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Non-linear effects of solute transfer from soil to runoff modeling on surface flow solute dispersion

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Solute transfer from soil surface to runoff water constitutes a potential pollutant source for both surface water and groundwater. Nofuentes and Polo (2008) showed from experimental work with tracers in an alluvial loamy soil that when the runoff is caused by sudden flooding, this process can be described by a decreasing exponential load function with two parameters related to the surface flow hydraulic conditions. These authors conducted a preliminary approach to the characterization of this process at the local scale (point source) and an exploration of the nonlinearity of the process at a middle scale when pollutants are distributed along a wide area (nonpoint source).

The accumulated load from upstream areas exhibits a non-linear behavior, hence the numerical modeling of a longitudinally distributed source term as a joint union of source cells produces overestimated solute concentrations in the surface water flow. Reasons for this are found in the decreased diffusion rates from soil water to runoff due to the antecedent concentrations from the upstream source area. Moreover, the nonlinearity exhibited by solute transport makes it necessary to study the process in more detail and obtain a good definition of solute transfer from soil when modeling surface water flow quality, for both point and nonpoint pollutant sources.

A parametric expression was proposed to include non-linearity in such source term for numerical 1D hydrodynamic modeling. The present work quantifies now these non-linear effects from experimental results of laboratory work, and estimates non-linearity for a wider range of water flow in uniform channels under steady discharge upstream. To this purpose, additional experimental work was carried out in a laboratory flume under different water inflow rates, first over a narrow fringe along the soil surface with a conservative tracer, and second over a wide fringe along the soil surface and using the same tracer. Numerical simulation of the water and solute surface flow were performed under linear and non-linear assumptions, respectively, using a 1D water and solute transport model, and compared to the experimental data.

Two types of soil were tested. First, experimental data from Nofuentes and Polo (2008) were analyzed, with a loam soil in which, for a 5 L/s flow rate, the maximum concentration value recorded in the wide strip test was 5 times the one recorded in the corresponding narrow strip test, while the width ratio was 14:1. Secondly, a sandy soil was tested in which, for flow rates between 6 and 10 L/s, the maximum concentration values recorded in the wide strip (14:1 width ratio) tests ranged between 5 and 9 times those recorded in the corresponding narrow strip tests, depending on the water surface flow.

Finally, the results include the relationship found between the values of the experimental parameters in the final exponential load function for a diffusive pollutant source and those obtained under the same upstream discharge conditions but with a point source. Numerical effects are also identified. The final load function parameters are related not only to the hydrodynamic conditions and the initial solute concentration in the upper soil layer, as found in previous work, but also related to the physical characteristic of the bed soil.