ENVIRONMENTAL CONCERNS OF BOREHOLE HEAT EXCHANGERS (BHE): THE ROLE OF HEAT-CARRIER FLUID AND GROUTING

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Borehole heat exchangers (BHE) are vertical loops placed into the subsurface to use the ground as a heat source/sink for domestic heating and/or cooling. The interest for environmental sustainability of such green renewable technology has been rising in recent years. The main concerns for groundwater quality regard the chemical riskiness of additives used in heat-carrier fluids circulating into the ground loops and inter-aquifer flow linked to defective borehole grouting.
In Italy the most common additive in BHE loops is the propylene glycol (PG), used for its anti-freeze properties. Introducing such organic compound into aquifers may enhance microbial activity and trigger alterations in redox conditions, with harmful consequences on groundwater, such as mobilization of heavy metals. The magnitude of metal release was investigated by means of microcosms, composed by a sandy sediment saturated with groundwater collected in two sites -one urban and one rural- in Turin Po Plain (NW Italy). In each microcosm an initial mass concentration of PG of 1% was set and the concentration of three Fe, Mn, Ni was monitored up to 60 days. Metals concentrations in water after 60 days reach nearly 104 µg/L for Mn, whereas Fe and Ni reach 400 and 1600 µg/L respectively. Such metal release is likely due to increase in microbial activity, stimulated by the PG, and the consequent change in redox conditions. In all cases the final concentrations are above the permissible quality thresholds for Italian standards: 200, 50 and 20 µg/L for Fe, Mn and Ni respectively. Triazoles (common corrosion protective agents in heat carrier fluids) were also detected in both fluids: concentrations (~0.05%) may be toxic for standard test organisms.
Concerning the second environmental concern, if the grout is uncomplete or damaged, there may be a hydraulic flow across the BHE and consequent groundwater quantity and quality degradation in multi-aquifer groundwater systems, such as the Piedmont Po Plain. To assess the grout integrity, a 7.5 m-long pilot BHE was installed in the SW Piedmont Po Plain. Many defects and void spaces were visually detected, likely due to the heterogeneity of the geologic medium (coarse gravels). Such observations were consistent with results from ultrasonic tests performed during and after grout maturation. A simplified analytical model was applied to detect the magnitude of the possible downward flux from shallow to deeper confined aquifers. The computed magnitude is up to 2.65 m^3/d in the worst scenarios with high head differences and thin separation layer. Such entity of inter-aquifer flow may lead to significant contaminants propagation from the shallow aquifer of Piedmont Po Plain, in which plumes are often found.

The two experiments indicate that carefulness is needed during BHE planning and installation phases. Additives for heat-carrier fluids of BHE loops should be avoided, if possible, and limitations should be proposed for new drillings in deep aquifers.