Assessment of Key Processes Affecting Vertical Transport of Brines in Low Permeability Till Beneath the Potash Salt Piles

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Summary

Key processes affecting transport of dense brines in till commonly underlying salt piles at the potash mining operations in Saskatchewan were assessed using a one-dimensional groundwater flow and transport model. These processes were: 1) advective and dispersive/diffusive transport due to transient changes in head differential across the till; 2) density-driven transport associated with the relatively high density of the brines compared to initial pore water in tills; and 3) pore pressure increases (Reeves et al., 2000, Dissanyake, 2008) and reductions in hydraulic conductivity associated with till consolidation resulting from surface loading. The model was developed using FEFLOW (Diersch, 2009) and represented a typical crossection consisting of 30 m of till overlain by a salt pile that is gradually constructed over a 30-year time period and is underlain by laterally extensive and highly-permeable aquifer.

The study found that, in the absence of consolidation effects, the breakthrough of the advective front occurred after 90 years for a moderate value of till hydraulic conductivity (10^{-9} m/s), and ranged between 20 years and 750 years, respectively for high (10^{-8} m/s) and low (10^{-10} m/s) values of hydraulic conductivity. This suggests that a good understanding of till hydraulic conductivity is critical in the assessments of brine transport and that sensitivity analyses of this parameter should be considered.

When the effects of pore pressure increases due to consolidation were included, the predicted time of breakthrough of the advective front increased by approximately a factor of two from the ones predicted in the absence of consolidation effects. Under a zero initial gradient, these pore increases were found to reverse the hydraulic gradient during early times of pile construction, thus preventing brine transport in the initial phases of construction; and led to a reduction of the downward gradient at later times until excess pore pressures fully dissipated. Similar increases in the time of breakthrough of the advective front (factor of 1.4 for the low hydraulic conductivity and factor of 2.7 for the high hydraulic conductivity) were predicted when the reduction in hydraulic conductivity due to till consolidation was included in the model. Overall, the effects of till consolidation were found to reduce the rate of downward migration of the brines, suggesting that assessments that did not include these effects predict arrival times that are shorter than actual (i.e. are conservative from the perspective of assessing contamination of the underlying aquifer).

The effects of brine density were predicted to have a lesser affect on brine migration. When these effects were excluded from model simulations, the time to breakthrough of the advective front increased by a factor of approximately 1.2. Nevertheless, assessments that do not consider density-coupled flow and transport are not conservative because the actual arrival times may be shorter than predicted.

Lastly, sensitivity of brine arrival times to mesh spatial discretization was assessed by varying the mesh spacing between 0.5 m and 10 m. Predicted breakthrough concentrations were essentially free of numerical instabilities (oscillations, numerical dispersion) when the mesh spacing was smaller than 2 m, whereas with coarser mesh spacing these effects became significant. The results suggest that sub-2 m vertical discretization over the entire till thickness must be used in order to provide reliable predictions thus raising practical issues for regional scale models that are typically based on relatively coarse vertical discretization. Depending on site configuration and hydrostratigraphy, assessments of brine migration that are based on a combination of detailed one- or two-dimensional model simulating the vertical transport under the salt piles in combination with a three-dimensional model representing regional flow system may be appropriate.

References

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