



Nitrate contamination of groundwater in the Lower Volta River Basin of Ghana: Sources and related human health risks

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A significant population within the Lower Volta River Basin of Ghana, an important international tourism destination, relies solely on untreated groundwater and surface water (SW) for various purposes. However, negative practices associated with increasing anthropogenic activities pose threats to especially groundwater in the basin. This study therefore explored an effective integrated approach to assess the origins of groundwater NO_3^- contamination and related human health risks using hydrochemistry, CCME model, multivariate statistics, isotopes ($\delta^2\text{H}$, $\delta^{18}\text{O}$, and ^{15}N) and USEPA human health risk model. Hydrochemical results showed a slightly acidic to alkaline SW and groundwater environments. Maximum EC of $15850 \mu\text{S}/\text{cm}$ with mean, $2929 \mu\text{S}/\text{cm}$ and elevated values $> 1000 \mu\text{S}/\text{cm}$ were observed in 45% of the groundwater across the basin. NO_3^- levels in the groundwater ranged from $0.12 - 733 \text{ mg}/\text{l}$ with average $59.59 \text{ mg}/\text{l}$ while a maximum of $5.33 \text{ mg}/\text{l}$ was observed for SW. A total of 75% and 35 % of the sampled groundwater exceeded background NO_3^- level of $2.1 \text{ mg}/\text{l}$ and WHO guideline value ($45 \text{ mg}/\text{l}$), suggesting anthropogenic influence on its quality. The CCME model revealed that, 85% of the SW was of excellent quality. Only 13% of the groundwater ranked good. $\text{NO}_3^-/\text{Cl}^-$ ratio indicated that 43% and 21% of the groundwater and SW respectively are contaminated by effluents and agrochemicals. NO_3^- positively correlated with $\text{K}^+ > \text{Ca} > \text{Mg}^{2+} > \text{Cl}^- > \text{Na}^+ > \text{EC}$ and PCA clearly defined trends of groundwater NO_3^- pollution with minimal natural attenuation. Manure, septic effluent and mineralized fertilizers were sources of NO_3^- contamination in the basin. Overall, 70%, 50% and 48% medium to high NO_3^- risk levels were determined for infants, children and adults with 79% high risk of SW NO_2^- contamination to infants. Appropriate management options to control groundwater NO_3^- pollution in the basin were proposed.