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Source Identification of Nitrate contamintation in Groundwater of an Agricultural Site, Jeungpyeong, Korea

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Abstract

This study applied a hydrogeological field survey and isotope investigation to identify source locations and delineate pathways of groundwater contamination by nitrogen compounds. The infiltration and recharge processes were analyzed with groundwater-level fluctuation data and oxygen-hydrogen stable isotope data. The groundwater flow pattern was investigated through groundwater flow modeling and spatial and temporal variation of oxygen isotope data. Based on the flow analysis and nitrogen isotope data, source types of nitrate contamination in groundwater are identified. Groundwater recharge largely occurs in spring and summer due to precipitation or irrigation water in rice fields. Based on oxygen isotope data and cross-correlation between precipitation and groundwater level changes, groundwater recharge was found to be mainly caused by irrigation in spring and by precipitation at other times. The groundwater flow velocity calculated by a time series of spatial correlations, 231 m/yr, is in good accordance with the linear velocity estimated from hydrogeologic data. Nitrate contamination sources are natural and fertilized soils as non-point sources, and septic and animal wastes as point sources. Seasonal loading and spatial distribution of nitrate sources are estimated by using oxygen and nitrogen isotopic data.

key word : nitrate, groundwater recharge, groundwater flow, groundwater-level fluctuation, oxygen and hydrogen isotope, nitrogen isotope, denitrification.

1. Introduction

Nitrate contamination is a major problem in shallow aquifers in rural area and poses a threat to groundwater supply. In the Republic of Korea, it was reported that 2.1% of groundwater in selected points had exceeded the tolerance limit of nitrate in 2000 (Ministry of Environment, 2001). The purpose of this research is to characterize nitrate-contaminated site using hydrological and isotopic investigations. For the purpose, the infiltration and recharge process of the study site were firstly analyzed with fluctuation data of groundwater-level and oxygen hydrogen stable isotope data. Secondly, the groundwater flow pattern was also investigated by flow simulation and oxygen isotope. Finally, the source type and attenuation mechanism of nitrate were found out by utilizing nitrogen isotopes.

2. Site description

The study site is an agricultural area with a small residential area called Moonhwa

Maul in Jeungpyeong Eup, Chung-buk, Korea.(Fig.1). Bedrock of the area is composed of Jurassic porphyritic granite and the basin is composed of Quaternary alluvium sand (KARICO, 2001). The groundwater flows from south to north. The observed hydraulic gradient was about 7×10^{-3}. As the reported hydraulic conductivity is in the range of 4.5 to 11m/day.

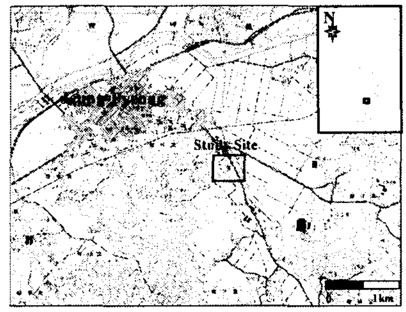


Fig 1. Location map of study site

3. Result

Data of groundwater level are collected at w00-13 and w00-5. w00-13 is located near domestic area and farm. The other is located near road and rice field. Figure 2 shows the variation of groundwater- level and amount of precipitation at w00-13. For analyzing oxygen and hydrogen isotope, samples had been collected in study area from November 28, 2001 to September 25, 2002. Figure 3 shows the temporal variation of $\delta^{18}O$ values. The $\delta^{18}O$ values had slightly changed during dry season, but largely rose up from late spring to early summer. Since late summer, the value dramatically became lighter again. Peculiarly the values of PRB-s4 have constant value. In the case of hydrogen, the tendency of variation is like to oxygen stable isotope. The samples for analysis of nitrogen isotope were collected at three times in winter and one time in summer. The concentrations of ammonium-nitrogen were very low in winter, and not detected in summer. The isotopic values of ammonium-nitrogen were very high. Also the concentrations of nitrate-nitrogen were not as high as expected, so they almost existed under the maximum permissible limit (Fig 4).

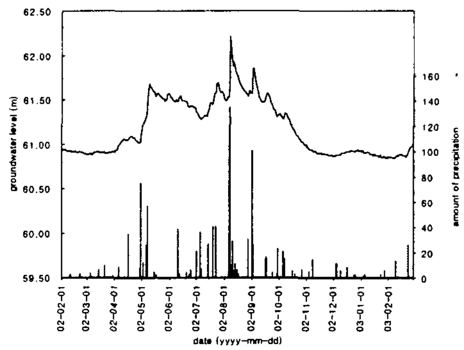


Fig 2. Ground water-level and amount of precipitation at w00-13

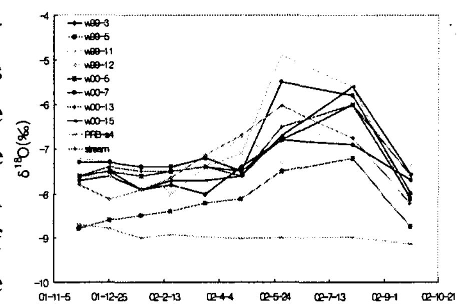


Fig 3. Variation of oxygen isotope

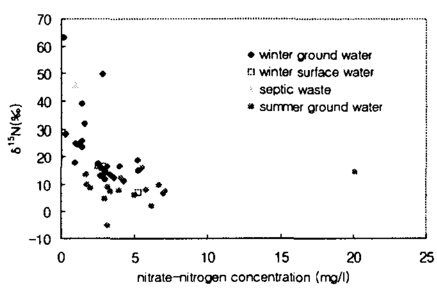


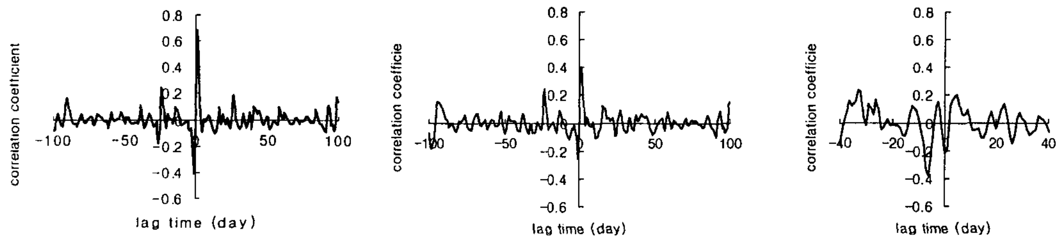
Fig 4. $[NO^{3-}-N]$ and $\delta^{15}N$

4. Interpretation and Discussion

4-1. Infiltration and recharge processes

The infiltration by precipitation is estimated with cross-correlation (Fig 5). For clear result, the running average was used at groundwater-level data. The peak time in w00-13 is 1 day and correlation coefficient is 0.679. The groundwater-levels at w00-13 are governed by precipitation. The peak time in w00-5 is 2 day and correlation coefficient is 0.401. By the cross-correlation of each season, w00-5 has late peak (Fig 5-c) in spring. Considering of the location, w00-5 could be affected by irrigation of stream water at a rice field.

The recharge ratio was estimated by the depression method (Choi and Ahn, 1998).



(a) w00-13 (b) w00-5 (c) w00-5 in Spring

Fig 5. Cross-correlation of precipitation and groundwater-level

The recharge ratio can be derived from monthly depression and maximum depression. The recharge ratios are both 0.140 at w00-13 and w00-5 (Fig 6).

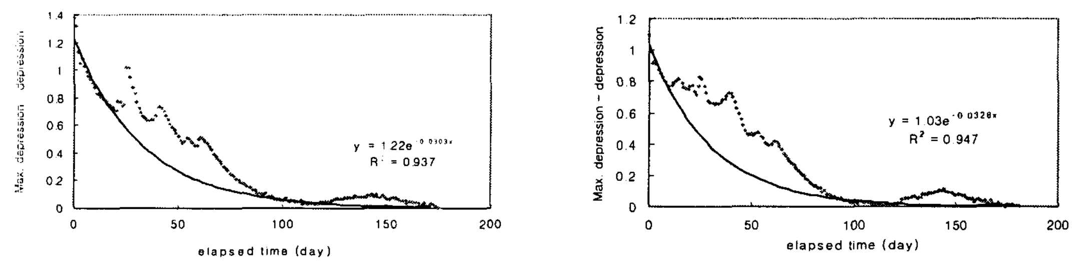


Fig 6. Regression of depression of groundwater-level

The relation of $\delta^{18}O$ versus δD are represented in Figure 7. The data points from November 28, 2001 to March 22, 2002 have similar positions, and it indicates the recharge by winter precipitation. In May, 2002, the heavy rain by temperature effect recharged into ground wate. The values of August 3, 2002 also shows the recharge of summer rain. The value of September 25, 2002 have the light composition similar to winter composition, and it shows the amount effect by heavy rainfalls.

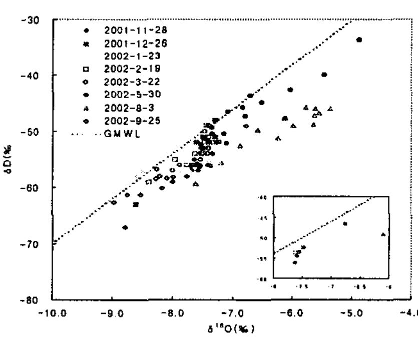


Fig 7. Distribution of $\delta^{18}O$ and δD

4-2. Groundwater flow

In order to estimate the moving velocity, well-to-well cross-correlations of isotopic data had been performed. The result of cross-correlation is represented Figure 8. The average of northern component in the velocities is 205m/yr, and that of eastern component is 106m/yr. Consequently the average linear velocity is about 231 m/yr. It is in good accordance with the linear velocity estimated from flow simulation.

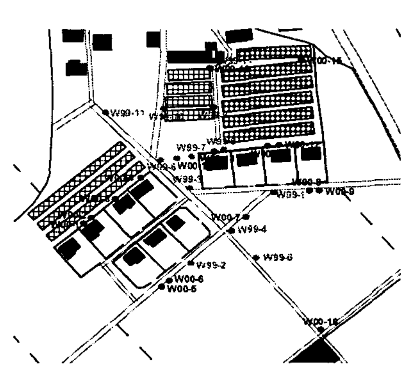
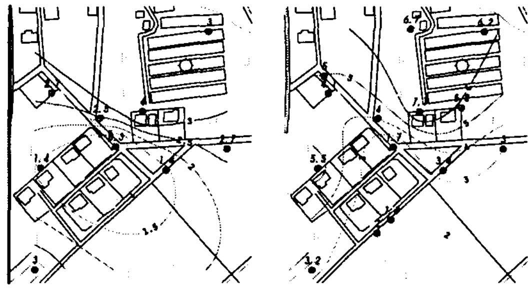


Fig 8. Linear velocities estimated by well-to-well correlation

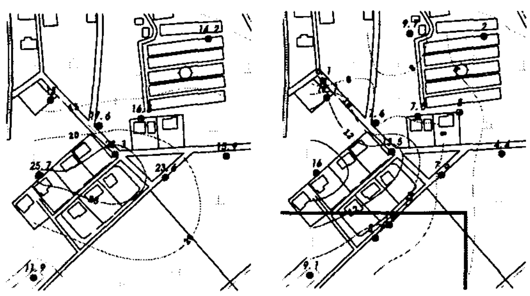
4-3. Nitrate contaminants source and their pathway

Nitrate-nitrogen has relative high concentration in summer and has relative high isotopic value in winter. The concentrations in northern parts are relative high, and those in southern parts are low (Fig 9). The non-point sources in this area are natural soil and fertilized soil with about $\delta^{15}N$ value about 5~10‰. While the point sources in the middle area is seemed to be septic waste. The contaminant source of w00-15 is considered to be animal waste (Fig 10). The small PRB had been constructed at the point of the highest nitrate concentration around w00-11. The major contaminant source of that was possibly septic waste, it is supported semi-constant $\delta^{18}O$ value of -9.0~-8.7‰ .The main mechanism of nitrate attenuation is the denitrification. The evidences of this are high $\delta^{15}N$ value, the good fitness with the Rayleigh equation of $\delta^{15}N$ and $[NO^{3-}\text{-}N]$ data (Fig 11).



(a) winter, 2001 (b) 2002, summer

Fig 9. Spatial distribution of $[NO^{3-}\text{-}N]$



(a) winter, 2001 (b) summer, 2002

Fig 10. Spatial distribution of $\delta^{15}N$

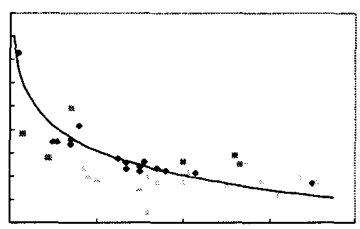


Fig 11. Relation of $[NO^{3-}\text{-}N]$ and $\delta^{15}N$

5. Summary and conclusion

Hydrological and the isotopic investigation had been performed in an agricultural residential area in Jeungpyeong, Choongbook, Korea in order to identify sources, fate and transport of nitrogen compounds in groundwater. In this area, nitrate contamination sources are natural and fertilized soils as non-point sources, and septic and animal wastes as point sources. They move into aquifer with the recharged water by precipitation and irrigation in spring and summer, and move from southwest to northeast at about 230m/yr following the groundwater flow while being naturally attenuated by denitrification.

6. Reference

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