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Impact of Injecting Heated Water into Aquifer on Groundwater Quality
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In late years, usage of geothermal heat energy, one of the renewable energy sources, draws attention in Japan. The geothermal heat can be used through heat pumps for building heating and cooling. A heat pump can extract heat energy either from the ground using underground heat exchangers or from pumped groundwater. While the former is referred to as a closed-type ground source heat pump (GSHP), the latter is known as an open-type ground source heat pump. The open-type GSHP systems also require either recharging heated or cooled groundwater into aquifers or discharging it into surface water systems. There are various advantages of using the open-type GSHP systems; energy efficiency is much higher than the closed-type GSHP systems. On the other hand, altering groundwater temperature may cause environmental impact such as elution of toxic elements from the aquifer or changes in microbial activities in the aquifer. However, such environmental impact caused by the open-type GSHP systems has been rarely studied and is generally poorly understood. To maintain its sustainable usage, more data on environmental impacts need to be collected from field experiments. The main objective of this study is, therefore, to investigate the impact of injecting heated water into the aquifer on groundwater temperature and its quality.

A field experiment was conducted from October 7 to December 2 in Fuchu campus of Tokyo University of Agriculture and Technology in 2014. Groundwater pumped from a pumping well was heated to 30 oC before it was injected to a confined aquifer at GL-50m from an injection well installed 10-m away from the pumping well at a rate of 20 L/min. The temperature of the ground below GL-10m is almost constant at 17 oC year-round at the experimental site. The heating load was therefore equivalent to 18.1 kW. Changes in temperature and element concentrations in groundwater were observed at two 50-m long observation wells installed at 1.4-m (O-1) and 5.3-m (O-5) away from the injection well. Temperature sensors were installed every 5 m at O-1 and O-5. Groundwater samples were collected from two aquifers; one at GL-40m (shallow) and another one at GL-50m (deep), from O-1 and O-5, every two or three days during the experiment. EC, pH, DO, ORP, and turbidity were measured immediately after samples were collected, while concentrations of sixteen trace elements and major ions were measured later using ICP-MS and IC, respectively.

Temperatures of the deep aquifer at O-1 and O-5 rose from 17 oC to 23 oC and 22 oC, respectively, while those of other depths remained almost unchanged or increased slightly, indicating that heated water was indeed directly injected to the deep aquifer. While pH, EC, and DO did not changed, ORP showed a gradual decreasing trend in both aquifers. Turbidity was largely affected by injecting heated water as it increased to 60 NTU at the deep aquifer at O-1. That of the other aquifers stayed almost unchanged before, during, and after injecting heated water. As concentrations of elements might be affected not only by changes in temperature, but also by physical injection, it may be required to separate the impact of different processes. One of the approaches to do that is to take concentration ratios with an inert tracer. This is known as an internal standard method. As there was no artificial tracer added in this experiment, zinc, one of the more stable elements, was used as a tracer. Ratios to Zn concentration increased significantly during heating for some elements, such as Al.

From the field experiment, it was clearly shown that the turbidity of groundwater was strongly affected. As for trace elements and major ions, while it was shown that injecting heated water might increase concentrations or concentration ratios for some elements, more careful data analysis needs to be done to clarify the mechanism of such effects.