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Evaluating the Impact of Contaminant Dilution and Biodegradation in Uncertainty Quantification of Human Health Risk

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We present a probabilistic framework for assessing human health risk due to groundwater contamination. Our goal is to quantify how physical hydrogeological and biochemical parameters control the magnitude and uncertainty of human health risk. Our methodology captures the whole risk chain from the aquifer contamination to the tap water assumption by human population. The contaminant concentration, the key parameter for the risk estimation, is governed by the interplay between the large-scale advection, caused by heterogeneity and the degradation processes strictly related to the local scale dispersion processes. The core of the hazard identification and of the methodology is the reactive transport model: erratic displacement of contaminant in groundwater, due to the spatial variability of hydraulic conductivity (K), is characterized by a first-order Lagrangian stochastic model; different dynamics are considered as possible ways of biodegradation in aerobic and anaerobic conditions. With the goal of quantifying uncertainty, the Beta distribution is assumed for the concentration probability density function (pdf) model, while different levels of approximation are explored for the estimation of the one-point concentration moments. The information pertaining the flow and transport is connected with a proper dose response assessment which generally involves the estimation of physiological parameters of the exposed population. Human health response depends on the exposed individual metabolism (e.g. variability) and is subject to uncertainty. Therefore, the health parameters are intrinsically a stochastic. As a consequence, we provide an integrated in a global probabilistic human health risk framework which allows the propagation of the uncertainty from multiple sources. The final result, the health risk pdf, is expressed as function of a few relevant, physically-based parameters such as the size of the injection area, the Péclet number, the K structure metrics and covariance shape, reaction parameters pertaining to aerobic and anaerobic degradation processes respectively as well as the dose response parameters. Even though the final result assumes a relatively simple form, few numerical quadratures are required in order to evaluate the trajectory moments of the solute plume. In order to perform a sensitivity analysis we apply the methodology to a hypothetical case study. The scenario investigated is made by an aquifer which constitutes a water supply for a population where a continuous source of NAPL contaminant feeds a steady plume. The risk analysis is limited to carcinogenic compounds for which the well-known linear relation for human risk is assumed. Analysis performed shows few interesting findings: the risk distribution is strictly dependent on the pore scale dynamics that trigger dilution and mixing; biodegradation may involve a significant reduction of the risk.