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Origin and behavior of nitrate in unsaturated alluvial aquifers, Nakdong river basin: hydrogeochemical and isotopic studies

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ABSTRACT

The contamination of shallow groundwater by nitrate is a serious problem encountered in rural regions of the world. The nitrate originates largely from diverse domestic and agricultural practices, and is typically found in oxygenated groundwaters in which nitrate is relatively stable and mobile. For an intensive investigation on the nitrate problem in Korea, we have collected systematically alluvial groundwaters (n = 137) from irrigated and domestic wells in three alluvial aquifers (Wolha, Daesan, and Yongdang areas) on the border of a lower reach of Nakdong River. We have elucidated both the origin and extent of nitrate pollution and the various factors and geochemical processes controlling the alluvial groundwater quality. These study areas are recently being considered as the sites for large-scale exploitation of alluvial ground waters and for riverside infiltration of contaminated river waters.

Nitrate concentrations in the three aquifers range widely from below the detection limit to 383.4 mg/L NO_3^-, with a median concentration of 55.4 mg/L NO_3^-. Of the 137 samples examined, 57.7% of samples have the NO_3^- concentrations exceeding the Korean drinking water standard (44.3 mg/L NO_3^-). Seasonal variation of nitrate concentration tends to be observed in irrigation ground waters, but is not clear.

The spatial distribution of nitrate concentration appears to be correlated well with land use characteristics. Elevated nitrate concentration is typically observed in irrigation wells at arable lands in the central part of alluvium. Ground waters from domestic wells in villages are lower in nitrate concentration. With depth in an aquifer, elevated nitrate concentration is observed at depths of about 8 m beneath the land surface. At depths greater than 8 m the nitrate concentration is generally decreased: an abrupt removal of

nitrate was observed in Yongdang area. The attenuation of nitrate with depth can be explained by the following two mechanisms: (1) microbial denitrification, (2) dispersive mixing with different water bodies. Careful examination of geochemical data such as redox states and NO_3/Cl ratio, as well as the characteristics of aquifer materials and environmental isotope data, indicate the importance of denitrification as an natural attenuation process. To identify the origin(s) of nitrate, $\delta^{15}N$ values (n = 19) of NO_3^- in ground water were analyzed. Two important sources of nitrate are identified: (1) nitrates ($\delta^{15}N$ = 4.3~6.2‰) originated from synthetic fertilizer applied in agricultural land at the middle part of alluvium, and (2) nitrates ($\delta^{15}N$ = 15.0~19.9‰) originated from animal manure and human wastes which were discharged from adjacent villages located at hydrogeologically upstream site. The former nitrate source appears to be more important in the study areas. The hydrologic mixing between the two nitrate sources (and two water bodies) in an aquifer was quantitatively evaluated by using the $\delta^{15}N$ data.

We will also discuss about the problems and misunderstanding of our general knowledges on hydrologic and hydrogeologic setting of riverside alluvial aquifers in Korea. Our present study will be also helpful for future sustainable development of alluvial ground waters.

Keywords: alluvial ground water, nitrate, spatial and temporal variation, pollution, agricultural activity, $\delta^{15}N$-NO_3^-

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