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# Probabilistic Health Risk Assessment of Chemical Mixtures: Importance of Travel Times and Connectivity

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Subsurface contamination cases giving rise to groundwater pollutions are extensively found in all industrialized countries. Under this pressure, risk assessment methods play an important role in population protection by (1) quantifying the potential impact on human health of an aquifer contamination and (2) helping and driving decisions of groundwater-resource managers.

Many reactive components such as chlorinated solvents or nitrates potentially experience attenuation processes under common geochemical conditions. This represents an attractive and extensively used remediation solution but leads often to the production of by-products before to reach a harmless chemical form. This renders mixtures of contaminants a common issue for groundwater resources managers. In this case, the threat posed by these contaminants to human health at a given sensitive location greatly depends on the competition between reactive and advective-dispersive characteristic times. However, hydraulic properties of the aquifer are known to be spatially variable, which can lead to the formation of preferential flow channels and fast contamination pathways. Therefore, the uncertainty on the spatial distribution of the aquifer properties controlling the plume travel time may then play a particular role in the human health risk assessment of chemical mixtures.

We investigate here the risk related to a multispecies system in response to different degrees of heterogeneity of the hydraulic conductivity ($K$ or $Y$=$ln(K)$).

This work focuses on a Perchloroethylene (PCE) contamination problem followed by the sequential first-order production/biodegradation of its daughter species Trichloroethylene (TCE), Dichloroethylene (DCE) and Vinyl Chlorine (VC). For this specific case, VC is known to be a highly toxic contaminant. By performing numerical experiments, we evaluate transport through three-dimensional mildly ($\sigma_Y^2$=1.0) and highly ($\sigma_Y^2$=4.0) heterogeneous aquifers. Uncertainty on the hydraulic conductivity field is considered through a Monte Carlo scheme, and statistics of the total risk for human health ($R_T$) related to the mixtures of the four carcinogenic plumes are evaluated.

Results show two distinct spatiotemporal behavior of the $R_T$ estimation. Simulations in highly heterogeneous aquifers display a lower mean of $R_T$ close to the injection and higher further away. We explain this by the distinct ranges of travel times and connectivity metrics related to the two sets of aquifers. A high $\sigma_Y^2$ trends to decrease the travel time (and increase the connectivity). Early travel times, associated to channeling effects, are intuitively perceived as an indicator for high risk. However, in our case, early travel times lead a limited production of highly toxic daughter species and a lower total risk.

Our results reflect then the interplay between the characteristic reactive time for each component and the characteristic travel time of the plume since the production of VC depends on these factors.