Impact of rainfall intensity and acidity on solute transport in variably saturated macroporous media

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Macropores generated by earthworms or plant roots are ubiquitously distributed in field and forest soils especially densely near ground surface. It is well known that macropores become conduits to transport solute quickly from surface to groundwater when macropore flow occurs. The occurrence of the macropore flow depends on rainfall properties. It is also known that the soils are playing an important role in acid neutralization processes which take place on receiving acid deposition at the surface.

Three sets of displacement experiments were conducted using a lysimeter (3mL,1mW,0.6mD) equipped with a rainfall generator to investigate the effects of rainfall properties and acidity on solute transport in variably saturated macroporous media. The first set of experiments involves application of rainfall amounts of 4.0, 6.8, 13 or 26 mm in 10 minutes durations every 24 hours over the lysimeter packed with field soil over fine sand. Groundwater table was set at 0.55m below the surface. The tracer which contained 1000mg/l of chloride and nitrate was applied prior to the experiment as 2 mm of irrigation and the movements of solutes in the lysimeter were monitored. The set of the experiments was repeated as the second set after creating artificial vertical macropores (100, 50 and 25 macropores per horizontal square meters between surface to 0.2m, 0.2 to 0.3 m and 0.3 to 0.6 m depths, respectively) in the lysimeter. The experiments of 13 and 26 mm rainfall experiments were repeated with low pH (pH 3.2) rain as the third set of experiments over a macroporous and non-macroporous media. Changes in the concentrations of chloride and nitrate as well as pH, EC (electric conductivity), and concentrations of Ca^{2+}, Mg^{2+}, Na^{+} in soil solution and the effluent were monitored in the third set of experiment.

High solute concentration remained in the topsoil layer and no vertical solute leaching was observed under light to intermediate (4.0 to 13 mm) rainfall applications in the first set of experiments (non-macroporous medium), while piston-type displacement with considerable leaching was observed at the highest (26mm) application rate.

In the second set of experiments (macroporous medium), high solute concentration remained in the topsoil layer under light to intermediate (4.0 to 13 mm) rainfall applications similar to the first set results, whereas double peak concentration profiles with considerable leaching were observed under 26mm applications. Double peaks suggest that a part of solute was transported by macropore flow while the rest was transported by matrix flow afterwards. Traces of nitrate reached groundwater under intermediate (13mm) rainfalls in a macroporous medium, indicating that macropore flow occurred rainfall intensity of more than 13mm/10min and that flow rate depended on rainfall intensity. The dual-porosity type 1-D numerical model was applied to describe observed double concentration peaks. After adjustment of soil hydraulic parameters, the numerical model was able to reproduce observed double concentration peaks confirming the double peaks were caused by the macropore and matrix flows.

Even after more than one pore volume of application of low pH rainfalls at 26 mm application rate in the third set of the experiments, no apparent change in pH in the effluent was observed in the non-macroporous medium, while EC of the effluent was dramatically increased during the experiments. Chemical analysis revealed that the EC increase was mainly caused by increase of $SO_4{}^{2-}$, Na^{+}, Mg^{2+} and Ca^{2+}. Slight decline of pH was observed in the effluent from the macroporous medium. These results suggest that acid deposition may not change pH of the groundwater, but may change its quality significantly and that macropore flow may transport low pH water directly to the depth with little neutralization.