Use of environmental isotopes to infer flow in the highly exploited aquifer system of the Diass region (Senegal)

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Introduction – Objectives

The horst system of the Diass region located 50 km east of Dakar (Senegal) has experienced intensive groundwater abstraction during the last 30 years to supply continously an increasing water demand for the Capital city. Water production from the five pumping fields is destined mainly to the city of Dakar and few other localities. Production is at present as high as 109.0000 m^3/d. This high yield has caused a continuous groundwater level decline (more than 30 m) in some parts of the system, a change in the flow regime and quality patterns evidenced by salinization of few boreholes located at Sebikotane and Mbour pumping fields.

The present study aims to an improved understanding of groundwater dynamics to foster a more appropriate groundwater management

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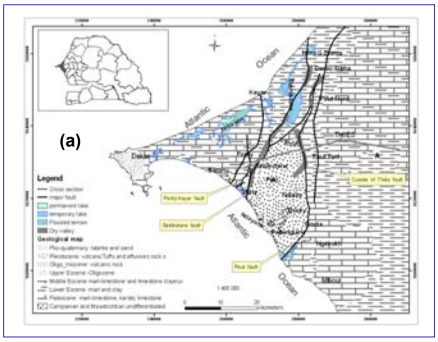

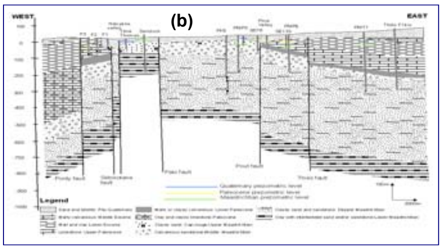

Figure 1: Location of the study area, geological map (a) and cross section (b)

Groundwater in the system is hosted in two main reservoirs, namely the confined/unconfined karstic Paleocene limestone configurated into two compartments (Sebikotane and Pout) and the central part where the Maastrichtian aquifer, made of sands and sandstones outcrops towards the south. The general structure lies out as an anticline horst system with interconnected compartments limited by normal faults.

Data and methods

The environmental isotopic composition of water ($\delta^{18}O$, δ^2H and Tritium) measured in April 2007 (before rainy season), November 2007 (after rainy season) and June 2008 (before rainy season), and few data of ^{13}C and ^{14}C measured in groundwater samples are considered to infer groundwater flow. Samples were taken in wells that are continuously pumped to guarantee that the sampled groundwater would be representative of the geological formations. Sampling were performed from the Paleocene and the Maastrichtian aquifers using standard procedure. Samples for ^{14}C were taken in each pumping field. Rainfall waters were sampled in six representative raingages.

Results and discussion

Isotope composition gives:

✓ for $\delta^{18}O$ -7.2‰ to -2.6‰ with a mean value of -5.3 ‰ and for δ^2H -47.2 ‰ to -12 ‰ with a mean value of -32.1 ‰ for **Rainfall** which defines a Local Meteoric Water Line (LMWL) of :

$$Y = 7.23\ \delta^{18}O + 5.9$$

(figure 2). Tritium values range between 1.3 and 3.9, with a mean value of 2.5TU,

✓for $\delta^{18}O$: -5.8 ‰ to -5‰ and between -38.2‰ to -30.5‰ for δ^2H, with mean values of -5.5‰ and -35.2‰ for the **Paleocene aquifer,**

✓ for the **Maastrichtian aquifer** $\delta^{18}O$ values range between -5.9 ‰ and -4.3‰ and -38.4‰ to -26.3‰ for δ^2H with mean values of -5.1‰ and -32.1‰ respectively.

✓ Tritium contents are very low and generally approach the detection limit (<0.7 TU), however values between 0.8 and 3.2TU are observed in some boreholes in the Paleocene and Maastrichtian aquifer.

Plotted in the conventional $\delta^{18}O$ *vs.* δ^2H diagram (figure 2), the three campaigns displayed three different trends reflecting different water masses inflow characterised by different isotopes signatures to the system.

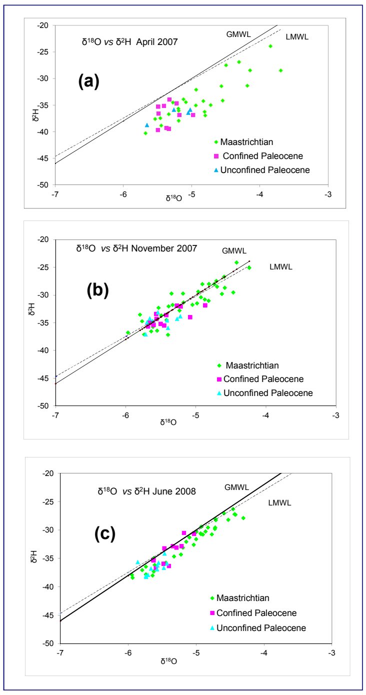

Figure 2 : $\delta^{18}O$ *vs* δ^2H before (a, c) and after rainy season (b)

✓ a trend parallel and below the GMWL (Craig, 1961) and the LMWL for the April campaign **(figure 2a)** indicating that this water originates from rainfall, has undergone evaporation during infiltration,

✓ a less evaporated water type, observed in November 2007, with some samples located above the GMWL **(figure 2b)** which may result from rainfall originating from mixing of recycled and atmospheric vapors;

✓ in June 2008, an homogeneous water composition is observed very close to the GMWL and LMWL **(figure 2c)** , then less evaporated.

✓Scattered range of stable isotope values gives an indication of the variation in the recharge mode and periods in the system, and illustrates the transient conditions of the system.

✓ This different water masses evidence change in groundwater flow, induced by the high pumping rate. The correlation between ^{14}C activities and the total pumping rate from 1989 to 2008 **(figure 3)** shows that ^{14}C activity decreases with increase of pumping, and *vice versa*, indicating that exploitation enables flow of older water in the system.

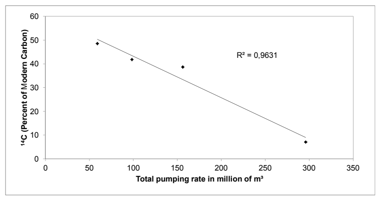

Figure 3: Total pumping rate *vs* ^{14}C

✓ Spatial distribution of isotopes follows the main groundwater flow paths. Samples located in the high piezometric level had the lowest $\delta^{18}O$, δ^2H and tritium values, while those in piezometric depression near the pumping field are more enriched and tritiated. These results are likely to occur since groundwater migrates along flow paths and mixes with water from faster recharge components. These ones have typically enriched $\delta^{18}O$ and δ^2H values, as a result of evaporation or condensation processes at warmer temperature (Gabora & Campana, 2003).

Conclusions

The Diass horst multilayered aquifer constitutes a complex hydrogeological system. But stable isotopes are illustrated to be powerful tools for clarifying the origin of recharge water, and the groundwater dynamics due to high exploitation of the system. Used with ^3H and ^{14}C, data confirms that most of the investigated groundwater are palaeowaters. Pumping has an impact on groundwater flow evidenced by the different water isotope compositions that illustrates the transient conditions of the system. Mixing of old waters and recently recharged (tritiated) waters occurs in some exploited boreholes, indicates lateral flow to the pumping field through the main groundwater flow directions.

Bibliographie

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