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Carbon-nitrogen-sulfur isotopic tracing method to understand different anaerobic bacterial processes in aquifer systems

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Denitrification is recognized as an important natural attenuation function for groundwater nitrate contamination. This study proposes a new concept for better understanding the major anaerobic bacterial reduction including denitrification occurring in aquifer systems by using C, N, and S stable isotopic combination as reaction net recorder. To verify the utility of C-N-S isotopic tracing method (named as CNS-IT method), we newly investigated delta 13C-DIC and delta 34S-SO4 characteristics of the Kumamoto groundwater systems, which denitrification mechanism has already been well studied based on the delta 15N-NO3 and delta 18O-NO3 tracing study.

Significant sulfate reduction (with maximum increase of delta 34S-SO4 of 55 permil) with progress of denitrification (with maximum increase of delta 15N-NO3 of 38 permil) was observed as groundwater flows down gradient. In contrast, decline of delta 34S-SO4 (with maximum decrease of delta 34S-SO4 of 8 permil) with denitrification was found only sporadically. These observations imply the possibility that denitrification found over the study area was mainly driven by heterotrophic process as did for sulfate reduction, but autotrophic denitrification was occurred in just very limited space. Moreover, low delta 13C-DIC feature (-21 ~ -17 permil) of groundwater at recharge area suggested that water was already enriched in organic C source DIC at most upgradient area prior to denitrification occurred. This fact prevented us to evaluate the isotopic fractionation effect by denitrification on delta 13C-DIC. However, we rather found that the CNS-IT method could be more efficiently used for the evidence of occurrence of methanogens reaction (actually, we found maximum increase of delta 13C-DIC of 8 permil at the denitrification hotspot).

The case study in Kumamoto demonstrated the usefulness of CNS-IT method for comprehensive understand of major anaerobic bacterial processes, including distinguishment between heterotrophic vs. autotrophic denitrification, occurring in aquifer systems. In the presentation, we will attempt to propose practical utility of CNS-IT method by showing delta 15N-NO3, delta 13C-DIC, and delta 34S-SO4 evolutional patterns according to combinations of major anaerobic bacterial reactions.

Keywords: isotope ratios, groundwater, Kumamoto, denitrification, heterotrophic, autotrophic