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Origin of nitrate in groundwaters of Kalahari, Botswana

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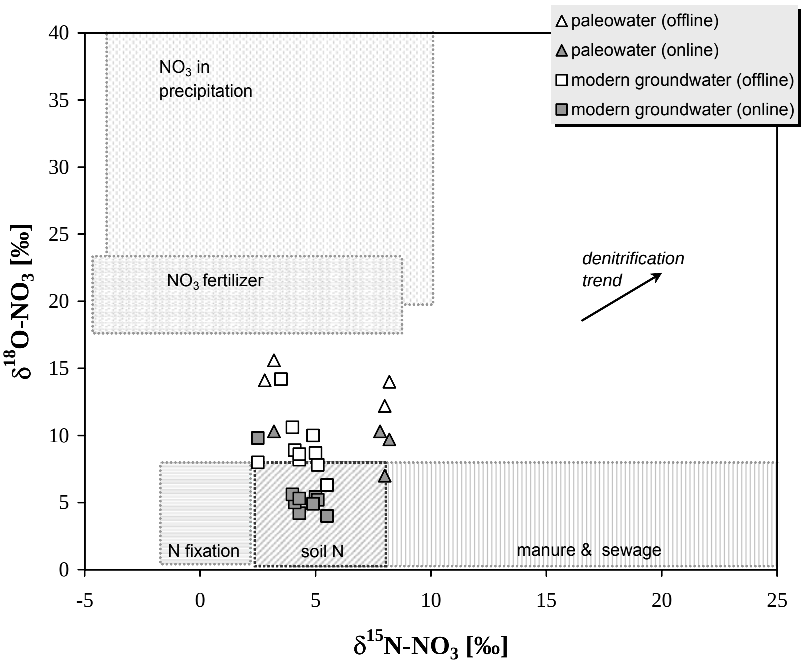
In groundwaters from Kalahari, Botswana, elevated nitrate concentrations exceeding the WHO-guideline value of 50 mg/L have been found in mostly uninhabited semi-arid areas. Here we present first results of an isotope hydrological investigation with main emphasis to identification of input factors and the origin of that nitrate in groundwater.

The investigation area is located on the eastern fringe of the Kalahari between Serowe and Orapa, Botswana. Mean annual rainfall in the investigation area is about 450 mm/yr. The area is characterized by a flat topography at about 1200 m above sea level. Groundwater samples were taken from the Triassic Ntane sandstone aquifer, which comprises the main aquifer of the Karoo strata in the investigated area. The aquifer is mostly confined by fractured Early Jurassic Stormberg basalts and an extensive cover with Kalahari sands.



According to their significantly different ^{14}C contents, the investigated groundwaters can be divided into two distinct groups: modern groundwaters (40 to 90 pmC) of

Ca-Mg-HCO_3-Cl type and Na-HCO_3 type paleowaters (< 15 pmC), respectively. The high radiocarbon contents of the first group clearly confirm the presence of active recharge in the order of 1-5 mm/yr (Verhagen 1991). Only the modern groundwaters are affected by high nitrate concentrations. According to nitrate stable isotopes (Fig. 1), natural accumulation processes in soil (Heaton et al. 1983; Aranibar et al. 2003; Walvoord et al. 2003) seem to play the important role concerning the source of nitrate. The lack of an anthropogenic nitrate pollution in the investigated groundwaters indicated in Fig. 1 is in accordance with long residence times in the unsaturated zone, as suggested by tritium below detection limit in all groundwater samples.

Within the ^{14}C containing (> 40 pmC) modern groundwaters, nitrate concentrations positively correlate with ^{14}C content. If not due to anthropogenic activities, the decreasing nitrate concentration with increasing (corrected) ^{14}C age (up to 3.000 years) must be a consequence of a change in nitrate leaching and/or of a change in recharge conditions.

The impact of different recharge conditions is confirmed by a strong linear correlation of nitrate with dissolved ^{20}Ne content (Fig. 2). ^{20}Ne is found in excess in all groundwater samples, which is due to excess air dissolved in course of the recharge process. The extend of excess air is influenced by the rate and extend of recharge and therefore may be used as an indicator to distinguish between dry and wet infiltration conditions (Heaton et al. 1983; Stute and Talma 1997; Beyerle et al. 2003). High nitrate contents correspond to low ^{20}Ne excess values, which sug-gest a slow re-charge where ^{20}Ne concentrations are maintained at so-

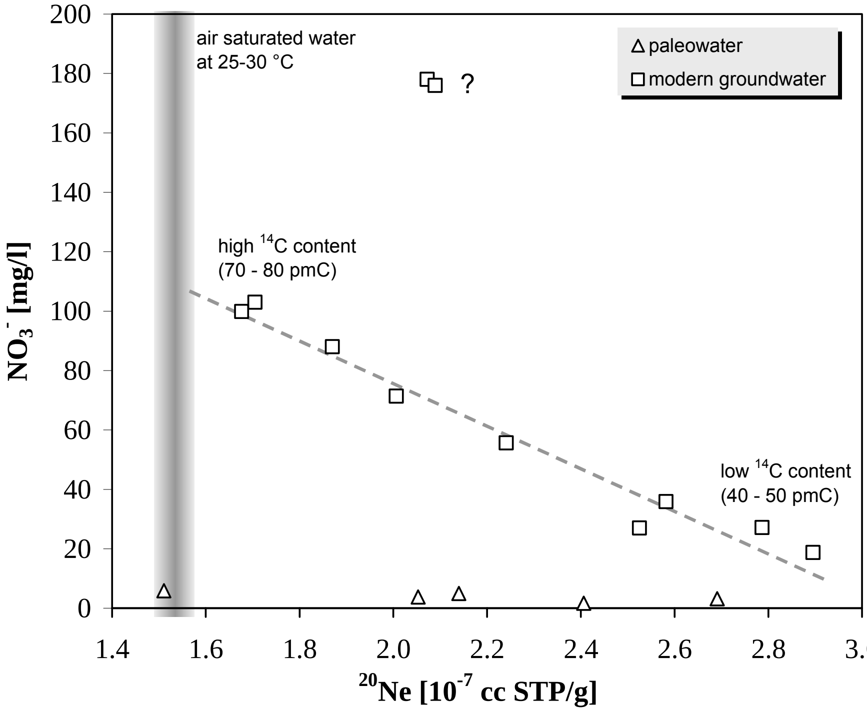


Fig. 2. Nitrate and ^{20}Ne contents of Kalahari groundwaters out of the Ntane sandstone aquifer. Today's low recharge rates yield low ^{20}Ne and high nitrate contents as end member of the mixing line with high ^{20}Ne/low nitrate containing groundwaters recharged under more humid conditions.

lubility equilibrium. Low nitrate on the other hand is connected to recharge under wet conditions, where air is captured below the water table.

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