Hydrocarbon Groundwater Plume Stability and Persistence: Lessons Learned from 29 Sites and 5 Million Data Points

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Background/Objectives.

Groundwater plume stability and persistence are key questions that site investigators address daily. Traditional approaches typically use 8 groundwater hydrocarbon estimates across 8 quarters, then apply a Mann-Kendall test to evaluate if concentrations increase or decrease at a specific location. Alternatively, the data can be brought into GWSDAT, and plume stability assessed using the spatial-temporal spline approach. Both approaches are retrospective and designed to evaluate past behaviour. Forward-looking approaches, such as USGS's ModFlow, suffer from under-specified models that struggle to provide robust predictions for a typical, small hydrocarbon site. We aimed to develop a data assimilation technique that would provide robust updates to ModFlow and create robust predictive estimates of plume stability and persistence.

Approach/Activities.

LiORA created a technology stack capable of making an initial ModFlow estimate based on historical data and then updating that estimate monthly based on sensor input. Typically, each site would receive 7,200 new estimates of groundwater monthly. Using these sensor inputs, we used a Kalman filter technique to update the ModFlow parameters and assimilated this new data with existing model predictions. We used anonymized data and the resulting model predictions across 29 sites and 5 million data points. We then evaluated how plume stability and persistence varied among four approaches: Mann-Kendall (MK), Spatial-Temporal Splines (ST), Historical ModFlow (HM),and Sensor Modflow (SM).

Results/Lessons Learned.

As expected, STs were more effective in detecting plume dynamics than MK analysis. Furthermore, HM typically overestimated plume velocity and plume persistence. ModFlow with sensor data, assimilated into the model, SM, demonstrated greatly reduced plume velocity and persistence compared to using only historical data. Model certainty also increased dramatically as sensor data was assimilated, dramatically decreasing extreme model outcomes. Our results indicate that traditional methods of estimated plume stability in the tight clay regions of Western Canada, likely over-estimate plume velocity and approaches using sensor data, provide models that are more reflective of actual site conditions.

Steven Siciliano

As CEO of LiORA, Dr. Steven Siciliano brings his experience as one of the world's foremost soil scientists to the task of helping clients to efficiently achieve their remediation goals. Dr. Siciliano is passionate about developing and applying enhanced instrumentation for continuous site monitoring and systems that turn that data into actionable decisions for clients.

He is a leading authority on remediation of cold region soils and his research in this area is changing how industry accomplishes the necessary work of remediation. Dr. Siciliano has made significant contributions to the progress of environmental and soil science with 11 book chapters and 220 scientific papers which have collectively been cited over 17,000 times.

Dr. Siciliano graduated from the University of Saskatchewan (U of S) with a PhD in Toxicology. In addition to leading LiORA, he is a Professor at the U of S and NSERC Chair for In Situ Remediation.