USE OF ISOTOPES TO IDENTIFY SALINE GROUNDWATER RECHARGE IN THE MERGUELLIL RIVER BASIN (TUNISIA): IMPLICATION OF DAM RESERVOIR WATER ACCOUNTING

Lassaad Dassi [1,2] , Kamel Zouari [1]
[1] Ecole National d'Ingénieurs de Sfax, BP : W. 3038 Sfax, Tunisie
[2] GSF-National Research Centre D-85764, Munich, Germany

INTRODUCTION

The Merguellil river basin, which covers an area of 1330 km^2, is located in central Tunisia between the longitudes 9°50' and 10°30'E, and the latitudes 39°50' and 39°70'N. It is characterized by a semi-arid "Mediterranean" climate, with mean annual precipitation of 340 mm and mean annual temperature of 19 °C.

In this basin, the groundwater aquifer is lodged in the Tertiary and Quaternary detrital sedimentation, which consists of clay, sand and gravel. Since the late 1970s, urban and agricultural expansions have caused an ever-growing need for fresh water. These expansions have generated a steady increase in groundwater withdrawal. This latter has raised concerns relating to the effects of the numerous new implemented wells have on this valuable groundwater resource since amount of replenishment has not been ascertain. Within this context, the Tunisian government had undertaken a strategy of mobilizing the surface water runoff in the region by constructing the Haouarb dam (in 1989) in the Merguellil Wadi course. This dam was constructed in order to impulse artificial recharge of the aquifer system, and also to prevent the region from the periodic floodings during the rainy season.

Despite this water development scheme, an acute environmental problem of groundwater salinization arose in the western part of the basin, close to the Haouareb dam, which has put a strain on the existing fresh water.

In order to analyse the relationship between the dam reservoir water and the groundwater salinization, an isotopic study using stable ($\delta^{18}O$, $\delta^{2}H$) and radiogenic (^{3}H, ^{14}C) isotopes was performed with the primary goal of determining whether the dam water is recharging the aquifer with saline water. In addition to this goal, the investigation aimed to identify the origin, age and mixing process in the Merguellil basin in order to have a better insight of the aquifer system functioning for viable long-term groundwater development in the region.

MATERIAL AND METHODS

A set of 32 groundwater samples was collected from boreholes tapping the aquifer at depth between 90 and 700 m. The groundwater sampling network was completed by 2 dam water samples collected in September and November 1999.

Stable isotopes ($^{18}O/^{16}O$ and $^{2}H/^{1}H$) and Tritium analyses were performed at the laboratory of the International Agency of Atomic Energy (IAEA) in Vienna. Radiocarbon analyses were done at the laboratory of Radio-analyses and Environment/National Engineering College of Sfax (ENIS) in Tunisia.

RESULTS AND DISCUSSION

1. Stable isotopes ^{18}O, ^{2}H

Stable isotopes in the groundwater show a wide range varying from -5.6 to -2.5 for $\delta^{18}O$ and from -37 to -24 for $\delta^{2}H$. The spatial distribution of $\delta^{18}O$ shows a gradual depletion from the southwestern part of the basin, where the Haouareb dam, toward the discharge area at the northeast. In order to evaluate the contribution of the dam water to recharging the groundwater, the $\delta^{18}O$ values have been plotted against the distance along a flow line. The results indicate a strong influence of the high saline dam water notable up to a distance between 6 and 7 Km.

Plots of the $\delta^{18}O$ and $\delta^{2}H$ values of the groundwater samples together with the dam water reservoir against the Sfax meteoric line (SML) (Celle-Jeanton et *al.*, 2001) and the Tunis-Carthage meteoric line (Celle, 2000) show two patterns (Fig. 1):

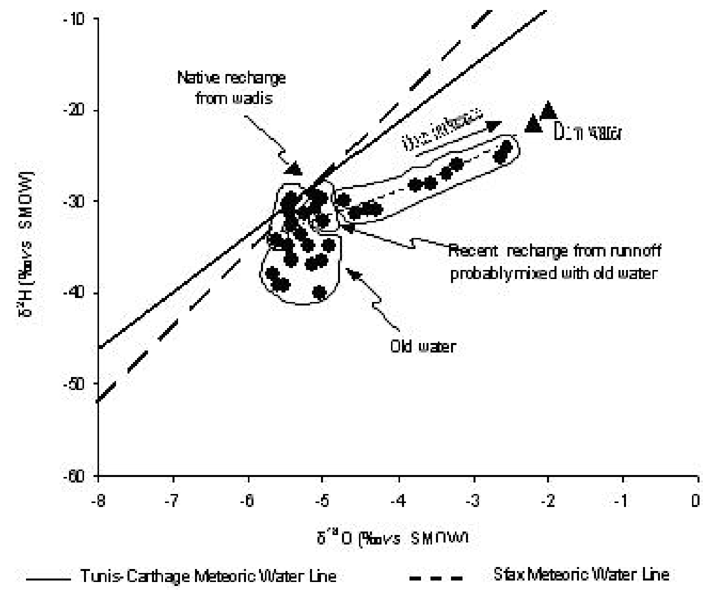

Figure 1: $\delta^{18}O/\delta^{2}H$ diagram of groundwater in the Merguellil river basin

- an enriched trend trailing away from the dominant cluster and toward the dam water reservoir "end-member" which indicates a mixing process between the infiltrated reservoir water and the groundwater. Applying the isotopic mass balance equation between the dam reservoir water "end-member" and the non-influenced groundwater "end-member", the contribution of the dam reservoir water component represents between 10 and 80%.
- a depleted isotopes cluster which plots roughly on and below the local meteoric lines (LWL) of Sfax and Tunis-Carthage. This unusual loosely clustering presumably represents stable isotopes signatures related to different sources and/or times of infiltration. The poorly distinguished clusters in the $\delta^{18}O/\delta^{2}H$ plot are:

- a "recent" water cluster which concerns the wells tapping the aquifer at the piedmont mountains zones and at the vicinity of the wadi courses. These waters are enriched relative to the local meteoric water and are presumably inferred from rainfall runoff infiltration at the piedmont zones and also from the wadi seepage.

- an "old" water cluster which data plot below the LWL. This group concerns the wells, which are located towards the NE of the region and are not likely to be affected by the wadis influence.

- a "native" recharged water infiltrated at the wadis prior to the Haouareb dam interferences and characterised by a relatively enriched trend found in the wells located mainly at the vicinity of wadi courses. These waters plot on LWL and/or slightly below.

2.Radiogenic isotopes (^{3}H, ^{14}C)

Plots of ^{3}H *vs.* $\delta^{18}O$ (Fig. 2) and ^{14}C *vs.* ^{3}H (Fig 3) distinguish fairly well the distinctive water types reviewed above and especially the implication of the dam water reservoir to recharging the groundwater. These plots show consistently the "old" water end-member with ^{3}H contents below detection limit, ^{14}C activities varying from 1 to 40 pmc and depleted stable isotopes. This trend of depleted stable isotopes is in agreement with other results (Fontes et *al,*. 1983; Zouari et *al.*, 2003) obtained in the south and central Tunisia where the groundwaters are interpreted as recharged during the late Pleistocene to early Holocene period, under cooler palaeoclimatic conditions. The "recent" recharged water, which occurs at the piedmont mountains area and the wadis vicinities, is characterised by low ^{3}H contents which is a reflection of the low ^{3}H level in the atmosphere of the northern hemisphere, but their low ^{14}C activities suggest a probable mixing with the "old" water component when infiltration reaches the water table.

Distinctive signatures are obtained with "native" recharge water and the dam infiltrated water, which trail away one to the other as end-members. The "native" recharge water end-member with ^{3}H content between 6.5 and 15.5 TU, and ^{14}C activities from 35 to 43 pmc suggests a recharge period as early as post nuclear bomb tests, if we take in account ^{3}H natural decay since this period.

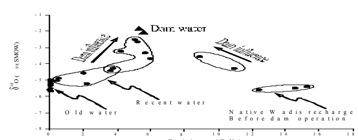

Figure 2: $\delta^{18}O$ /^{3}H relationship

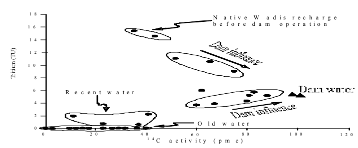

Figure 3: ^{14}C activity/ ^{3}H relationship

CONCLUSION

The use of stable and radiogenic isotopes to identify groundwater recharge sources and mixing process in the Merguellil aquifer system has been demonstrated to well suite for these purposes. Based on the stable isotopes of the oxygen and deuterium as "conservative" tracers of the potential recharge sources together with tritium and ^{14}C *contents, it has been possible to confirm the impact of the dam saline water, which contributes as much as 80% in the wells located in the south-western part of the aquifer. The stable isotopes used in conjunction with radiogenic ones evidenced two mixing trends of the dam recharge water; with the "native" recharged water and the "old" water, respectively.*

This study has shown that stable and radiogenic isotopes contribute to a better understanding of the aquifer hydrodynamics, times of recharge and the mixing process occurring once infiltration reaches the water table. They provide also a precious tool on the dam reservoir implications in the groundwater system.

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BIBLIOGRAPHIE

1. Celle H. Caractérisation des précipitations sur le pourtour de la méditerranée occidentale. Approche isotopique et chimique : PhD Thesis 2000, Univ d'Avignon et des Pays-de-Vaucluse, France 222p.
2. Celle-Jeanton H., Zouari K., Travi Y., Daoud A. Caractérisation isotopique des pluies en Tunisie. Essai de typologie dans la région de Sfax. C.R. Acad. Sci. 2001; 6 : 625-631.
3. Fontes J.C., Coque R., Dever L., Filly A, Mamou A. Paléohydrologie isotopique de l'wadi el Akarit (sud tunisien) au Pléistocène et à l'Holocène [Palaeohydrology isotopic study of the Pleistocene and Holocene in the wadi el Akarit (South Tunisia)]. Pal. Pal. Pal 1983; 43: 41-61
4. Zouari K., Chkir N., Ouda B. Palaeoclimatic variation in Maknassi basin (central Tunisia) during Holocene period using pluridisplinary approaches. IAEA, Vienna, 2003, 2: 80-28