Identifying Contaminant Release Conditions to Reduce Uncertainty in Plume Spreading and Dilution in Heterogeneous Aquifers

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The initial width of contaminant plumes has a key influence on expected plume development, dispersion and travel time statistics. In past studies, initial plume width has been perceived identical to the geometric width of a contaminant source or injection volume. A recent study on optimal sampling layouts for minimum variance prediction of contaminant concentration (Nowak *et al.* [2009], submitted to *Water Resources Research*) showed that the largest uncertainty in predicting plume migration stems from the total hydraulic flux through the source area, overwhelming other sources of uncertainty along the further travel distance in a large range of situations. This result points towards a missing link between source geometry and plume statistics, which we denote as the effective source width. We define the effective source width by the actual, rather than the expected hydraulic flux, through the source area. It is a stochastic quantity that may strongly differ from the actual geometric source width for small sources, and becomes identical only at the limit of wide sources (approaching ergodicity). We derive its stochastic moments in order to explore the dependency on scale and to define the limit of ergodic contaminant source (not plume) width. Effective source width is a contribution to dispersion since it is linked to the prediction variance of plume width. It is separable from the dilution part of dispersion similar to spreading and the uncertainty in predicting the center of mass is separable from dilution. We show that the chance of plumes to be consumed in a single hot-spot of mixing and dilution depends strongly on its overall width. Therefore, its knowledge will improve the prediction of contaminant dilution and mixing. In addition, we illustrate that if the effective source width at a given site is known rather than the geometric width, predictions of plume development, dispersion and travel time statistics would greatly increase in predictive power. The results of this study also offer advice in what situations sampling efforts should focus primarily on release conditions rather than on other sources of uncertainty.