The Shared Resources in the North-Western Sahara Aquifer System (Algeria-Tunisia-Libya): The use of Environmental Isotopes (Algeria part)

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ABSTRACT

The North-Western Sahara Basin (NWSAS) comprises two main aquifers: the deep "Continental Intercalaire" (CI), and the "Complexe Terminal" (CT). With a surface area of approximately 1 000 000 km^2, the CI extends across three countries, Algeria,Tunisia and Libya (Fig. 1) and constitutes one of the largest groundwater systems in the world. This resource is generally considered as being "fossil", i.e. inherited from previous climatic conditions, more humid than at present, with a very limited modern recharge. This basin supplied an estimated volume of 2.2 billion m^3 fresh water for domestic water supply, agriculture and other industrial purposes. Groundwater withdrawals from the NWSAS increased from about 14 m^3/s in 1950 to $82 m^3/s$ in 2000, resulting in decreases in the natural water flows.
Over the last two decades, isotopic investigations have been carried out (^{18}O, ^{14}C, ^{36}Cl) and rare gas (He, Ne, Ar, Kr, Xe) to assess the groundwater resource potential in the Sahara of Algeria, Tunisia and Libya. The compilation of isotopic data indicate that waters from CT and CI aquifers are characterised by depleted oxygen-18 and deuterium isotope contents as compared to that of the modern rainfall. This would suggest that the modern rainfall is not recharging these ground waters. Although some sources for active recharge cannot be neglected. Different studies have shown that the NWSAS is recharged by infiltration of surface runoff around the periphery of the domain, particularly around the Saharan Atlas, the Dahar, Tadmait and Tinrhert as well as in the Great Occidental basin during years of exceptional rainfall.
The main objective of the present study, is to gather all these data and to examine how they may be interpreted in terms of groundwater residence time, recharge rate, evaporation losses can help the water managers of the three involved countries to ***develop or refine*** appropriate models. *This should facilitate the implementation of a trans-boundary integrated management of the shared resources.*

__Key words__ **:** Isotope, Shared, Water Resources, Fossil Water, Saharan Basin

1. INTRODUCTION

The North-Western Sahara Basin (figure 1) extends over much of Algeria (700.000 km2), Libya (250.000 km2) and Tunisia (80.000 km2) and is an arid region with rainfall ranging from 20 to 100 mm·yr-1. The majority of the 4 million people living in this basin depend on groundwater resources for its water needs. As groundwater abstraction increases, the need increases for more precise hydrologic data to help refine management decision tools/models on water use. As a consequence, the three countries sharing the system are endeavouring to improve the state of hydro-geologic knowledge for sustainable management of their shared groundwater resources. The purpose of this study is to document the current knowledge of the NWSAS based on recent results of isotopic investigations.

2. OBJECTIVES

The main objective of the current study is therefore, to gather essential and updated information on groundwater isotopic characteristics that would be usable by water managers of the three involved countries to *develop or refine* appropriate models. *This should facilitate the implementation of a trans-boundary integrated management of the shared resources.*

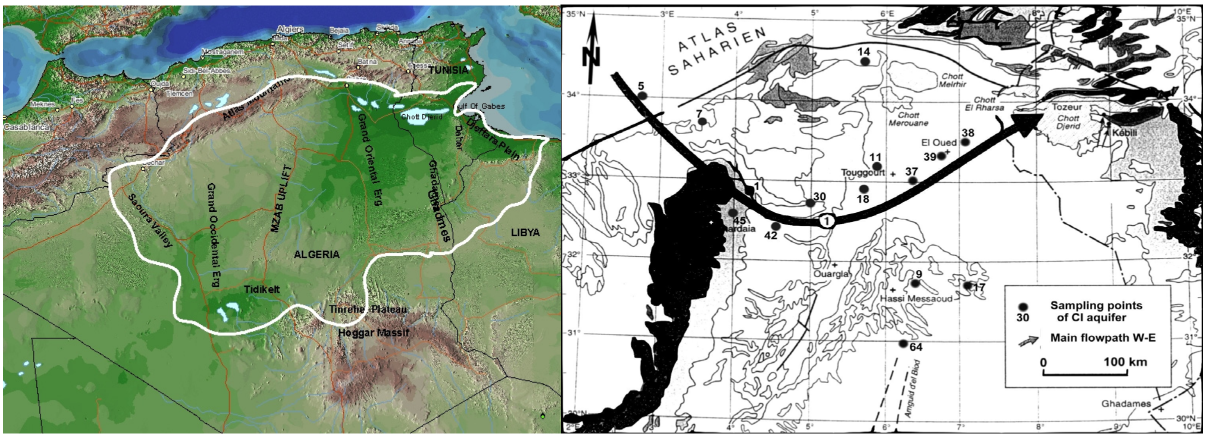

Fig.1. Map showing major basin features of the NWSAS and sampling points (Algeria part)

3.ISOTOPE RESULTS AND DISCUSSIONS

The isotopic data acquired so far from the aquifers show clear variations from one aquifer system to another reflecting differences in aquifer composition, recharge mechanisms, groundwater flow directions, groundwater age, groundwater mixing conditions, and hydraulic connections between aquifers.

3.1Stable isotopes results:

Comparison between the isotopic compositions of the aquifer systems with that of the present day rainfalls show major differences (Fig.2). Although some exceptions can be observed, the groundwaters in all the aquifer systems are generally isotopically depleted than the weighted mean isotopic composition of present day rainfall. In the Great Oriental Erg the groundwaters from the CI are the most depleted and the most isotopically homogenous, the values ranges between -5 and -9 ‰ (^{18}O) (Guendouz, 1985, Andrews, et al, 1985, Guendouz, et al,2003, Edmunds et al., 1997, 2003). The most depleted part represents the deepest and confined part of the aquifer (-7.9 and -9.0 ‰). The most enriched part of the aquifer water is limited to the recharge areas: Saharan Atlas, the Dahar mountains in Tunisia (-6 to -8.5) ‰.. However, high variability and generally enriched waters are common in the aquifers of the CI in the Occidental Erg, with ranges from -4.0‰ to -8.0‰ for ^{18}O and from -49.6‰ to -65.1 ‰ for ^{2}H. Waters of the CT aquifers have variable compositions, the majority of them plot below the GMWL following an evaporation slope. In some places, highly depleted waters from the CT are observed.

1.2 Carbon-14 activities

The carbon-14 activity shows two major trends (Guendouz, 1985, Andrews, et al, 1985, Guendouz et al, 2003, Edmunds et al.,1997, 2003). Up to 100 km from the supposed recharge zone in the Atlas Mountain detectable values were obtained (50 to 60 pmc). At distances greater than 100 km, the C-14 activity is nearly the detection limit until it reaches the Tunisian outlets where the C-14 activity reaches nearly zero.

CT aquifers generally contain variable C-14 activity though it is generally higher than that in the CI. The radiocarbon data indicate that a gradient in groundwater age exists in the main CI and CT aquifer system as one goes along the groundwater flow directions. Some tritium containing and relatively high carbon activity waters are observed in shallow unconfined aquifers and in groundwater bodies around the mountainous areas indicating the presence of modern recharge.

At the scale of the whole Sahara basin (North Africa) (Fig.3) shows that there is a depletion in heavy isotopes which is a function of age. The deep CI aquifer waters are old and depleted in ^{18}O, whereas the CT waters are younger and have more varied, but higher, δ^{18}O values. This same trend has already been observed in aquifers of the Kufra and Sirte basins in Libya. This indicates that the recharge coincides with the humid period of the late Pleistocene (20-40 ka) that has been demonstrated to have existed across the whole of northern Africa (Edmunds, W.M., Wright, E.P. (1979) Gibert 1990, Fontes and Gasse, 1991). (Gasse, F. Tehet, R. Durant, A., Gibert. E., & Fontes, J.CH., 1990)

3.1Chlorine-36 and Noble gases

Chlorine-36: Chlorine-36 contents in the CI aquifer, expressed as atomic ratio ($^{36}Cl/Cl$) and in atomic concentration ($at.l^{-1}$), vary respectively from 8_99x10^{-15} $at.at^{-1}$ and from 0.90_3.53 x10^{8} at.

The meteoric, epigene and groundwaters production of ^{36}Cl is respectively*:* 116x10^{-15} $at.at^{-1}$, 116-133x10^{-15}, and from 8-99x10^{-15} $at.at^{-1}$. The calculated ^{36}Cl residence time, for the points situated on the main flowpath (fig.1), varies between (500 and 1Mka). This increase of residence time is observed up to about 500 km from the recharge zone. (Guendouz, A. and Michelot, J.L., 2006).

Noble gases: The recharge temperatures derived from noble gases (He, Ne, Ar, Kr, Xe) for the CI samples were generally lower than the samples collection temperatures and the present day air in the areas of recharge. Along the main flow direction west to east from the Atlas mountains, the recharge temperatures range, with no noticeable spatial evolution from 14-24 °C with an average of 16.9°C. This is some to 4-5°C cooler than the present mean annual temperature in the recharge area (20°C) (Guendouz et al, 1997).

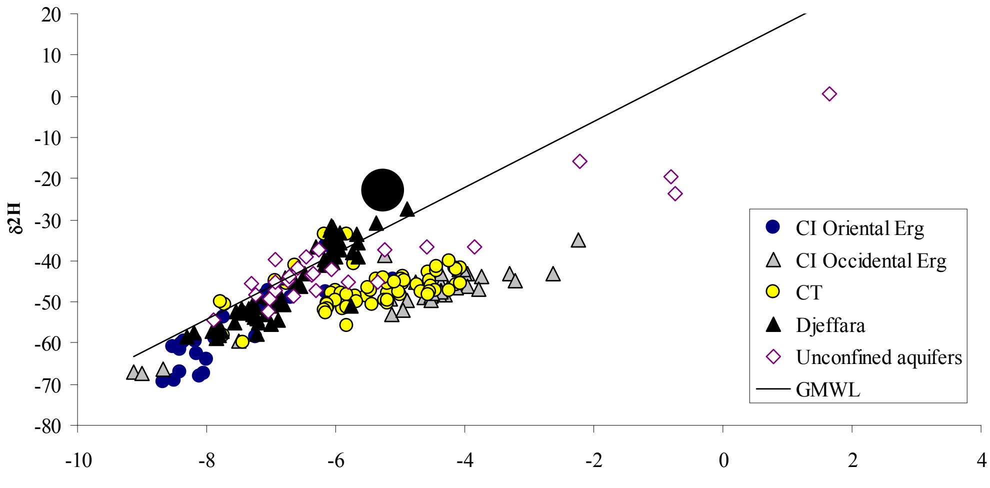

Fig.2. $\delta^{18}O$-δD plot of all water samples from the basin with respect to the GMWL and the weighted mean isotopic composition of rainfall (big circle).

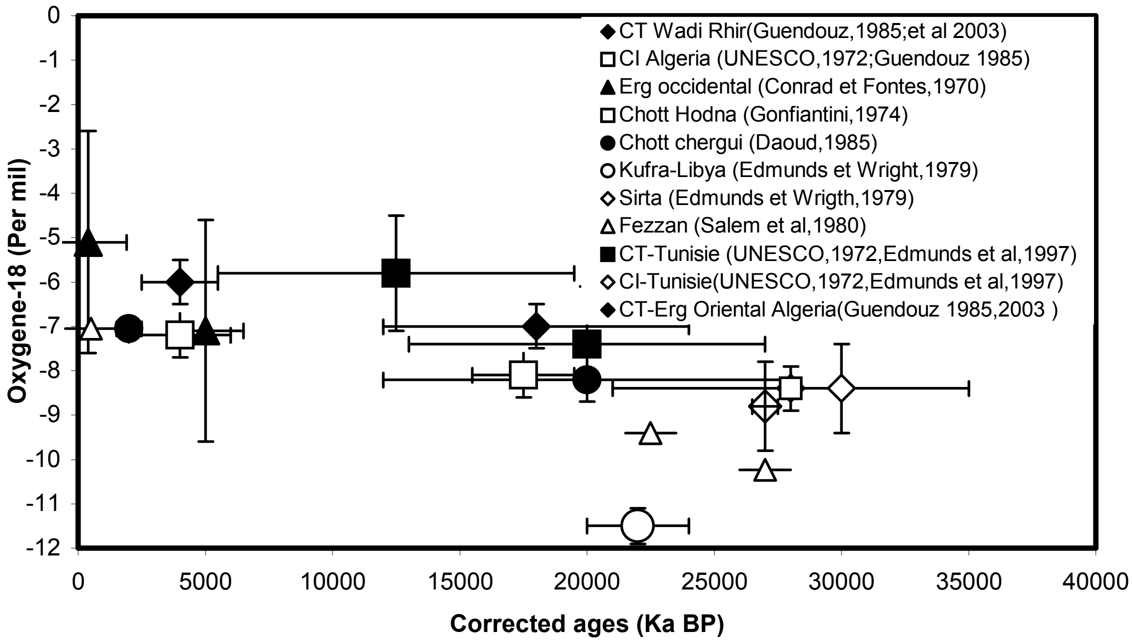

Fig.3. Plot of $\delta^{18}O$ against ^{14}C (pmc) of all groundwaters at the scale of the Saharan basin (North Africa)

4. CONCLUSION

The relationship between $\delta^{18}O$ and ^{14}C ages confirms the palaeoclimatic feature of the recharge which occurred during the humid periods of the late Pleistocene (20-40 ka) and the Holocene (0-4 ka) corresponding with what is known from past climatic records.

The estimated range of initial ratio $^{36}Cl/Cl$ was found very close to that observed for groundwater occurring elsewhere in the world. Moreover, radioactive decay accounts for the observed decrease of ^{36}Cl concentration along the main flowpath (W_E) from the Atlas mountains in Algeria to the Gulf of Gabes in the Mediterranean coast of Tunisia. This leads to age estimates up to 500 ka to more than 1 Ma.

The recharge temperatures derived from the noble gas contents in the CI were found to be 4-5°C cooler than the present mean annual air temperature. The relationship between recharge temperature and ^{14}C supports the hypothesis that these waters infiltrated during cooler, more humid climatic conditions.

The recharge temperatures derived for the CT samples, are consistent with the current annual mean ambient temperature prevailing in the recharge area of the Grand Erg Oriental, consistent with Holocene recharge. This is supported by the isotopic data, in particular the corrected radiocarbon ages (0-4ka) which imply relatively modern recharge

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