Spatially-Averaged, Flow-Weighted Concentrations: A More Relevant Regulatory Metric for Groundwater Cleanup

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Background/Objectives. Under CERCLA, maximum contaminant levels (MCLs) have become de facto cleanup standards for contaminated sites in the U.S. Experience remediating sites in the last 35 years; however, shows that cleaning up groundwater to MCLs has been challenging, if not impossible, at many sites.

Once released into the subsurface, the distribution of the contaminant typically becomes very complex and heterogeneous. Scores of investigations confirm that the distribution of contaminants in the subsurface is typically complex, with much residual mass residing in fine-grained strata. Subsurface assessments using high resolution site characterization (HRSC) technologies show that dissolved COC concentrations often range over four orders of magnitude between samples that are only a few meters apart.

The discovery of the heterogeneous distribution of solute concentrations in the subsurface has created a regulatory conundrum. There are myriad solute concentrations in the subsurface at most contaminated sites. Which ones should be compared to MCLs for cleanup? All of them? Just the ones in the higher permeability flow zones that could convey contaminants to downgradient receptors? What about the contaminant mass that is sequestered in low-permeability, low-flow zones?

What is clearly needed is a spatially-averaged, flow-weighted concentration metric that considers the significance of where the mass is distributed. This concentration value should be spatially-averaged and flow-weighted to give more weight to the mass that resides in the high flow zones. Fortunately, this is possible via a simple manipulation of the mass discharge equation. The use of mass loading or mass discharge as a metric for assessment and remediation of subsurface contamination is gaining popularity in the U.S. and in other countries. Regulatory acceptance of the mass loading framework, however, has been slow in the United States, primarily because concentration-based standards are well established in statutes, regulations, and practice.

Approach/Activities. A spatially-averaged, flow weighted concentration can be calculated by dividing the contaminant mass discharge by the groundwater discharge of the plume. This yields one concentration value (C_A) that reflects not only the spatial average but is also weighted toward the more permeable flow zones that convey contaminants to potential groundwater receptors. This modification results in a spatially-averaged, flow-weighted concentration metric that could replace or augment point concentrations as a more meaningful cleanup metric at sites with contaminated groundwater.

Results/Lessons Learned. While contaminant mass discharge is likely still the most direct and relevant metric of the risk posed by a contaminated site to a downgradient groundwater receptor, spatially-averaged, flow-weighted concentrations are better predictors of risk than individual concentration measurements and should be incorporated into regulatory statutes and orders that require compliance with concentration-based standards.