Key Controls on Mine-water Temperature in Flooded Mine Shafts: Insights from Temperature Profiles and Numerical Modelling

Flooded Coal Mines, Mine-Water Heat, Numerical Modelling, OpenGeoSys, Temperature Profiles

Heat demand for domestic space heating represents more than 1/3 of the energy consumption in the UK. Most of this energy is currently supplied by natural gas, contributing to 19% of the carbon footprint of the country in 2017. To reach the Net-Zero carbon emissions by 2050, the UK Government is looking at new approaches to decarbonize residential heating. Among them, low-carbon mine-water heat sources abstracted from abandoned flooded collieries largely available across the UK has been of growing interests. Using open-loop ground-source heat pump systems, heat energy can be harnessed from the 12-20°C water stored in the large underground voids inherited from past mining activities. Although the temperature of the water is expected to increase with depth according to local geothermal gradient, temperature measurements in former mine shafts in the UK revealed the lack of correlation between the depth of the measurements and the mine-water temperature. The aim of this study is therefore to assess the key parameters controlling the temperature profiles in mine shafts. This will be used to understand to what extent those can be used to calibrate mine models aiming at assessing their long-term geothermal potential.

We use the finite-element modelling software OpenGeoSys to simulate groundwater flow and heat transfers in a 2D porous media representing a mine of simple geometry. The mine consists of three mined coal seams interconnected via two open shafts embedded in a homogeneous host rock, whose properties have been attributed accordingly to the geology of the Coal Measures in UK Coalfields. We first analyse the effects of pumping and mine-water recovery on the temperature distribution in both pumping and monitoring shafts for different hydraulic boundary conditions, assuming a constant geothermal flux of 0.068 W/m². For each scenario, we then investigate the effects of the volume of mined rock, the geometry of the mined seams, the material properties and the pumping rate and depth on the modelled temperature profiles. The overall change in energy content of the system is moreover calculated to get insights into the relationships between the observed mine-water temperature and the actual heat potential of the mine. Results are finally compared to temperature profiles acquired during periods of flooding and water abstraction in shafts from the Dawdon-Horden Coalfield, North-East England.

Preliminary results indicate that the pattern of the temperature profile measured in mine shafts highly depends on the source and on the extent of water recharge i.e. from surrounding aquifers, lateral flooded mines or surface water. Allowing groundwater inflow from lateral areas via mined seams permits to reproduce the steps pattern of the temperature profile observed at Dawdon-Horden during water recovery and pumping. The amplitude of the shifts observed at the intersection between the mined seams and the shafts mainly depends on the pumping depth and on the volume of mined rocks. Additional results suggest that the density of mined seams and long-term pumping activities tend to permanently impact the temperature distribution within the mine. Further analysis is being undertaken to evaluate the relationship between the degree of complexity of mine workings and the observed temperature profiles. This will be used to understand the amount of simplification possible to build representative mine model when assessing their large-scale geothermal potential.