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title: **Past recharge conditions in the Guarani Aquifer System**

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Analysis of groundwater isotopic ratios are routinely used in hydrogeology to complement the hydrogeochemical and hydrodynamic data, and can supply important information about patterns of flow, age and origin of groundwater, occurrence of mixtures, and environmental conditions during the recharge of these waters. The purpose of this article is to analyse the spatial distribution of groundwaters isotopic ratios (δ^2H and $\delta^{18}O$) in the western portion of Guarani Aquifer System (GAS), and how these isotopic variations are associated with present and past climatic conditions in the recharge zones.

GAS is the most important hydrostratigraphic unit in the southern portion of South America where it covers about 1,090,000 Km^2. GAS comprised a package of Mesozoic sedimentary continental clastic rocks which occurs in the Parana Sedimentary Basin (LEBAC, 2008). In its western part the groundwater flow pattern is characterized by the existence of two regional recharge areas in the north, and a potentiometric divide in the south, which trends approximately NS. Groundwater flow is radial from the regional recharge areas towards the center of Paraná Sedimentary Basin and towards the western outcrop areas (Gastmans et al., 2009).

Rain shows wide dispersion in isotopic ratios ($\delta^{18}O$ varying from –15.8 to +5.2‰ SMOW and δ^2H varying from –111.4 to +47‰ SMOW), with a clear differentiation between rainy summer season (November to April) and drier winter season (May to October). Summer rains show, throughout the sampled period, –5.74 ± 3.35‰ SMOW for average $\delta^{18}O$ and –34.43 ±24.32‰ SMOW for δ^2H. The $\delta^{18}O$ for GAS groundwater vary from –9.1 to –4.8‰ SMOW and the δ^2H vary from –58.4 to –21.7‰ SMOW (Fig. 1).

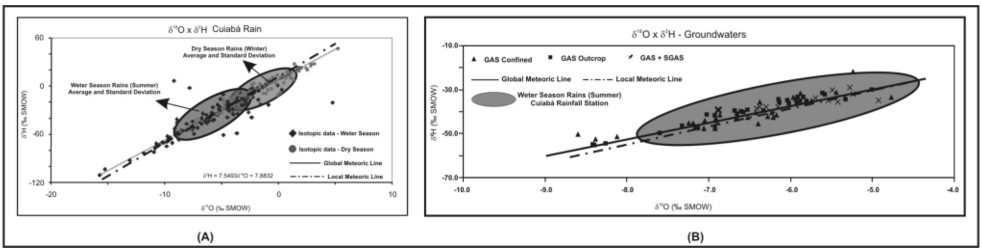

Figure 1. (A) $\delta^{18}O$ versus δ^2H cross plot of rain water. (B) $\delta^{18}O$ versus δ^2H cross plot for GAS groundwaters.

The spatial distribution of groundwater $\delta^{18}O$ indicates values comparable to the present day rain in the outcrop and regional GAS recharge zones, located in the north of the area, and most depleted $\delta^{18}O$ groundwaters are in the confined zone (Fig. 2).

This isotopic distribution reflects directly paleoclimatic evolution in the southern portion of South American continent through the Pleistocene, when climates were colder and more humid in lower latitude zones. Under these climatic conditions, the rain waters are more depleted in $\delta^{18}O$ and δ^2H than the present day. These ratios are similar to those observed in the central portion of the study area (–8.2‰ SMOW $\delta^{18}O$ and –45‰ SMOW δ^2H). Groundwaters more enriched in $\delta^{18}O$ are observed close from recharge areas; this fact reflects the increase in average temperature during the Holocene. Based on these ages for the recharge, groundwater flow velocities were calculated, and the values reach tens meters per year, similar to those observed by Silva (1983) in the east border of the aquifer. These velocities are important for the groundwater resource management, because the renewal of GAS groundwater, mainly in the confined portion, is very slow, occurring in longer time intervals than normally are used in management plans.

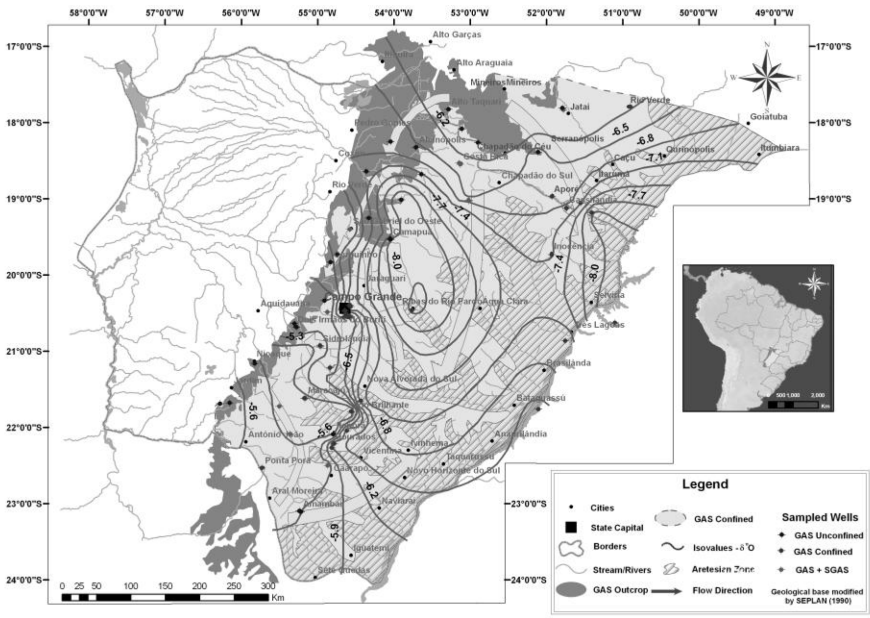

Figure 2. Map of $\delta^{18}O$ GAS groundwater spatial distribution in the western portion of the Guarani Aquifer System.

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