Temperature Plume Migration in Aquifers: Support to Geochemical Evaluation of Thermally-Mobilized Constituents

Nelson Molina Giraldo, Ron Coutts and Gordon MacMillan, Matrix Solutions

Geochemical evaluation of thermally-mobilized constituents in aquifers can be supported through better defining the spatial and temporal extent of temperature plumes. Heat transfer from thermal wells to aquifers results in groundwater heating and mobilizes otherwise immobile constituents such as arsenic. This mobilization can be triggered by several mechanisms which may include thermal desorption and enhanced microbial activity, thereby creating chemically reducing groundwater conditions and corresponding trace metals mobilization. The importance of these potential mechanisms on trace metals mobilization is likely aquifer and site specific.

Evaluation of the spatial and temporal evolution of a thermal plume is the first step to understanding the potential for environmental impact from mobilized constituents. Heat transfer in porous media occurs by conduction through water and soil solids, and by forced convection as heat is carried by moving groundwater. Simple calculations and more sophisticated analytic models can be used to assess the upper bound transport distance of a thermal plume. However, these approaches may be overly conservative for estimating transport distance because they neglect heat losses to confining aquitards and, in the case of relatively shallow aquifers, heat loss at the ground surface.

To provide information regarding the spatial and temporal evolution of thermal plumes in a confined aquifer, a study was undertaken using 3D numerical modelling. The model considered a confined aquifer and was used to assess thermal plume transport through time as affected by variables such as groundwater flow velocity, aquifer thickness, and aquifer depth. A total of 1,300 numerical simulations were performed and are summarized for use by hydrogeologists for rapid estimation of thermal plume transport distance under a variety of hydrogeologic conditions typical of confined aquifers in the oil sands that are penetrated by thermal wells. Important insights gained by evaluating the model results include: 1) Faster groundwater velocities result in shorter travel distance of the high zone within a thermal plume; 2) Thermal plume transport distances are shorter in shallow aquifers.

Families of curves relating the length of the temperature plume with aquifer parameters and geometry can be used to quickly plan monitoring programs (optimum locations for monitoring well placement) or to evaluate the extent of any isotherm that is suspected to trigger the release of trace metals. This numerical modelling study contributes to advance the understanding of heat transport in the subsurface and provides decision-making tools for regulatory approvals and environmental and risk assessments.

Nelson Molina Giraldo, MSc, PhD
Dr. Nelson Molina Giraldo is an engineer in training with a Master of Science degree and a doctorate in applied environmental geosciences, as well as 4 years of experience in groundwater modelling. He received his Ph.D. from the University of Tübingen in Germany, in 2011 where he conducted research into heat transport modelling in shallow aquifers. He has strengths in numerical methods applied to heat transport problems, as well as developing numerical models for flow and transport.