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Influence of flow homogeneity on solute transport – a numerical investigation

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Pollutants are transported by water into the soil. Consequently, their fate is closely linked to water pathways and flow homogeneity. Most previous studies have stated that uniform flow ensures the best access to sorption sites and maximizes pollutant retention. On the contrary, when water flow is non-uniform, solute is transported through preferential pathways which may represent only a small fraction of the soil and the access to sorption sites may be restricted. With respect to mineral precipitation/dissolution, flow non-uniformity may impact the magnitude of mineral dissolution (such as carbonates) and reduce the formation of mineral phases that incorporate pollutants such as heavy metals. Although it is generally assumed that flow non-uniformity has a negative impact on pollutant retention in the soil, such assumptions have never been quantified. In this study, we investigate the quantitative effects on flow uniformity on pollutant transfer using numerically generated data. For this purpose, we use HYDRUS-1D to simulate the reactive transport of pollutants as a function of flow uniformity in a 1-m soil column under steady-state flow conditions. We assume a dual-porosity system and investigate the impact of the mobile water fraction and the solute mass exchange rate on solute transport of both a tracer and sorbing pollutants. Pollutant reactivity is modeled using several types of adsorption isotherms (i.e. Langmuir, Freundlich, and linear) and several types of sink functions . In all cases, the mass balance ratios and retardation factors are evaluated and related to parameters of flow non-uniformity (i.e. the mobile water fraction and the solute exchange rate). These relations are discussed and compared to experimental data from the literature. This study helps in characterizing and quantifying the impact of flow uniformity on pollutant retention.