Groundwater contamination in Tokyo and potential use in disasters

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Recently, the situation surrounding groundwater use in urban areas has been changing. For example, groundwater table has been rising in central Tokyo owing to the restriction on groundwater abstraction since the 1970s, which is currently threatening underground structures including subway stations. One of the possible measures for this issue is the use of groundwater in disasters, landscape irrigation, and sprinklers. Also, large water consumers such as hospitals have recently started to switch the water source from public to private water supply systems using groundwater.

Groundwater in urban areas is, however, potentially contaminated by several pollutants from both natural and anthropogenic sources including soils and sewage through leakage from decrepit sewer pipes, respectively. Contamination by pollutants, most frequently by nitrogen and *E. coli*, often hinders the use of groundwater. In order to improve the groundwater quality, it is important to investigate the groundwater contamination and to identify the sources of pollutants. Also, it is necessary to evaluate the potential of the groundwater use based on the water quality.

Therefore, we revealed the current status of groundwater contamination by nitrogen in central Tokyo, and analyzed the sources using nitrogen isotope ratios ($d^{15}N$). Also, we performed a case study to evaluate the potential use in disasters in Chiyoda Ward, Tokyo, where there are large differences in populations between day and night.

We collected 174 groundwater samples from 96 public boreholes and 25 private boreholes such in central Tokyo in 2005 to 2007. We analyzed ammonia-, nitrite-, and nitrate-nitrogen. 4.1% (5/121) and 3.3% (4/121) of groundwater samples exceeded 10 mgNH_4-N/L and 10 mgNO_3-N/L, respectively. It is confirmed that groundwater in central Tokyo was heavily contaminated by nitrogen. We analyzed $d^{15}N$ to unravel their sources. There were significant positive correlations between ammonia-nitrogen concentrations and $d^{15}N$ (Spearman's rank correlation coefficient = 0.60; P = 0.04), indicating that ammonia-nitrogen was derived from natural sources and sewage, and that heavy contamination of ammonia-nitrogen in groundwater was attributable to sewage. Contrary, $d^{15}N$ was low in groundwater heavily contaminated by nitrate-nitrogen, indicating that heavy contamination of nitrate-nitrogen in groundwater was attributable to other sources such as fertilizers and natural soils. There were significant negative correlations between nitrate-nitrogen concentrations and $d^{15}N$ (Spearman's rank correlation coefficient = -0.44; P = 0.01) suggesting that denitrification occurred in groundwater.

Then, the groundwater availability in the Chiyoda Ward was determined for different application purposes at a huge epicentral earthquake presumed in this study. We collected 30 groundwater samples from emergency wells in the Chiyoda Ward in 2008 and analyzed pH, turbidity, *E. coli*, nitrogen (ammonia-, nitrite, nitrate-, and total nitrogen), dissolved oxygen, electrical conductivity, alkalinity, dissolved organic carbon, chlorine consumption, and so on. Based on the quality, groundwater samples were classified into 4 groups of application: (1) potable without treatment, (2) potable after disinfection and filtration treatments, (3) miscellaneous, and (4) unusable. Groundwater samples from 8 (27%), 9 (30%), 10 (33%) and 3 (10%) wells were classified as potable without treatment, potable after disinfection and filtration treatments, miscellaneous and unusable, respectively. Furthermore, available amount of groundwater from each well was roughly estimated based on the aquifer characterization and geological information. Groundwater was suggested to compensate the water shortage in disasters, while water demand in disasters was suggested to be larger than the stock waters in emergency water supply tanks and water receiving tanks.