

Hydrogeochemical processes and behavior of nitrate in an alluvial aquifer: A preliminary result from Cheonan area, Korea

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<Abstract>

To understand the geochemical processes controlling the distribution of nitrate and other agricultural constituents in an alluvial aquifer, hydrogeological and hydro geochemical studies were carried out in an agricultural area within Cheonan. In this selected field, nitrate concentrations were very wide in range but was locally attenuated significantly down to very low levels (<1.0 mg/L). Abrupt removal of nitrate coincided with the pattern of redox change and thus indicated that geochemical processes occurring during and after recharge events control the behavior and distribution of nitrate and other redox-sensitive chemical species.

Key words : geochemical process, alluvial aquifer, redox-sensitive species

1. Introduction

Identifying and characterizing the geochemical processes responsible for the development of and transition between redox zones is crucial to understanding how natural and/or anthropogenic contaminants such as metals, iron and manganese, and nitrogen compounds behave and are ultimately removed in groundwater environment. In these aspects, understanding the hydrogeochemical dynamics associated with the redox state of an aquifer system is very important because redox condition controls the form, mobility and persistence of nitrogen contaminants.

In Korea, alluvial groundwaters are highly vulnerable to nitrate contamination as a result of intense agricultural activity (i.e., over-use of N-fertilizers). However, hydrogeochemical and hydrogeologic studies on the origin and behaviors of nitrogen compounds were quite lacking in Korea. For this study, we chose an alluvial groundwater in an agricultural area within Cheonan, because nitrate concentrations in the field were very wide in range and locally suddenly dropped down to negligible level.

2. Study area

The characteristics of the study area can be summarized as follows (see Fig. 1): 1) Alluvium in the area is characteristically developed at the confluence of two streams and is surrounded by topographically highs, 2) The alluvium is used for rice paddy field, 3) Silt layer with low permeability overlies the alluvial aquifer. Therefore, the aquifers are mildly-reduced and semi-confined, and 4) In spite of an intense agricultural activity, many groundwater samples taken from some agricultural wells showed negligible contamination by nitrate.

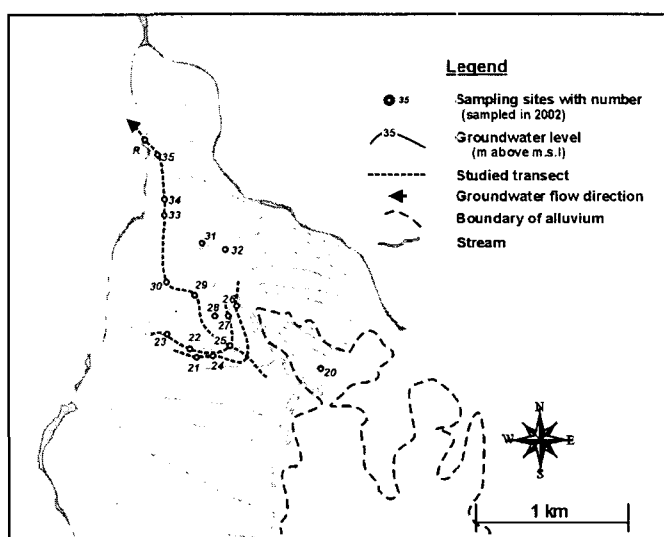


Fig. 1. Map showing the distribution of equipotential lines and a local flow path of groundwater in the study area

3. Result and discussion

Figure 2 shows the spatial distribution of the concentrations of redox-sensitive chemical species and related physicochemical parameters (pH, Eh, DO) along the designated local flow path. In the nitrate depleted zones, geochemical environments typically become anoxic, as indicated by Eh and DO values.

Spatially, alluvial aquifer of the study area locally contain a distinct reduction zone along the local flow path (Fig. 3), where high concentration of dissolved Fe appears due to the process of Fe reduction. Therefore, we consider that the lowest redox potential in such zone probably corresponds to the reducing step of iron species. However, the presence of laterally proceeding redox sequences was not recognized in the area.

It is evident that such reduction process occurs restrictedly in the area where silt layer overlies the aquifer. The silt layer likely controls the groundwater recharge through unsaturated zone. In anaerobic condition, it is considered that recharge events can initiate changes in TEAPs by delivering more favorable TEAPs such as oxygen, nitrate, and sulfate.

Significant decrease of the $\text{NO}_3^-/\text{Cl}^-$ ratio in groundwater is observed in the anaerobic zone (Fig. 4). This phenomenon is a result of heterotrophic denitrification, which involves oxidation of organic matter in the reaction. The conditions required for denitrification are easily achieved in the anaerobic

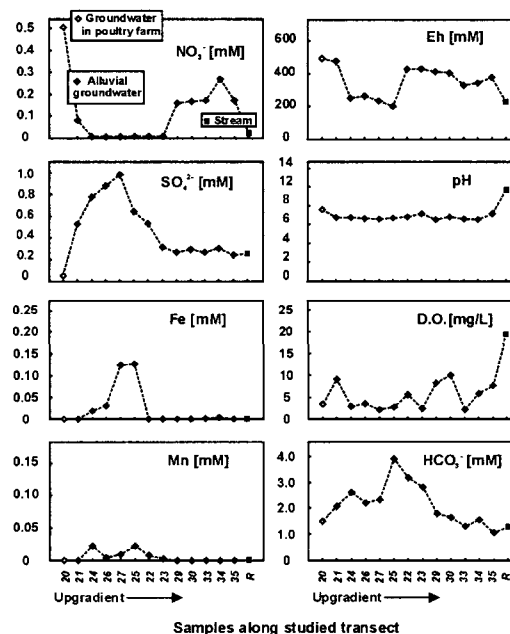


Fig. 2. Variations of chemical data of groundwater along flow direction.

zone, because 1) the remarkable decrease of Eh values indicates the restricted O₂ availability, 2) organic matter as a suitable electron donor is also assumed to be present in such area. In the reduction zone, DOC value slightly increases, as does DIC (Fig. 4). The DOC is considered as a by-product of organic matter oxidation through $5\text{CH}_2\text{O} + 4\text{NO}_3^- + 4\text{H}^+ = 5\text{CO}_2 + 2\text{N}_2 + 7\text{H}_2\text{O}$ (Trudell et al., 1986). Furthermore, a remarkable increase of sulfate concentration was observed in the reduction zone, which can be associated with denitrification through pyrite oxidation. However, we should consider that sulfate also can be originated from various sources. Therefore, it is still difficult to identify the possibility of autotrophic denitrification in the study area.

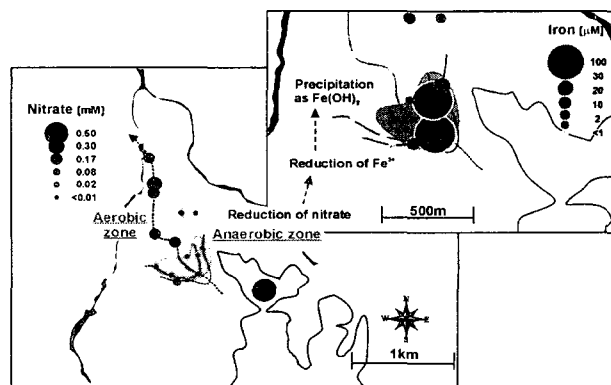


Fig. 3. The occurrence of a distinct reduction zone along the flow path in the study area.

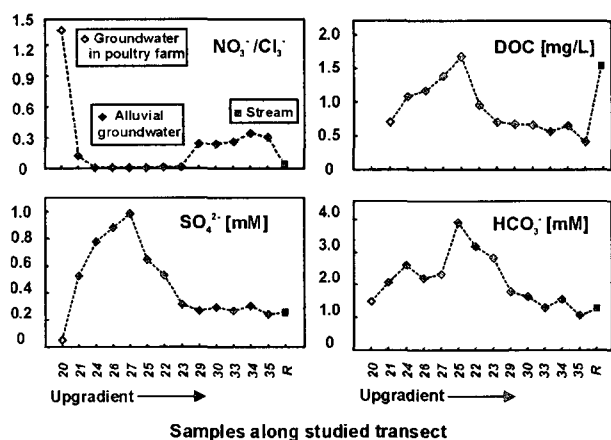


Fig. 4. Variations of denitrification indices along the flow path.

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