Geophysical Research Abstracts
Vol. 17, EGU2015-5503, 2015
EGU General Assembly 2015

Modeling the establishment of preferential flow during infiltration in a heterogeneous glaciofluvial deposit

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Large cities are mostly situated in areas close to water resources in order to meet the water needs of their populations. Alluvial soils harbor large aquifers that are used to supply water, the Rhone-Alpes region being a good illustration. However, the increase of soil sealing has led to the development of best management practices such as infiltration basins which are aimed at infiltrating stormwater in order to reduce the amount of water collected and treated in usual systems. Yet, these infiltration basins are mainly settled over highly permeable geologic formations so as to ensure water infiltration and a proper functioning of these infiltration basins. Most of these formations are strongly heterogeneous, since they are made of different materials with contrasting sedimentological properties (e.g. particle size distribution) and transfer properties. This paper addresses flow modeling during the infiltration phase in the vadose zone underneath infiltration basins settled over a strongly heterogeneous glaciofluvial deposit. In particular, we want to pinpoint numerically the worst conditions with regards to preferential flow, in terms of initial hydric conditions (initial water contents) and imposed flow rates. For this purpose, a numerical study is proposed on the basis of previous studies offering a sedimentological description of the subsoil with the detail of its architecture and a precise description of the different lithofacies and their hydraulic properties. Considering this, we worked on a section (13.5m long and 2.5m high) for which a complete sedimentological and hydraulic description had already been performed. Water infiltration was modeled for different initial and boundary conditions (mostly the values of the flux imposed at surface). At first, different numerical tests and adjustments have been made including mesh optimization with regards to both accuracy and computation time. Following these tests, the "tight" mesh has been validated since it proved to be necessary for the detection of preferential flow. Then, a sensitivity analysis addressed the role of initial and boundary conditions on the establishment of preferential flow. According to these conditions, the time required to reach steady state over the whole soil profile, wetting fronts and water fluxes during transient state and water fluxes at steady state were accurately characterized and compared to those of a uniform section. These results are quite counter-intuitive and suggest that unsaturated flow can favor preferential flow, mostly for low water fluxes imposed at surface. In addition, these results are relevant with regards to ongoing researches on the fate of pollutants into heterogeneous deposits. These data are of a great interest since they allow generating a conceptual and numerical model to better understand and predict the development of preferential flows and their impact on pollutant transfer in highly heterogeneous glaciofluvial deposits.