Estimation of clogging factors in injection wells of geothermal heat pump system based on the clogging material analysis

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In the open-loop geothermal heat pump system, clogging may occur in injection wells, which may interfere with the injection of groundwater. Suspended materials in groundwater are one of the contributors of clogging. The purpose of this study is to clarify the characteristics of the suspended materials and estimate the cause of clogging by analyzing the suspended materials collected by the backwash.
The research field of this study is in Yokkaichi city, Mie Prefecture, central Japan. The aquifer consists of a sand layer, and the iron content in the groundwater was 0.58 mg/L in the natural state. The pumping and injection wells are changed every cumulative operation 48 to 72 hours between the circulating wells, and backwash is performed.
Backwash water was collected in June 1, August 27 and November 25 of 2021 to understand the characteristics change of clogging materials depending on the injection temperature. In June 1, the cumulative operation time was about 24 hours before water collection. In August 27, the cumulative operation time was about 12 hours. In November 25, the cumulative operation time was about 24 hours. The backwash water was collected several times from 6 seconds after backwashing to avoid the water retained in the circulation pipe for a long time. It was also collected 20 minutes after backwashing. The former water contains suspended materials near the borehole wall. The latter is far away from the borehole, indicating the suspending material in natural state groundwater.
The results of SS measurements reveal that the sample 6 seconds after baskwashing is higher and those of 1 and 20 minutes are lower in backwash water with about 24 hours of cumulative operation. The samples 6 seconds, 1 and 20 minutes after baskwashing are lower in backwash water with about 12 hours of cumulative operation. The SS was remarkably higher when the completely clogging occurred.
The results of SEM observation show that the suspended materials consist of twisted, spherical, oval, fibrous and ragged shapes. Twisted, spherical and oval types shows both of single and aggregate.
The results of SEM-EDX exhibit that twisted type contains mainly O and Fe, and often Si, Ca, Cu, Cr, Al. Spherical type is mainly O and Fe, often Si, Ca, Cu, and rarely Zn and Al. Oval and fibrous types are mainly O and often Si, Al. Ragged type is mainly O and Si, often Al and Mg.
Twisted type is considered to be *Gallionella ferruginea* of iron-oxidizing bacteria based on its shape. The SEM-EDX spectrum of *G. ferruginea* (Suzuki et al., 2011) is similar to that of twisted type, suggesting that it is *G. ferruginea.* The SEM-EDX spectrum of spherical type is also similar to that of twisted type, implying that spherical type is also iron-oxidizing bacteria. *Siderococcus* is iron-oxidizing bacteria with spherical shape (Kojima et al., 1995), and it is candidate bacteria. Kojima et al. (1995) describes that *Siderococcus* stays in groundwater. Its cell is shherical shape with 0.2 to 0.5 μm of diameter. It is connected each other like chain or network by its propagation. These characteristics are concordant with the observation results of spherical type.
Twisted and spherical types 6 seconds after backwashing show larger aggregate, meaning that they grow up near the borehole wall and contribute clogging. Oval and fibrous types are inferred to be diatom, and ragged type is considered to be minerals because of their shapes and SEM-EDX results. These are included in natural groundwater, because they are not detected from the sample 6 seconds after backwashing and present commonly in natural groundwater. These do not contribute clogging, because

they are smaller and do not become larger. Kojima et al. (1995) shows that the product of iron-oxidizing bacteria has adhesiveness. SEM observation in this study shows that twisted and spherical types involve ragged type. This suggests that oval, fibrous and ragged types are involved by iron-oxidizing bacteria and become larger.
SS results imply that iron-oxidizing bacteria propagates from 12 to 24 hours. The injection well is backwashed and suspended materials are removed before severe clogging. If no backwash, iron-oxidizing bacteria is propagated, involves diatom and minerals, and finally grow up to exceed to the slit width of the injection wells.

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