

ASSESSMENT OF A NEW RECHARGE PROCESS IN THE KAIROUAN PLAIN AQUIFER CAUSED BY LEAKAGE FROM THE EL HAOUAREB DAM, CENTRAL TUNISIA

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Location:

The Merguellil Catchment (Central Tunisia): 35° 35' N, 9° 45' E (Figure 1).

Main Problem Illustrated:

The study assesses the impact of the dam on local recharge so one can calculate a water budget using different isotopic tracers.

Summary:

In order to protect Kairouan City against the destructive floods of Wadi Merguellil, the El Haouareb Dam was constructed in 1989. In addition, it promotes the artificial recharge of the downstream alluvial aquifer of the Kairouan plain and groundwater pumping for irrigation. Its construction on a karstic sill completely changed the surface and groundwater flow movement. The dam water is now shared between infiltration through the karstic fissures (52%), evaporation (30%), pumping (12%) and dam releases (6%). The isotopic analysis of the different compartments (dam, spring, up and downstream catchments) provides a clearer idea of the water budget and helps to identify new hydrological processes.

Tracers Used:

Stable isotopes (^{18}O , ^2H), ^3H and ^{14}C .

Hydrogeological Setting:

The Kairouan plain aquifer (more than 3000 km²) is the most important aquifer in the semi-arid central part of Tunisia. It represents also the main source for fresh and agriculture water supply. The Kairouan plain groundwater reservoir is made of Mio-Pliocene and Quaternary detrital deposits. Under natural conditions, the groundwater recharge occurs by infiltration of the Merguellil floods in the river bed. Since the construction of the El Haouareb dam in 1989, these natural mechanisms have been strongly modified: the dam waters infiltrate into the karst, mix with the Ain el Beidha groundwater (upstream catchment), and feed the karst before reaching the Kairouan plain aquifer via springs (see Figure 2, next page). Groundwater underflow is estimated at 9 Mm³ year⁻¹ and the karstic spring flow is evaluated at 10 Mm³ year⁻¹.

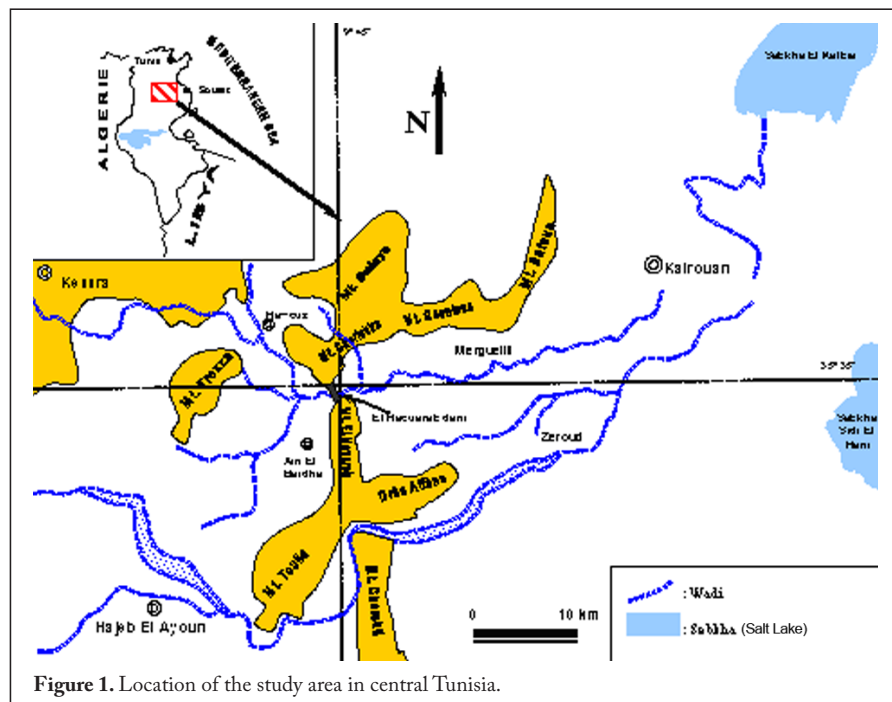


Figure 1. Location of the study area in central Tunisia.

People Affected, Environmental, and Ecological Impacts:

The Kairouan plain is one of most important agricultural areas in Tunisia, with more than 5,000 shallow wells and more than 150 boreholes. Water pumped from boreholes is used for agricultural activity (63%) and for domestic use (35%). Much of the groundwater is transferred to the coastal and touristic cities of Sousse, Mahdia and Monastir situated 80 km in the East of Kairouan.

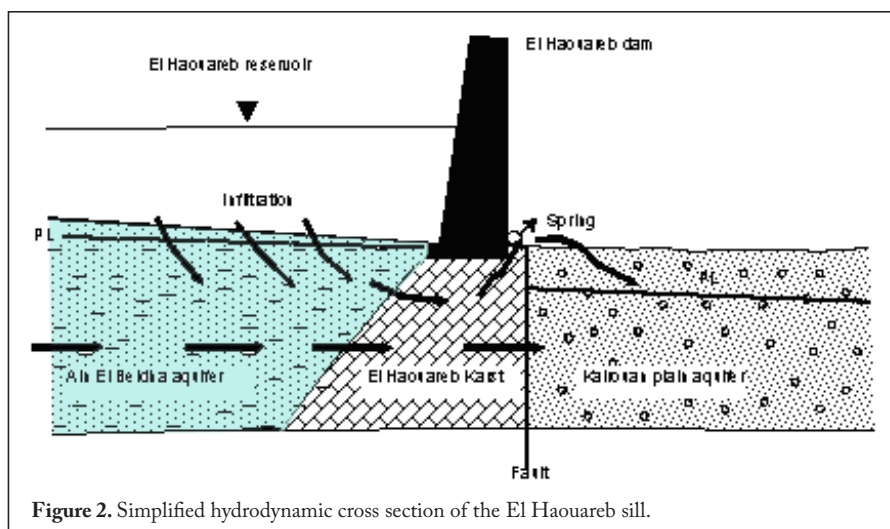


Figure 2. Simplified hydrodynamic cross section of the El Haouareb sill.

Water Sampling and Analysis Summary:

Dam water and groundwater sampling was carried out from November 1997 to May 2000: 5 samples from dam water (dam and springs), 34 samples from Ain El Beidha basin and 50 samples from the Kairouan plain. Earlier isotopic analyses of ^{18}O (Merguellil River in El Haouareb site and Ain El Beidha groundwater) were made within the framework of other studies undertaken in 1976.

Results of Tracer Studies:

Dam water and karstic spring: Dam reservoir isotope data show a variation values from -3.97 to 7.41‰ for ^{18}O and from -29.6 to 27.9‰ for ^2H . Stable isotope values measured in the karstic spring vary from -3.91 to -3.18‰ for ^{18}O and from -25.6 to -22.6‰ for ^2H . The evaporation line for surface water defined from stable isotopic data is $\delta^2\text{H} = 4.75 \delta^{18}\text{O} - 5.92$. For stream water, the isotopic signature of the upstream catchment can be estimated by the intercept of surface water line and the Local Meteoric Water Line (LMWL) i.e., $-5.2/-31.6\text{‰}$ ($^{18}\text{O}/^2\text{H}$). The latter composition differs from the average composition of precipitation in Kairouan (-4.23‰ and -24.1‰ in ^{18}O and ^2H respectively). This difference can be explained by an altitude effect and the higher rainfall in the Merguellil upstream basin.

The spring water shows an intermediate isotope composition between dam reservoir water and the upper catchment of Ain el Beidha basin. The contribution of these two systems was calculated using an isotope balance equation. The contribution of dam water in mixed water (spring) varies between 21 to 66% depending on time. Values from ^{18}O and ^2H ratio are well correlated with the karstic spring flow and with the altitude of the reservoir.

Groundwater in Kairouan plain: The isotopic composition of groundwater samples collected from the Kairouan plain (Merguellil basin) shows that the mean isotopic content ($\delta^{18}\text{O} = -5.13$ and $\delta^2\text{H} = -32.60\text{‰}$) differs from rainfall in Kairouan (-4.23‰ and -24.1‰ in ^{18}O and ^2H respectively) and is closer to rainfall in the upstream Merguellil catchment (ranges between -5.0 and -5.5‰). This suggests that the most present-day groundwater in the Kairouan plain aquifer comes from Merguellil floods and that the contribution of groundwater recharge from the plain is very small. This is confirmed by radiogenic isotope values (^{14}C and ^3H): samples collected in Merguellil vicinity are characterised by high ^3H content and high ^{14}C activities.

Stable isotope values measured in the upstream part of the plain, close to the dam, differ from the rest of the aquifer, which suggests a “contamination” from evaporated dam water mixed with Ain el Beidha unchanged (with respect to ^{18}O) groundwater (spring water coming from the karst). This contamination can be observed as far as 7 km downstream of the dam (Figure 3). Three kilometres away from the dam the water karst contribution is estimated at 48%.

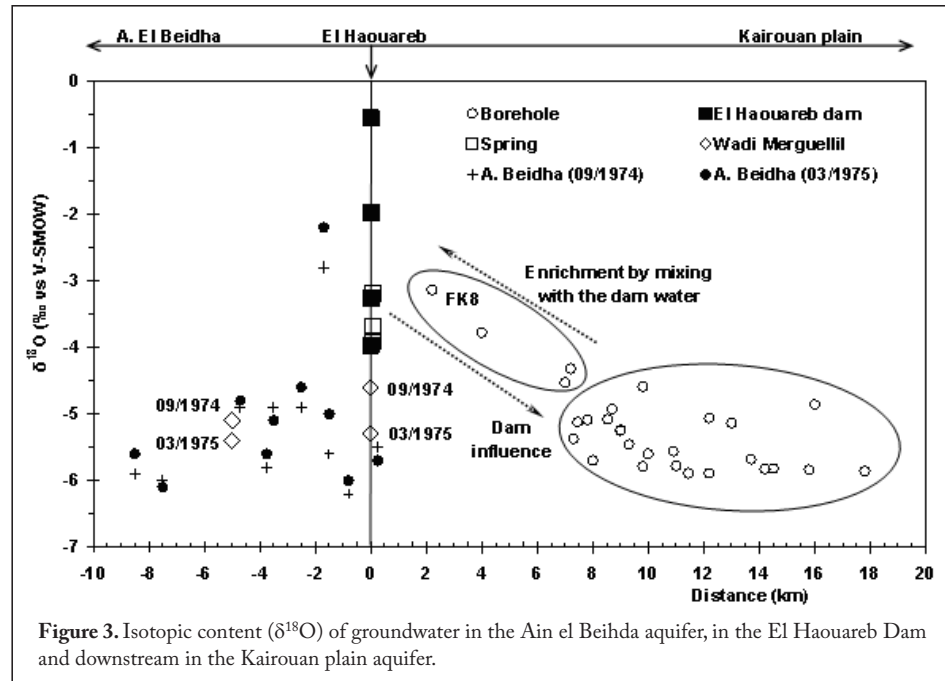


Figure 3. Isotopic content ($\delta^{18}\text{O}$) of groundwater in the Ain el Beidha aquifer, in the El Haouareb Dam and downstream in the Kairouan plain aquifer.

The isotopic signatures (^{18}O and ^3H) discriminate three geochemical water types with various mixing situations (Figure 4):

- The first group forms the present water (dam, spring and FK8; a borehole situated at 3 km downstream from the dam). Its ^{18}O content vary widely from -3.97 to 7.41‰, whereas the ^3H values are in agreement with those of local precipitation (5 to 6 TU).
- The high ^3H values in the second group are attributed to recent recharge coming in the post-nuclear tests period and before the dam construction.
- The third group represents old water infiltrated in a completely natural context. This groundwater is free from tritium and the ^{18}O content varies from -4 to -6‰ vs V-SMOW.

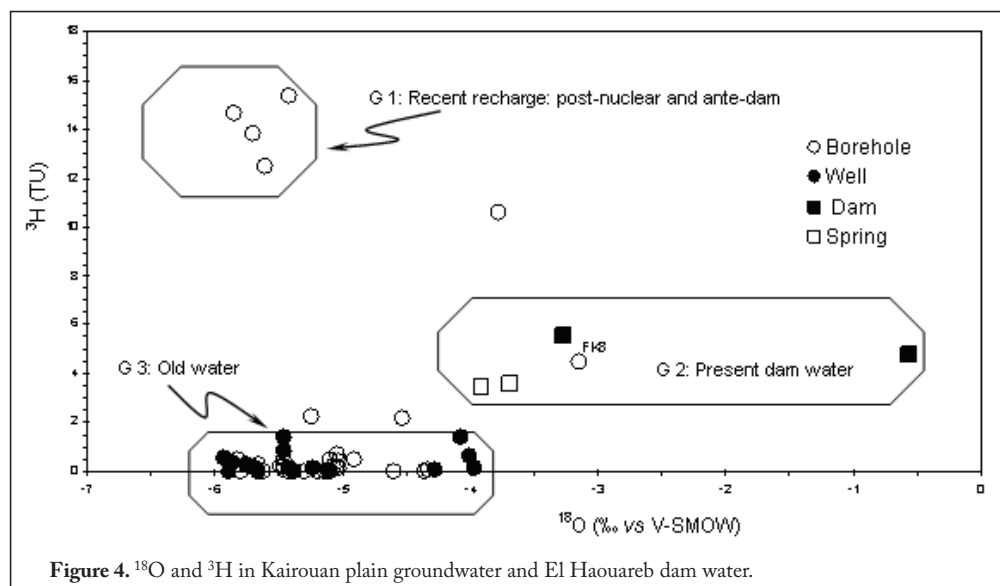


Figure 4. ^{18}O and ^3H in Kairouan plain groundwater and El Haouareb dam water.

Findings and Conclusions:

The isotopic study of different hydrological compartments around El Haouareb dam gives a clearer idea of the changed groundwater flow conditions after the dam construction. These investigations require follow-up at a decadal scale in future years. However, the significant recharge of the Kairouan plain aquifer by the dam leakage can partly replace the water deficit caused by the dam itself resulting from evapotranspiration and the overexploitation of groundwater resources.

Key Message:

The isotopic tracers provide an effective way to identify the different components of groundwater in the Kairouan plain caused by recharge from evaporated dam water.

Credits:

The analytical work by Laboratoire de Radio-Analyses et Environnement (ENI Sfax, Tunisia) was funded by IAEA, in collaboration with Direction Générale des Ressources en Eau (Tunis, Tunisia).

Further Readings:

Ben Ammar S., Zouari K., Leduc C. & M'barek J. (2006) – Isotopic characterization of the dam-aquifer water transfer in the Merguellil catchment (Kairouan plain, central Tunisia). Hydrol. Sci. J., 52, 2, 272-284.

Leduc C., Ben Ammar S., Faveraeu G., Beji R., Virrion R., Lacombe G., Tarhouni J., Aouadi C., Zenati C. B., Jebnoun N., Oi M. Michelot J.L., Zouari K. (2007) – Impacts of hydrological changes in the Mediterranean zone: environmental modifications and rural development in the Merguellil catchment, central Tunisi. Hydrol. Sci. J., 52, 6, 1162.