Geophysical Research Abstracts
Vol. 19, EGU2017-13669, 2017
EGU General Assembly 2017

An approximate analytical methodology for the concentration CDF and corresponding adverse health effects in 3D heterogeneous aquifers

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Predicting solutes displacement in ecosystems is a complex task because of heterogeneity of hydrogeological properties and limited financial resources for characterization. As a consequence, solute transport model predictions are subject to uncertainty and probabilistic methods are invoked. Despite the significant theoretical advances in subsurface hydrology, there is a compelling need to transfer those specialized know-hows into an easy-to-use practical tool. The deterministic approach is able to capture some features of the transport behavior but its adoption in practical applications (e.g. remediation strategies or health risk assessment) is often inadequate because of its inability to accurately model the phenomena triggered by the spatial heterogeneity. The rigorous evaluation of the local contaminant concentration in natural aquifers requires an accurate estimate of the domain properties and huge computational times; those aspects limit the adoption of fully 3D numerical models. In this presentation, we illustrate a physically-based methodology to analytically estimate of the statistics of the solute concentration in natural aquifers and the related health risk. Our methodology aims to provide a simple tool for a quick assessment of the contamination level in aquifers, as function of a few relevant, physically based parameters such as the log conductivity variance, the mean flow velocity, the Péclet number. Solutions of the 3D analytical model adopt the results of previous works: transport model is based on the solutions proposed by Zarlenga and Fiori (2013, 2014) where semi-analytical relations for the statics of local contaminant concentration are carry out through a Lagrangian first-order model. As suggested in de Barros and Fiori (2014), the Beta distribution is assumed for the concentration cumulative density function (CDF). We illustrate the use of the closed-form equations for the probability of local contaminant concentration and health risk in a series of problems of practical relevance. The basic scenario is constituted by a steady state plume in a 3D heterogeneous formation. In this case the non-reactive transport is ruled by interplay of the spreading (lateral and vertical) and dilution. The second scenario considers two different dynamics of degradation in aerobic and anaerobic conditions which allows the contaminant abatement. The final example links the environmental concentration with adverse health effects. For this case, additional information on toxicological and behavioral parameters are required. Despite the simplifying assumptions adopted, the proposed solutions are appealing in applications due to their simplicity and the fact that they allow to easily propagate the uncertainty from different sources in the final risk endpoint.

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