 1). The study area has arid climate with average annual rainfall of 120 mm. Annual rainfall is variable and irregular, in the order of 129 mm in the northern zone (Errachidia) and 50 mm in the southern zone (Erfoud). Autumn and spring are the rainy seasons. July is the hottest month with 37.6°C as monthly mean maximum temperature. January is the coldest with -0.8°C as monthly mean minimum temperature. The dry season extends to often months. Evaporation is very high (4,266 mm per year) with extreme values in January (121.8 mm) and July (668.3 mm) resulting in very low recharge rate of 6-3 mm during six cycle periods (1980-1986) and 44-14 mm during only one cycle period (1979-1980). From a hydrogeological (Figure 2) point of view, this area consists of a multilayer aquifer system consisting of four main aquifer levels more or less communicating them through layers of semipermeable clastic lithology Margat [1].

The quaternary alluvial deposits

The Quaternary alluvial deposits are present in the south part of the basin; they are reduced to 100 m width along the river. The recharge is mainly assured by flood waters in the river and rainfall; thickness ranges from 15 to 20 m; permeability from 10^{-3} to 3×10^{-2} ms^{-1} with sand, gravel and alluvium; transmissivity ranges from 3×10^{-3} to 9×10^{-5} m^2s^{-1} for gravel and sand horizons; the storage coefficient is 10^{-3} to 10^{-4}; mean discharge is 0.6×105 m^3 day^{-1}; free flow is 50-100 m^3 day^{-1}; hydraulic gradient is 1.7-3‰; and porosity is 5.5 to 2.5‰.

The senonian: This Senonian aquifer is located in the north part of Errachidia basin. It is a detritic layer with some sandstone, sand, red marl, gypsum, sodium chloride and limestone. The transmissivity is of the order of 5×10^{-4} m^2s^{-1}. It is mainly used as traditional wells with bandwidths from 2 to 10 Ls^{-1} as a discharge. The deepest wells (100-130 m) do not exceed 20 Ls^{-1} as a discharge. Water quality is highly variable and the dry residue varies between 0.5 and 10 gL^{-1}. The general flow direction is from north to south, with areas of preferential flow in the same direction as the Turonian. These lines convert sources from Meski, Aoufous and Tarda, which indicates that the Senonian is drained by these sources.

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The turonian: The Turonian aquifer consists mainly of fractured dolomitic limestone to a depth of 100 m; transmissivity is 10^{-3} to 2×10^{-5} m^2s^{-1}. Its recharge is done by drainage upstream and upper aquifers. They are natural outlets and are represented by the Meski-Tarda and Tifounassine. In the Ziz Valley, in addition to traditional wells, the aquifer is exploited by pumping station group, with rates varying between 60 and 100 Ls^{-1}. Apart from some wells with salinity increasing with depth, the dry residue varies between 1 and 2 gL^{-1}. The general sense of flow is from north to south. These natural outlets are presented by many springs, which contribute to agricultural development.

The infracenomanian: This artesian aquifer is made of clays and stone and gypsum sands. It is the Paleozoic bedrock as a substratum. Its recharge is done from the north border of the basin and flood influents. This aquifer is 400-600 m below the surface at the upstream of catchment area (near the dam) and close to 0 m at the upstream part of Tafilalt plain; thickness is 350 m (argillaceous liking and gypseous sands). The transmissivities are low and vary between 2×10^{-4} and 2.2×10^{-3} m^2s^{-1} Directorate of Research, Planning and Water [2]. The storage coefficient is 10^{-3} to 10^{-4}; the discharge is 0.5×10^{-5} m^3 day-1. Water quality varies greatly from one sector to another: good quality at the west of the study sector (dry residue varies from 0.8 to 1.6 gL^{-1}), brackish at Aoufous (2-3 gL^{-1}) and highly mineralized between Douira and foundation raft Erfoud (the residue reached 14.4 gL^{-1}).

Materials and Methods

Starting from the 20th of May 1997, 15 monitoring campaigns and sampling were conducted every 3 months in the study area. This monitoring includes in situ measurements of hydrodynamic (piezometric level, depth of wells, etc.) and physicochemical properties (temperature, pH, salinity indirectly using electrical conductivity, TDS and alkalinity) for a sampler of groundwater by a piezometric probe, a conductivity meter and pH meter (WTW LF-320/SA). The chemical analysis (cations and anions) was carried out in the laboratories of INRA-Rabat and the AGR-Rabat (Directorate of Management Water). The isotopic analysis was performed in the laboratory of Radiation and Isotope Application Division, PINSTECH, Islamabad, from 1997 to 2000, and Hydrology Laboratory in Vienna, Austria, during 2000 and 2004. Moreover, empty bottles (500 and 50 ml) were used to collect rainwater.

Isotope analysis

The range of $\delta^{18}O$ (-9.98 to -0.81 ‰) and of δD (-69.2 to -12.3‰) is large; it indicates that these aquifers are highly depleted Sajjad [3]. The diagrams of (Figures 3 and 4) $\delta^{18}O$ versus the date of sampling showed that water exchange occurs between the Infracenomanian and the Turonian aquifers. However, this exchange did not happen with the rest from other aquifers (Senonian, Quaternary). The diagram δD- $\delta^{18}O$

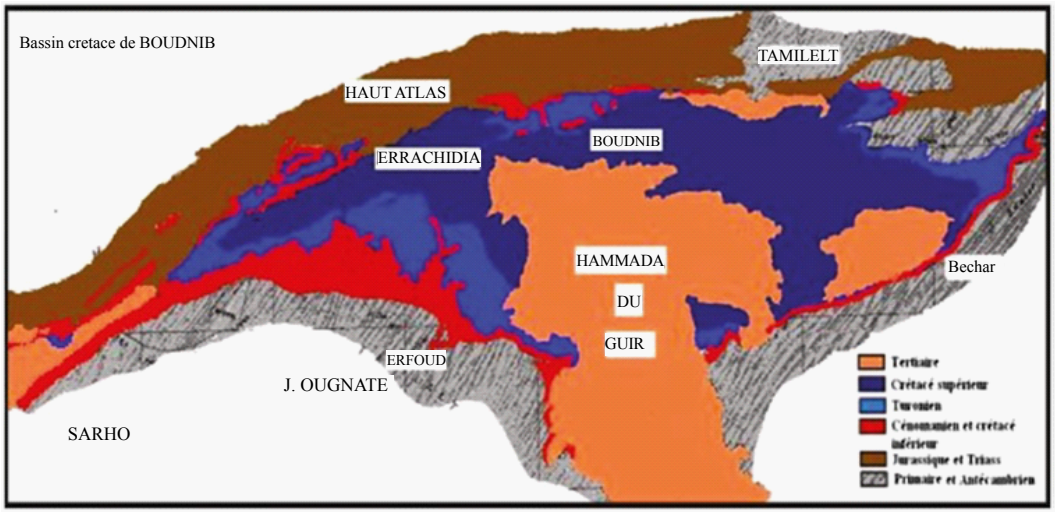

Figure 1: Location of Errachidia-Boudenib basin.

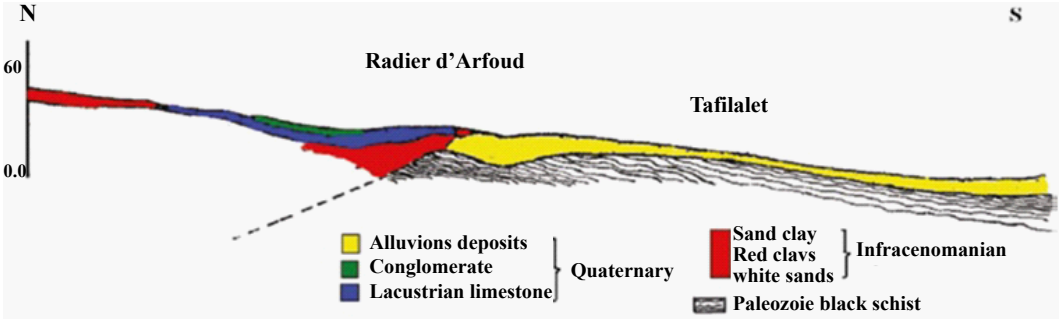

Figure 2: Interpretative geological section of the Errachidia basin.

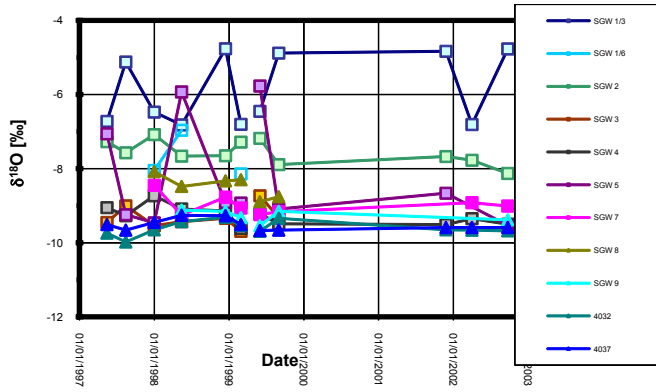

Figure 3: $\delta^{18}O$ versus date of sampling.

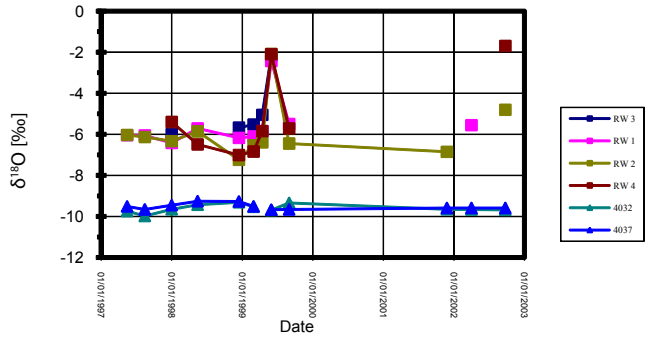

Figure 4: $\delta^{18}O$ versus date of sampling.

(Figure 5) shows that there are at least four sources of recharge Stumpp et al. [4]. The first group of water points capturing Infracenomanian "4032/57, 4037/57, SGW3 and SGW4 "located on the GMWL" is represented by two artesian wells at 100 m depth and they have almost constant discharge of 15 and 10 Ls^{-1}, respectively. They have $\delta^{18}O$ as mean value (-9.52‰). The mean δD is (-66.19‰) and d-excess is (-9.95‰). These wells are characterized as zero [0] UT indicating that these recharges are very old. It can be inferred that recharge of the aquifer is very old and the water has undergone no evaporation, d-excess [-9.95‰]. The absence of tritium [0] UT confirms that this aquifer is confined. The source of recharge is distant and is at high altitude as indicated by the values of depleted $\delta^{18}O$-CE (Figure 6). Figure 6 indicates that high salinity (EC=14.4 dS m^{-1}) is attributed to leaching from the aquifer. Artesian well number (4037/57) compared with that of the experimental station indicates that it is richer in stable isotopes and tritium, but it is less salty (EC=11.6 dS m^{-1}). In the south sector, groundwaters (SGW1/6) have the same isotopic character but are evaporated. Increasing salinity (EC=22.4 dS m^{-1}) indicates a layer in isolated pockets. The second group of items captured the Cenomanian-Turonian "SGW7 and SGW9". This point group is also low in stable isotopes, $\delta^{18}O$ [-9.54 to -8.45‰] and is located slightly below the first. Low levels of tritium from [0.40] UT, indicating an old recharge, and values of d-excess [6.84‰] indicate that the water has undergone no evaporation. This aquifer influenced by Infracenomanian has a high salinity (EC=3.6 dS m^{-1}). The third group of items captured the Senonian "SGW5 and SGW8". This point group is relatively richer in stable isotopes, -$\delta^{18}O$ (-8.89 to -8.08‰) and δD (-63.34 to -59.29‰), and away from the first group. These waters contain significant concentrations of tritium [0.92-2.65] UT, indicating a recent recharge. In addition, values of d-excess (6.91‰) indicate that the water of this aquifer is not evaporated. This aquifer is not affected by the artesian aquifer, but the effect of rainfall and floodwaters is clear. The salinity is moderate (EC=2.6 dS m^{-1}). The fourth group of items captured the Quaternary "SGW2 and SGW6". This group of points is very rich in stable isotope $\delta^{18}O$ [-7.89 to -5.65‰], and δD is [-63.34 to -47.13‰] and located near the water surface of Ziz wadi. The levels of tritium are of the order of waters of precipitation, [6.3-8.35‰] UT, indicating recent recharge. The d-excess of [7.5‰] indicates that the water of this aquifer is not evaporated. The groundwater quality is average (EC=2.5 dS m^{-1}).

Surface water

The composition of isotopic elements of the group of points of surface water RW1-4, is between -$\delta^{18}O$ [-7.01 to -2.08‰] and δD [-53.71 to -12.3‰]. The very high content of tritium [9.43] UT (Figure

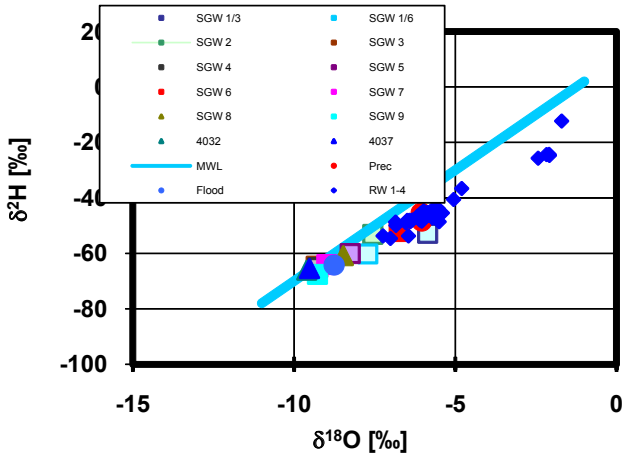

Figure 5: δD- $\delta^{18}O$ [‰]-[‰].

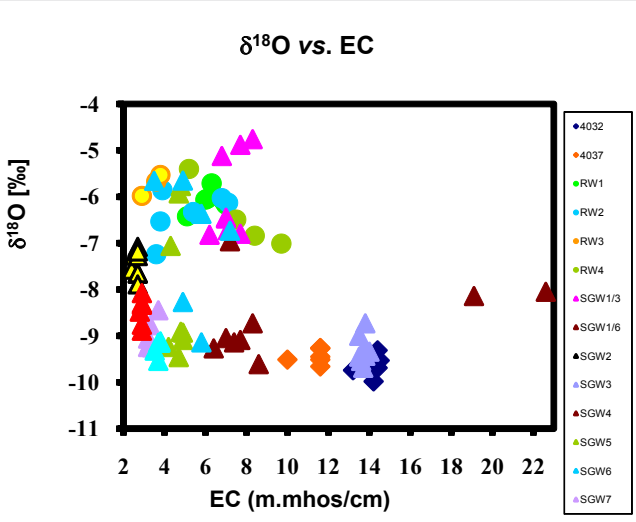

Figure 6: $\delta^{18}O$ -CE [‰]-[dS m^{-1}].

7) confirms that water is actual. This group of water points is extremely evaporated, with d-excess [0] and a variable salinity (EC: 1 to 9.7 dS m^{-1}).

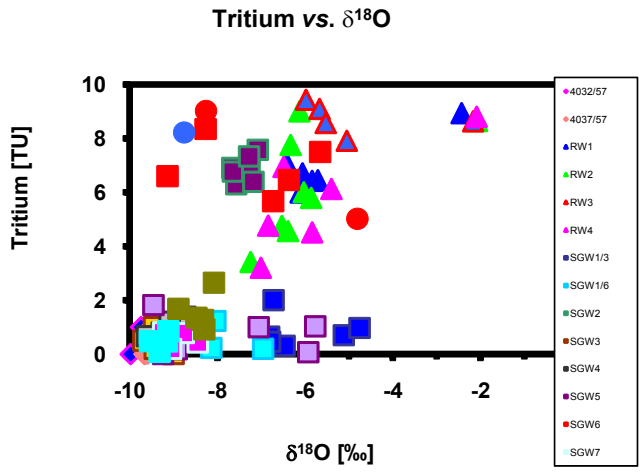

Figure 7: Tr- δ^{18}O [UT]-[‰].

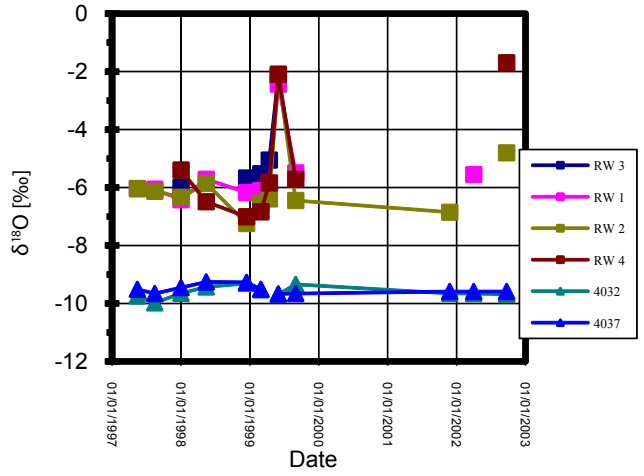

Figure 8: d-Excess– δ^{18}O [UT][‰]–[‰].

Conclusions

The area of Ain El Atti consists of a multilayer aquifer system consisting of four main aquifer levels more or less communicating them through layers of semipermeable clastic lithology. The waters are generally highly depleted. The Infracenomanian is low and stable isotopes do not contain tritium, confirming that this aquifer is confined. The source of recharge is distant and located at high altitude as indicated by the values of depleted δD and δ^{18}O. On the other hand, the aquifers of the Turonian, Senonian and Quaternary receive recharge from the recent flood of the river Ziz and local rainfall. In addition, isotopic analysis shows that water exchange occurs mainly between the aquifer and the Infracenomanian, the Turonian and in any case with other Senonian aquifers and overlying Quaternary, indicating the presence of a geological barrier. The quick response and instantaneous of these aquifers (Figure 8) to dam inflows and precipitation [5,6] is for a feed "piston flow effect" through training Turonian basin Ziz. The isotopic composition of rainwater is well correlated with the Meteoric Water Line Global (δD=8 δ^{18}O + 10). The relationship dD-8 δ^{18}O samples of surface water of the Ziz wadi coincides with the evaporative line (δD=5.74-12.55). The enrichment of wadi water (δD=-43.88 ‰ and d18O=-5.48 ‰) as a result of evaporation is evident. Increasing salinity is attributed to the dissolution and leaching of geological aquifers. Variations in isotopic δ^{18}O and tritium versus chlorides do not appear to show a clear compositions effect of evaporation. Increasing the concentration of chloride is related to the leaching of materials (sodium chloride) and/or mixing waters with the brine.

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