Environmental Impact Assessment of Open Loop Geothermal Heat Pump System in Gifu City, Central Japan

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Geothermal heat pumps (GHPs) are most efficient and eco-friendly energy that used for heating and cooling system. In Japan, the number of shallow geothermal installations has increased by year. Open loop GHPs is a type of GHP system which use groundwater as heat source for heating and cooling of building. In fact, there are still no regulations related to thermal use of groundwater and the subsurface in Japan. The aim of this study is to simulate regional and local groundwater flow and heat transport in study area and to assess the environmental impact by extraction and injection of open loop system from the wells into subsurface.

The study area is an alluvial fan of the Nagara River, Gifu city central, Japan. It is bounded by mountain ranges from north to northeast side and plain area remains. The Nagara River flows in the center of the plain. The underground temperature in alluvial fan is influenced by rapid groundwater flow recharged from the river. Rapid groundwater flow has potentiality to spread the environmental impact of GHP system greater than slow groundwater flow. This alluvial fan is composed of sands and gravels and often intercalate thin fine sand and silt layers. Groundwater flow occur mainly in the Quaternary sediments. For assessment of potential energy of open loop GHP system, regional 3D model of groundwater flow with heat transport in study area was developed using FEFLOW program. Model area has size of 13 km (NS), 12 km (EW) and 300 m (depth). Model is constructed first by geological data. In addition, pre-existing hydrogeological data which consist of groundwater table, underground temperature, and temperature of river water data in study area are compiled to construct the simulation model. Boundary condition of groundwater flow system is defined by water table distribution. Bottom of the model is basement rock, treated as impermeable boundary and lateral sides are set as no flow boundaries. For boundary conditions of heat transport, top and bottom of the model are fixed by constant temperature boundaries. In order to study environmental impact of open loop system, local simulation of open loop system was operated. We built local simulation with more fine mesh to create detailed information with wide area 1.2 km (NS), 1 km (EW) and 100 m (depth). Open loop simulation model was consisting of one extraction and injection wells. Both the extraction and injection wells were screened in the first aquifer (gravel layer). The operation mode was applied for heating from January to March, and cooling from July to September. The operation mode of pumping/injection was obtained a time-varying rate with keeping the temperature difference at constant pumping rate 288 m^3/d. The temperature difference of the pumping and injection are contained 3 variant values: 3, 5, 10˚C for heating and cooling periods.

To confirm the results of regional groundwater flow and heat transport simulation, there were comparison groundwater temperature data between calculated results and measured ones at some points. Based on this result, there is reasonably good match between calculated and measured data at southern region of model. Furthermore, the local simulation of open loop GHP system was shown that the distance of thermal discharge from injection activities gets further as variation of temperature difference increase. When the temperature difference between the pumping and injection is 10˚C, temperature changes caused rising groundwater temperatures surrounding injection area up to 37 m in the beginning of winter season and 47 m in the beginning of summer season. Temperature change is defined by a change more than 0.1°C at groundwater temperatures around injection activities. However, variation of temperature changes have impact to rise groundwater temperature less than 300 m from injection well and it is still in allowable range of interference effect from another open loop GHP system according to regulation of

other countries (Haehnlein et al., 2010).

Keywords: Geothermal heat pump, Open loop system, Groundwater flow, Environmental impact

