Hydrochemical and Isotopes Studies of Shallow Basement Aquifers in Nigeria: Implications for Groundwater Recharge

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Shallow crystalline basement aquifers play important role in sustaining potable drinking water supplies in many rural areas of Nigeria. However, there is little understanding of the interrelationship between the recharge dynamic, residence time and the reality of climate change impacts on such shallow groundwater system. This study evaluates the hydrochemical and isotopic signatures vis-à-vis recharge and residence times of the shallow groundwaters in basement aquifers across three different climatic zones in Nigeria (rainforest, savannah and sahel zones).

Field measurements of physico-chemical parameters were made at the well head using a flow-through cell while sampling were carried out only after stable instrument readings were obtained. Subsequently, the water samples were subjected to hydrochemical analyses of major ions and measurements of stable isotopes (^{18}O, ^{2}H) and environmental tracers (CFC-12, CFC-11, SF_6 and ^{3}H) using standard preparation and appropriate analytical techniques.

Hydrochemical results revealed similar pH value of 5.5 – 7.0 across the different climatic zones with low dissolved oxygen (0.03 – 7.6mg/L) suggesting reducing conditions. The electrical conductivity (EC) of 234 – 705 µS/cm in the Abeokuta forest zone compared to 170 – 394 µS/cm in Minna savannah zone and 115 – 629 µS/cm in Gusau Sahel zone. Calcium is the dominant cation constituting 34-45% of the total cations with subordinate Na^+ and Mg^{2+} with average values of 30% and 25% respectively. HCO_3 is the dominant anion constituting 60-91% of the total anions while subordinate Cl of 25% in the Abeokuta rainforest zone suggests possible influence of coastal aerosols on the water quality. The stable isotopes results revealed significant differences signatures between the different study areas (p<0.001) characterized by decreasing average values of ^{18}O and ^{2}H from -2.9‰ and -12.9‰ in the rainforest zone to -4.0‰ and 22.5‰ in the Sahel zone respectively. In addition, ^{3}H concentrations revealed a general increase in average values from 2.6TU in Abeokuta to 3.2TU in Minna to 4.7TU in Gusau area. The measured CFCs of 0.29 - 1.0 pmol/L are mostly below the maximum equilibrium values for a recharge temperature of 28°C (CFC-12 = 1.4 pmol/L, CFC-11 = 2.4 pmol/L), suggesting little or no input from anthropogenic or terrigenic sources.

The observed isotopic trends can be attributed to enrichment with decreasing rainfall northward from the Gulf of Guinea (latitude effect) while the low EC (115 – 705 µS/cm) is an indication of low mineralized shallow groundwater system of meteoric origin with little or no evidence of evaporation prior to recharge. In addition, the mean residence times (MRT), based on an exponential mixing model, revealed comparable results across the three climatic zones (>13 – 70 years). This indicates significant rapid groundwater recharge, even in semi-arid areas, and sustainable resources for diffuse low level abstraction such as hand pumps within shallow crystalline basement aquifers across Nigeria.

Keywords: Shallow basement aquifer, hydrochemistry, stable isotopes, environmental tracers, groundwater recharge and climatic zones.