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A Modeling Framework to Quantify Dilution Enhancement in Spatially Heterogeneous Aquifers

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Solute dilution rates are strongly affected by the spatial fluctuations of the permeability. Current challenges consist of establishing a quantitative link between the statistical properties of the heterogeneous porous media and the concentration field. Proper quantification of solute dilution is crucial for the success of a remediation campaign and for risk assessment. In this work, we provide a modeling framework to quantify the dilution of a non-reactive solute. More precisely, we model that heterogeneity induced dilution enhancement within a steady state flow. Adopting the Lagrangian framework, we obtain semi-analytical solutions for the dilution index as a function of the structural parameters characterizing the permeability field. The solutions provided are valid for uniform-in-the-mean steady flow fields, small injection source and weak-to-mild heterogeneity in the log-permeability. Results show how the dilution enhancement of the solute plume depends the statistical anisotropy ratio and the heterogeneity level of the porous medium. The modeling framework also captures the temporal evolution of the dilution rate at distinct time regimes thus recovering previous results from the literature. Finally, the performance of the framework is verified with high resolution numerical results and successfully tested against the Cape Cod field data.