

## Environmental isotope studies on the origin and transformation of nitrate and sulfate in alluvial groundwater

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The sources and transformation of nitrate and sulfate and their effects on groundwater quality were studied using environmental isotopes ( $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}$  of nitrate, and  $\delta^{34}\text{S}$  of sulfate) for groundwater samples from a largely two-layered alluvial aquifer. Each layer has the different groundwater recharge sources and redox condition with depth. The  $\delta^{15}\text{N}_{\text{nitrate}}$  and  $\delta^{18}\text{O}_{\text{nitrate}}$  values clearly show that the sources of nitrate in oxic groundwater at near surface are the mixture of ammonia or urea-containing fertilizer and manure. In addition, the decrease of nitrate concentrations with depth is caused by denitrification. The estimated enrichment factor for  $\delta^{15}\text{N}_{\text{nitrate}}$  is -5.8‰. About 40-50% of nitrate is attenuated by denitrification. In oxic groundwater,  $\delta^{34}\text{S}_{\text{sulfate}}$  values range from -14.4 to 2.4‰, which indicate that sulfate may be originated from pyrite oxidation, fertilizers and soil S. However, a simple mass calculation for sulfate indicates that pyrite oxidation by denitrification considerably generates sulfate in oxic groundwater, leading to a decrease in nitrate concentration. This illustrates that the recharge of nitrate-contaminated water may cause a secondary water quality problem such as increased sulfate and hydrogen ions. On the other hand, in sub-oxic groundwater the increased  $\delta^{34}\text{S}_{\text{sulfate}}$  values (up to 64.1‰) evidently indicate that sulfate is removed by microbial-mediated sulfate reduction.