geoconvention
Virtual Event
September 21-23
2020
CSPG • CSEG • CWLS • GAC • MAC • IAH

Multi-phase numerical modelling of fugitive methane emissions in shallow aquifers

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Summary

Fugitive methane emissions from leaky wells into shallow aquifers are simulated using a multi-phase numerical model with the objective to better understand methane migration behavior and potential environmental impacts. Simulations are completed using the DuMux code including migration of water, gas and dissolved phase methane, applied to conceptual models at the lab and field scale. Methane degradation is not considered in these preliminary simulations.

The primary transport mechanisms simulated with DuMux are the transport of free phase methane subject to capillary and buoyancy forces, the dissolution of methane into the surrounding groundwater, advective transport of dissolved phase methane coupled with water flow, and diffusive transport of dissolved methane. DuMux multi-phase simulations are based on capillary pressure curves which are calibrated using the Brooks & Corey model.

The model is first applied to a series of 2D laboratory experiments of gas phase injection performed at Queen's University under a background flow gradient and including homogeneous and heterogeneous (layered) structures. Simulations are compared to the observed behavior with respect to gas phase mass distribution over time, and to breakthrough of the dissolved phase methane at selected monitoring points. Insights are provided into the role of spatial property distributions on methane migration, in particular gas phase pooling below low-permeability layers.

Field-scale simulations are then carried out based on conceptualized hydrogeological systems at the Saint Édouard site in southern Quebec where an exploration well was drilled into the Utica shale. Selected site conceptual models include methane source emissions into confined, unconfined and partially confined aquifers. These preliminary simulations will also assess the effect of leakage rates, hydrodynamic parameters and aquifer heterogeneity. The simulations show how methane migration and hence potential environmental impacts are controlled primarily by aquifer structure.