Recharge Mechanism To North-Western Sahara Aquifer System (NWSAS) Using Environmental Isotopes

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1. INTRODUCTION

1.1. Methodologies and Techniques

Palaeoclimatic condition were assessed from the isotopic composition of groundwater samples taken from the foregoing water bearing formations using stable isotopes of O-18 ,H-2, and radioactive isotopes of H-3 and C-14 .

A statistical package "SSC-Stat v2.nn" developed by Statistical Center of Reading University as well as isotope hydrology program 'Diagram" were acknowledgeably used for the analysis of isotopic data

1.2. Hydrogeological Setting

The North –Western Sahara Aquifer System(NWSAS)(Fig. 1) can be categorized as a multi-layered system of aquifers which embodies a huge stock of non-renewable, fossil water. It displays a mostly porous and fissured / fractured structure (Struckmeier / Richts 2006). Among its different layers, two have to be distinguished as being of major size and importance. The so called *Continental Intercalaire* (CI) is located on the lower level (Fig.2).

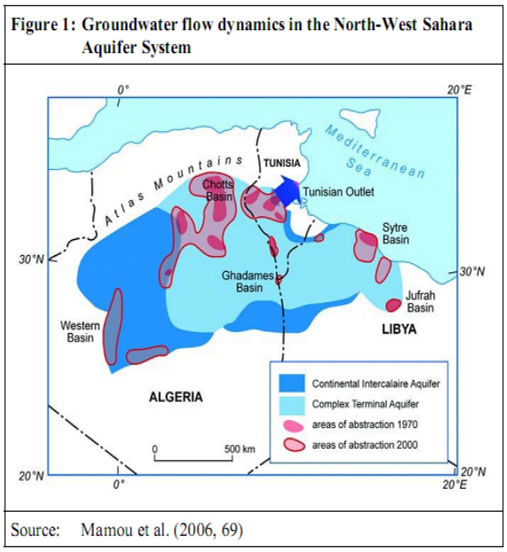

Fig.1 Location map

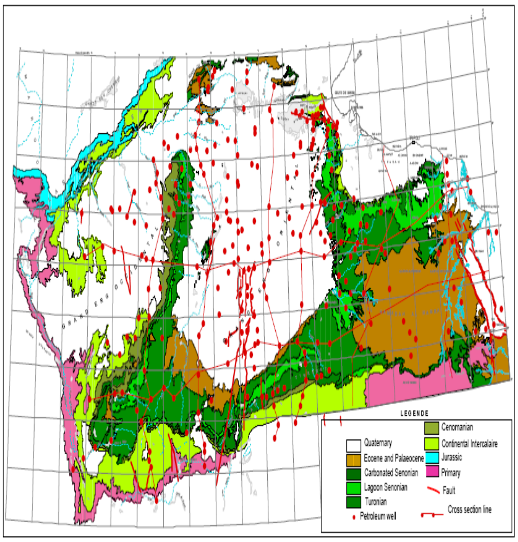

Fig.2 Geological map of NWSAS.

2. RESULTS AND DISCUSSION

2.1.Evidences Enhancing the Renewability of NWSAS

2.1.1.Statistical evidence

Isotopic data were treated using the boxplots for water isotopes of $\delta^{18}O$ and $\delta^{2}H$. The inspection of the boxplots for $\delta^{18}O$ for the three countries shows that the isotopic data of Algeria are completely skewed and to a lesser extent the data of Libya .However, the isotopic data of Tunisia are totally non-skewed.The mean value for C.I. in Lybia amounts to -8 ‰ with coefficient of variation of 14% compared to -9‰ and coeffienct of variation of 5 % for Tunisian C.I.The foregoing situation reflects a rainfall originating from homogenous air masses in both countries.However, the mean $\delta^{18}O$ for the Algerian C.I. is -7‰ with coefficient of variation of 62% which reflects non-homogeneity in isotopic data and confirm that C.I. aquifer in Algeria receive recharge originating from different air masses with different isotopic composition.

2.1.2. Geochemical evidences

2.1.2.1. Evidence using $\delta^{18}O$ - depth relationship

The relationship between depths to water level, in meters versus $\delta^{18}O$ was established. The inspection reveals a clear cut relationship in which, two isotopically different water are mixed down to depth of about 400 m, in the Libyan C.I. and that, the range of stable isotopes contents is interrupted as a result of mixing between deep water depleted in heavy isotopes with shallow modern water enriched in heavy isotopes.

2.1.2.2. Evidence using salinity - $\delta^{18}O$ relation

Salinity versus $\delta^{18}O$ was established.The inspection of this relation reveals that the isotope data in Tunisian part of aquifer in which, though the big difference in salinity, groundwater samples have the same isotopic signature no matter they present high salinity concentration or not. This implies a homogeneous mixing inside aquifers. However, this is not occurring in the whole system as can be seen in the Algerian part of aquifer where aquifer shows the same signature versus a wide range of salinity variation.

2.1.2.3. Evidence using the characteristics of d-excess

The maximum for d-excess for C.I. in *Tunisia is 10.‰ ,the minimum is 1‰ and the mean is 6 ‰ while maximum for the Algerian part of C.I.* is 11‰, Minimum is -1‰(a negative value of d – excess) and *mean is 5.45‰* .This implies that the anomalous samples are derived from local isolated moist air masses with anomalous low d values. The'd-excess' values in groundwater of C.I. are less than ten in most part of C.I.in the three countries. However, the d-excess values ~8–10‰ in Sahara Atlas in Algeria and the Dahar and the Dj. Nefoussa in Tunisia and Libya may be inherited from the precipitation. The low 'd-excess' values (≤6‰) in major part of the C.I. areas suggest that there is significant evaporation of rainwater leaving the residual groundwater with lower values of 'd-excess'.

2.1.2.4. Evidence using C-14 (pmc) and H-3 data

The frequent occurrence of significant amount of ^{14}C >2 % expressed as percent modern carbon (pmc) and ^{3}H , expressed as tritium unit (TU) in the isotopic data of NWSAS(OSS internal report,Vol. II/annex 8) should be attributed to a mixing with shallow and modern water, where old water practically contains neither ^{14}C nor ^{3}H.

2.1.2.5. Evidence using the conventional relationship of $\delta^{18}O$ and δD

Most of the groundwater samples of C.I.in Libya plot on the GMWL while a considerable number plot slightly below the GMWL , and has thus a lower slope than GMWL. The slight deviation of C.I .of Libya samples from the GMWL suggests that some evaporation occurs prior to or during infiltration, or that recharge represents a mixture of isotopically enriched and depleted waters.

2.1.3..Hydrologic evidences

The groundwater flows at velocities between 0.1 meter per day and 1 meter per year (Foster/ Margat / Droubi 2006; Mamou et al. 2006) represents a real mismatch. In the latter case it would take recharge water which entered the NWSAS on its western border, nearly 2 million years to reach its eastern border and **900,000** years to travel from the south to the north and would therefore, contradicts the fact of having frequent data of pmc up to 60 % and Tritium data up to 16 T.U., which corresponds to an age resolution of about ± 16 to ± 40 years. Even at a speed of 1 m/day, a full turn –over of the present water stock will therefore never occur within human life time dimensions.

3. CONCLUSIONS

Isotopic data interpreted in conjunction with conventional hydrologic data has confirmed the fact that NWSAS is receiving a considerable fraction of modern water recharging the aquifer. This was clearly indicated by the frequent occurrences of significant amount ^{14}C >2 % pmc, ^{3}H ≥5 T.U. and the abnormally low values of d-excess (-1‰).

Accordingly, the description of NWSAS as non renewable, devoid of any meaningful recharge , a rather stagnant water body, disconnected from any surface water body in addition to its classification as "non-renewable" would therefore be misleading and represents one of the most obvious inaccuracy as well.

SELECTED REFERENCES

Besbes, M.(2004): Conceptual framework of the North-Western Sahara Aquifer System", in: B. Appelgren (ed.): Managing Shared Aquifer Resources in Africa, Paris: United Nations Educational, Scientific and Cultural Organization(*IHP-VI Series on Groundwater 8), 163-70*

*Bied-Charreton, M. (*2002): Le System Aquifere du Sahara Septentrional": Une conscience de bassin. Synthese de la premiere phase du projet `OSS/SASS´;online: http://www.csf-ertification.org/catalogue/2002_Synthese_OSS_SASS.pdf(accessed: 7 Aug. 2007)

Cappa, C.D., Hendricks, M.B., DePaolo, D.J., Cohen, R.C.(2003): Isotopic fractionation of water during evaporation. *Journal of Geophysical Research-Atmospheres 108 (D16),1–10.*

Eckstein, G., Eckstein,Y.(2003): A hydrogeological approach to transboundary ground water resources and international law, in: *American University InternationalLaw Review* 19, 201–58

Foster, S., Margat,J., Droubi,A.(2006): Concept and importance of nonrenewable resources, in: S. Foster / D. P. Loucks, Non-renewable GroundwaterResources: A guidebook on socially sustainable management for waterpolicymakers, Paris: United Nations Educational, Scientific and Cultural Organization(IHP-*VI Series on Groundwater 10), 13–2*

Mamou, A.(2006):North-Western Sahara Aquifer System (NWSAS), in: S.Foster / D. P. Loucks (eds.), Non-renewable Groundwater Resources: A guidebookon socially sustainable management for water-policy makers, Paris:United Nations Educational, Scientific and Cultural Organization (*IHP-VI Serieson Groundwater 10), 68–74*.