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Fate and source of nitrate contamination in the groundwater along its flow in Kumamoto region, using nitrate isotopes

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Kumamoto city has a population of about 0.7 million people. This region is unique in the world because 100% of the drinking water is dependent on groundwater. Huge amount of groundwater is stored in high permeable Quaternary volcanic deposits and andesitic lavas mainly composed of four volcanic layers associated with 4 times Aso volcanic eruptions.

Nitrate-nitrogen contamination of groundwater has previously been observed in the aquifer system in Kumamoto area. Nitrate-N concentration in groundwater has been increasing and exceeding 10 mg/l in some places. However, the source and fate of nitrogen in groundwater in this region has not yet been clarified. For sustainable utilization of groundwater in this region, this issue needs to be addressed. Therefore, the purpose of our study was to confirm the source of nitrogen in groundwater and to understand the fate of contaminant in groundwater system in this region using nitrogen isotope and oxygen isotope.

The main land-use is consisting of farm land and livestock farm in upland areas and rice paddies in the lowland area. It would therefore be possible that nitrate in groundwater is originated from fertilizers and livestock wastes. The other notable features of this area is that large amount of irrigation water using Shira River infiltrates into deep groundwater around mid-watershed area.

In the year 2011, water samples were collected from 68 production wells (shallow groundwater 15 samples, deep groundwater 53 samples) in January to March, from 50 private wells (shallow groundwater 31 samples, deep groundwater 19 samples) in July, and from 78 production wells (shallow groundwater 21 samples, deep groundwater 57 samples) in October to November, respectively.

Average nitrate concentration in shallow groundwater was 10.4 mg/l (Max 44.0mg/l) while that in deep groundwater was 11.8mg/l (Max 72.0mg/l). Nitrate concentrations in the groundwater were high in highland areas where groundwater recharges. Nitrogen isotope ratios of most of groundwater samples ranged from +2 to +7 permillage. With comparison of all possible source materials, the source of nitrate in groundwater in this area was estimated to be mineral fertilizers applied in the agricultural fields. This conclusion differs from earlier study that concludes the nitrate source as livestock waste.

On nitrogen isotope vs oxygen isotope diagram, the shallow and deep groundwater samples having nitrogen isotope of above 7 permillage plot along the evolutional line for denitrification. In spatial point of view, most of the denitrification phenomenon was found in coastal area. Denitrification rates of these groundwater samples are calculated above 90% in most of case. Nitrate concentration tends to be lower towards the end of flow path because significant denitrification is occurred at coastal area.

In addition, in mid-watershed area, reduction of nitrate concentration was also found due to the dilution effect with mixing of Shira River with much lower nitrate concentrations. Using hydrogen and oxygen isotope ratios and sulfate concentration, mixing rates of both end-members (Shira River water and groundwater in recharge area) were calculated. Mixing rates of Shira River into deep groundwater were estimated to be from 40% to 70%. All of these results are important information to be used in the program of groundwater resource management of the Kumamoto City.

Keywords: Groundwater contamination, NO3-N, Nitrate isotopes, Denitrification, Source of nitrate