Long-term monitoring of groundwater quality in Arakawa Lowland and Musashino Upland, Southern Kanto Plain, Central Japan

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Abstract: Subsurface temperature increase (i.e. subsurface warming) has been recognized in many parts of the world. The subsurface warming will be likely more common and pronounced in the near future due to combined effects of global warming, urbanization, and exhaust heat from underground infrastructures such as subways, shopping complexes, and sewage systems especially in megacities worldwide. This can trigger changes in physical, chemical, and biological processes in subsurface environment and may cause change in groundwater quality. In this study, long-term monitoring of groundwater quality in Arakawa Lowland and Musashino Upland near Tokyo metropolitan area in Japan was carried out for collecting baseline data of groundwater quality prior to escalation of the subsurface warming. In both study areas, long-term monitoring data were obtained and the acquired data showed almost constant groundwater quality. The unconfined and confined aquifers in Arakawa Lowland were under moderate to strong reductive conditions. On the other hand, the confined aquifers were basically under oxidative conditions. These different groundwater redox conditions might be associated with markedly different topographic features between Lowland (mainly groundwater discharge area) and Upland (mainly groundwater recharge area).

Keywords: Subsurface warming, groundwater quality, long-term monitoring, groundwater redox condition, Arakawa lowland, Musashino upland.

1. INTRODUCTION

Recently, a temperature increase in subsurface environment (i.e., subsurface warming) has been observed in many parts of the world (e.g., Huang et al. 2000; Perrier et al. 2005; Taniguchi et al. 2007; Kool, 2008). The subsurface warming is strongly related to surface warming effects including global warming and urbanization. In the near future, there is a possibility of a serious increase in subsurface temperature due to both the surface warming effects and exhaust heat from underground infrastructures such as subways, shopping complexes, and sewage systems especially in megacities worldwide.

The subsurface warming can trigger changes in physical, chemical, and biological processes in subsurface environment including groundwater systems. For example, change in groundwater quality may be induced by changes in solubility, chemical reaction rate, and adsorption and desorption characteristics (e.g., Banks, 2008; Bonte et al. 2011; Hänlein et al. 2013; Saito and Komatsu, 2014). Actually, a previous study investigated changes in 34 groundwater quality parameters during in-situ 13 month heating and 14 month natural cooling periods in a confined marine sediment aquifer in the Saitama University campus close to Tokyo metropolitan area of Japan (Saito et al. 2016). The results showed approximately linear relationships for eight chemical components of B, Si, Li, dissolved organic carbon (DOC), Mg\textsuperscript{2+}, NH\textsubscript{4}\textsuperscript{+}, Na\textsuperscript{+}, and K\textsuperscript{+}, suggesting changes in chemical concentration between 4% and 31% for a temperature change of 7°C.

However, there are few previous studies regarding the negative impacts of the temperature change on the subsurface environment. For evaluating and predicting the negative impacts especially on groundwater systems, long-term monitoring of groundwater quality as baseline data prior to escalation
of the subsurface warming is essentially needed. Therefore, the objective of this study was to investigate and characterize the groundwater quality (mainly focused on major cations and anions) at two study sites with having markedly different topographic features. Both study sites are located close to Tokyo metropolitan area in Japan as one of the biggest megacities in the world.

2. MATERIALS AND METHODS

This research focused on two study sites at campuses of Saitama University (35°51′44.146″N, 139°36′34.034″E) and Tokyo University of Agriculture and Technology (35°41′1.37″N, 139°28′58.44″E) near Tokyo metropolitan area of Japan (Figure 1).

![Figure 1 Location of Study Sites in the Saitama University (SU) Campus of the Arakawa Lowland and the Tokyo University of Agriculture and Technology (TUAT) Campus of the Musashino Upland Close to Tokyo Metropolitan Area in Japan. The Base Map was downloaded from the Website of Geospatial Information Authority of Japan (GSI)](image-url)

The Saitama University site (hereafter, SU site) is located on the Arakawa Lowland and groundwater monitoring wells were installed to unconfined (around 2 m depth: top aquifer) and two confined (around 17 m and 39 m depths: middle and bottom aquifers, respectively) aquifers. The middle aquifer consists of marine sediment with silt to sand layer, while for the other two aquifers, the top and bottom aquifers are composed of non-marine silt to clay and sand and gravel layers, respectively. On the other hand, the Tokyo University of Agriculture and Technology site (TUAT site) is located near the border of the Tachikawa terrace and the Musashino terrace on the western Musashino Upland. Groundwater monitoring wells were installed to two confined aquifers with non-marine gravel layers in around 33 m (upper aquifer) and 44 m (lower aquifer) depths, respectively. More detailed information on these study sites is presented in Saito et al. (2014), Thuyet et al. (2016), Ueshima et al. (2017), and Brunetti et al. (2017).

At both study sites, groundwater was periodically sampled using a sampling bailer after purging the groundwater of at least two wells volumes. Field measurement of pH, electric conductivity (EC), dissolved oxygen (DO), and oxidation-reduction potential (ORP) were immediately conducted. Then, the obtained groundwater was filtered using a 0.20 μm membrane filter and major cations and anions (Na+, NH4+, K+, Mg2+, Ca2+, Cl-, NO3-, Br-, NO2-, SO42-, and HCO3-) DOC, heavy metals and trace elements (Li, B, Al, Si, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Sr, Cd, Sb, and Pb), and dissolved gas (CH4) were measured in the laboratory.
3. RESULTS AND DISCUSSION

Temporal variations of major cations and anions in the groundwater taken from the top, middle, and bottom aquifers at the SU site are illustrated in Figure 2. In the middle and bottom aquifers, long-term monitoring data were obtained. Data showed almost constant groundwater quality during the monitoring period. On the other hand, the monitoring of groundwater quality in the top aquifer started on July 2016 and the obtained data up to now showed that the sum of positive and negative charges within the groundwater basically balance if we consider high concentration of Fe (several mg/L to around 10 mg/L) detected in this aquifer. Figure 3 presents temporal variations of major cations and anions in the groundwater of the upper and lower aquifers at the TUAT site. The groundwater quality data were almost stable also in both aquifers of the TUAT site and they showed similar chemical compositions each other.

Figure 2 Temporal Variations of Major Cations and Anions in the Groundwater from the Top (Unconfined), Middle (Confined), and Bottom (Confined) Aquifers at the SU Site

Figure 3 Temporal Variations of Major Cations and Anions in the Groundwater from the Upper (Confined) and Lower (Confined) Aquifers at the TUAT Site
Figure 4 and 5 illustrate Trilinear diagram with plotting all acquired data at both sites and Stiff diagrams for each aquifer made by using averaged data, respectively. In the middle and bottom aquifers of the SU site, NH₄⁺ and CH₄ were detected with no NO₃⁻ and SO₄²⁻ present, while for the top aquifer, there was no NO₃⁻ with SO₄²⁻ detection. The type of groundwater quality in the top and bottom aquifers consisting of non-marine sediments showed Ca-HCO₃ dominated type, which is a typical water quality in shallow groundwater. Oppositely, the middle aquifer showed Na, K, Mg-HCO₃ type because this aquifer is composed of marine sediment and the groundwater quality can be affected by the sediment. At the TUAT site, there were NO₃⁻ and SO₄²⁻ with no detection of NH₄⁺. Here, both aquifers consist of non-marine sediments and they showed the same type of groundwater quality, namely Ca-HCO₃ dominated type.

Figure 4 Trilinear Diagram with plotting all Groundwater Quality Data in Five Aquifers at the SU and TUAT Sites

Figure 5 Stiff Diagram for the Averaged Groundwater Quality Data in Five Aquifers at the SU and TUAT Sites

At the SU site, the top unconfined aquifer was under moderate reductive condition (suggested as denitrification environment) and the other two confined aquifers were under strong reductive conditions (suggested as methanogenic environment), while for the TUAT site, both confined aquifers were
basically under oxidative conditions. These different groundwater redox conditions may be associated with markedly different topographic features that the SU and TUAT sites are located in Lowland (mainly groundwater discharge area) and Upland (mainly groundwater recharge area), respectively. Generally, the groundwater in discharge area can be under reductive condition due to groundwater flow, compared to the groundwater in recharge area that can be under oxidative condition (e.g., Ioka et al., 2007).

4. CONCLUSIONS

Long-term monitoring of groundwater quality (mainly focused on major cations and anions) in Arakawa Lowland and Musashino Upland near Tokyo metropolitan area of Japan was carried out for collecting baseline data of groundwater quality prior to escalation of the subsurface warming. In both study areas, long-term monitoring data were obtained and the acquired data showed almost constant groundwater quality. The unconfined and confined aquifers in Arakawa Lowland were under moderate to strong reductive conditions. On the other hand, the confined aquifers were basically under oxidative conditions. These different groundwater redox conditions might be associated with markedly different topographic features between Lowland (mainly groundwater discharge area) and Upland (mainly groundwater recharge area).

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6. REFERENCES


