



Deciphering natural variability of groundwater chemistry using hydrochemical and stable isotope data in Axum aquifer, Ethiopia

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The groundwater from volcanic aquifer is the main source for water supply of the Axum town in semi-arid region of northern Ethiopia. Poor quality of groundwater from high yielding bore holes in study area has been a major problem for the water supply of the town. The groundwater geochemistry of the area shows distinctive spatial variation suggesting diverse geochemical processes and aquifer composition. Hydrogeochemical data and isotopic tracers are used to characterize the hydrogeochemical behaviour of the groundwater and to identify different sources of groundwater and mixing behaviour within the aquifer.

Interpretation of the hydrochemical data of groundwater indicates that the chemistry varies from fresh Ca-Mg-HCO₃-NO₃ water type and moderate total dissolved solid (TDS) groundwater at shallow wells to Mg-Na-Ca-HCO₃ water type with very high TDS content in the deep wells. Weathering of silicates and to lesser extent the dissolution of carbonates as well as ion-exchange and neoformation of solids explain most of the observed spatial variability in groundwater composition. In deep groundwaters, where HCO₃⁻ and Na⁺ concentrations are higher, the dissolution of silicate and precipitation of carbonates become important. Precipitation of calcite may reduce significantly the dissolved Ca²⁺ in the solution. On the other hand, dissolution of calcite enhances the HCO₃⁻ content of the solution in areas where carbonate minerals are present as filling veins. The groundwater compositions appear to be controlled by kinetics of silicate weathering at different pCO₂ and neoformation of silicate like kaolinite and smectite.

The geochemical trends are supported by ¹³CVPDB values of dissolved inorganic carbon (DIC) where the inorganic carbon in the aquifer shows carbon dynamics in catchments. The ¹³CDIC values for sampled solutions lie between +1.1 and -11.4 ‰. The range of ¹³CDIC values indicates the contribution of carbon from two predominant sources. The isotopically heavier group with ¹³CDIC value from +1 to -5 ‰ is related to the presence of magmatic CO₂ gas reservoir in the aquifer whereas ¹³CDIC value in the range from -5 to -12 ‰ reflects uptake of soil CO₂. Moreover, CO₂ of magmatic and soil origin is consumed by weathering of silicate, such as albite to result in elevated major cation concentrations and the formation of secondary clay minerals. Stable isotope data (²H and ¹⁸O) indicate that the groundwaters are derived from local precipitation under present climate condition and have shallow circulation. Most ²H and ¹⁸O values scatter along the global meteoric water line (GMWL). However, the isotopic composition of several solutions reveals the influence of evaporation and a few groundwaters show a stable oxygen isotope shift to heavier ¹⁸O-values due to water-rock interaction.