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Global Sensitivity Analysis of a model of radionuclide transport in groundwater bodies by Polynomial Chaos Expansion

V. Ciriello (1), V. Di Federico (1), M. Riva (2), F. Cadini (3), J. De Sanctis (3), E. Zio (3,4), and A. Guadagnini (2)

(1) Dipartimento di Ingegneria Civile, Ambientale e dei Materiali, Università di Bologna, Italy (valentina.ciriello3@unibo.it), (2) Dipartimento di Ingegneria Idraulica, Ambientale, Infrastrutture Viarie, Rilevamento, Politecnico di Milano, Milano, Italy, (3) Dipartimento di Energia, Politecnico di Milano, Milano, Italy, (4) Chair on Systems Science and the Energetic challenge, European Foundation for New Energy- Électricité de France, Ecole Centrale Paris and Supelec

We perform a Global Sensitivity Analysis (GSA) of a transport model used to compute the peak radionuclide concentration at a given control location in a randomly heterogeneous aquifer, following a release from a near surface repository of radioactive waste and subsequent contaminant migration within the host porous medium. We illustrate how uncertainty stemming from incomplete characterization of (a) the correlation scale of the variogram of hydraulic conductivity, (b) the partition coefficient associated with sorption of the migrating radionuclide, and (c) the effective dispersivity at the scale of interest propagates to the first two (ensemble) moments of the peak solute concentration detected at a target location within a two-dimensional randomly heterogeneous hydraulic conductivity field. We treat the uncertain system parameters as independent random variables and perform a variance-based GSA within a numerical Monte Carlo framework. Groundwater flow and transport are solved by randomly sampling the space of the uncertain parameters for an ensemble of generated hydraulic conductivity realizations. The Sobol indices are adopted as sensitivity measures. These are calculated by employing a Polynomial Chaos Expansion (PCE) technique. The PCE-based representation of the response surface of the adopted transport model is then adopted as a surrogate model of the transport process to reduce the computational burden associated with a standard Monte Carlo solution of the original governing equations. This methodology allows identifying the relative influence of the selected uncertain parameters on the target (ensemble) moments of peak concentrations. Our results suggest that the ensemble mean of peak concentration is strongly influenced by the partition coefficient and the longitudinal dispersivity for the scenario analyzed. On the other hand, the hydraulic conductivity correlation scale plays an important role in the variance of the calculated peak concentration values. An additional advantage of the methodology adopted is that it enables extending the number of Monte Carlo iterations to attain reliable results, in terms of convergence of the statistical moments of interest, with an acceptable computational cost.