

## Evaluation of shallow groundwater quality for use in open-loop type groundwater-based heat pump system

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In cold snowy regions, kerosene is used as fuel to melt snow in the winter, but geothermal heat is more suitable in terms of suppressing greenhouse gas emissions. Regarding shallow geothermal heat utilization heat pump systems, there are closed-loop and open-loop systems. In a closed-loop system, a high initial cost is required for installation of the underground heat exchanger, but in the case of the open-loop system using the shallow groundwater, the initial cost can be suppressed as compared with the case of the conventional method. Therefore, we think it is important to promote open-loop systems using shallow groundwater. However, in floodplains and deltas excluding alluvial fans used as farmlands and residential lots, shallow groundwater may contain a large amount of iron and free carbonic acid, which may affect the use of heat pumps. In particular, it is not clear whether the free carbonate concentration is constant in shallow groundwater or variable, greatly or otherwise. Therefore, in this study, we aimed to clarify the fluctuation characteristics of several water quality parameters, especially free carbonate concentration, in shallow groundwater. For almost one year, groundwater was monthly collected from three depths of about 3 m, 8 m, and 18 m in the downstream area of the Tsugaru plain of the Aomori River in Aomori Prefecture. At the time of collection, pH, electrical conductivity, and water temperature were measured in the field. Concentrations of  $\text{Na}^+$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{F}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ , Fe, Mn, Sr, Ba, Si, and alkalinity were analyzed. Using the measurement results from such, the free carbonate concentration was determined using the aqueous geochemical calculation computer program PHREEQC. The free carbonate concentration fluctuated, with a range of approximately 50 to 100 mg/L of groundwater at a depth of 3 m, about 40 to 80 mg/L at a depth of 8 m, and approximately 10 to 30 mg/L at a depth of 18 m. This is possibly due to the fact that the influence of events occurring on the ground surface decreases with an increase in depth.

Keywords: open-loop type groundwater-based heat pump system, shallow groundwater, water quality