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Editorial

Unsaturated Zone: Advances in Experimental and Theoretical Investigations

Maria Clementina Caputo

CNR-IRSA (Italian National Research Council—Water Research Institute), Viale F. De Blasio, 5, 70132 Bari, Italy; maria.caputo@ba.irsa.cnr.it

1. Introduction to the Special Issue

The unsaturated zone has a crucial role in subsurface processes that, in turn, impact soil moisture, groundwater quality and quantity, and ecosystem function. Different theoretical and experimental approaches have been developed to increase the knowledge of this portion of the subsurface, but still there are gaps in comprehension and quantification of the processes that occur in the unsaturated zone.

The purpose of this Special Issue is to collect and publish the most recent research concerning both the theretical [1,2] and experimental studies, aiming to increase knowledge of how fluids and susbstances move in the unsaturated zone which is different from the traditional theories and tools.

Papers dealing with preferential flow are particularly welcome, including new experimental observation tools for their evidence [3] and new theoretical formulations for their prediction.

After a rigorous peer-review process, six original papers have been accepted for publication [4–9] in order to provide a valuable overview of the newest approaches used, and to better understand the various mechanisms that act in different situations in the unsaturated zone.

To give better insight into the essence of the Special Issue, highlights of the published papers are briefly summarized below.

2. Overview of the Contributions of the Special Issue

In this study [4], the authors discuss the implications of the hysteresis phenomenon on the horizontal soil water redistribution that occurs after infiltration. Using Hydrus 1D software, they demonstrate that the hysteresis of the soil water retention curve strongly affects the redistribution process. In detail, the form of the redistributed soil water content profiles is similar to the shape of the initial horizontal infiltration profiles; this result is different from those of vertical infiltration–redistribution processes. In addition, they found that the redistribution rate is inversely related to the soil water depth and to the time duration of the redistribution process. In conclusion, the authors stated the need for reliable experimental data to compare with the numerical data.

In the paper [5], the authors, using real experimental results from both fine and coarse-grained soils, propose an original model based on simple assumptions regarding both the saturated and unsaturated branches of the soil water retention curves. The new soil water retention curve is obtained as a logistic function after an ordinary differential equation is solved. Moreover, ordinary differential equations are also solved numerically using the finite difference method, which means that the discrete version of the soil water retention curve can be represented as the logistic map for specific parameters. As this discrete representation is able to encompass chaotic and fractal behaviors, the paper represents the first step to better understating how a chaotic framework could be related to soil water retention curves and geotechnics in general.

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The authors of the study described in [6] tested four different methods to measure water retention curves of two lithotypes of carbonate porous rocks, with the aim of finding the most effective to be applied to rock samples. Suction table, evaporation, quasi-steady centrifuge, and WP4-T dewpoint potentiameter methods have been applied. The quasi-steady centrifuge method proved to be the only one capable of determining water retention curves in the entire water content range, and capable of capturing the bimodality of the tested media with respect to the other methods. The measured water retention data were fitted with HYPROP-FIT software that allows accurate description of the water retention curves and obtainment of the critical parameters for the numerical simulation of flow and transport through the vadose zone, which plays a key role in various environmental issues.

The study described in [7] investigated the effects of soil's physical properties and mineral types on the soil–water characteristic curve and pore-size distribution, using eight different soils from an alluvial deposit in Istanbul and Adapazarı/Türkiye. The authors found that (i) the soil which contains illite-type minerals has higher matric suction than that containing kaolin-type minerals, and that the effect of the clay percentage is more pronounced in silty soils than plasticity and activity; (ii) the soil suction increased with decreasing compaction water content in clayey soils, and that the air entry water contents rose as the void ratio, liquid limit, clay content, and plasticity increased; and (iii) the compaction conditions affected the macropore structure more than the micropore structure, and the ratio of macro–micro pore sizes increased with the increase in the compaction water content.

The authors of [8], using a long series of hydrometeorological monitoring data in the plain area of the Taihu Basin, China, studied the soil–water characteristic curve and soil–water movement in the unsaturated zone of the humid plain area, and investigated its influence on the regional water cycle process. The parameters of the van Genuchten model, obtained by numerical inversion of field monitoring data using HYDRUS-1D code, were used to simulate soil water movement in each soil horizon for six precipitation events, and were compared with the simulation results of laboratory data. The authors found that the soil water simulation based on field data is better, which verifies the accuracy and reliability of the van Genuchten model obtained from field observation and provides a reliable theoretical basis for soil water movement and the calculation of runoff yield in the plain area of the Taihu Basin.

In the work described in [9], the authors used electrical resistivity tomography (ERT) as a powerful tool to predict the hydrological parameters and state variables that influence the flow and transport processes in the vadose zone because of the strong correlation between the electrical and hydrological properties of the filtering medium. In the context wherein the unsaturated zone is made of hard rocks, and the installation of such sensors is not a trivial issue, the geophysical data combined with moment analysis and numerical modeling techniques can effectively overcome the lack of information of the rocky unsaturated subsurface. The results of this study encourage the use of geophysical data as a routine monitoring technique for providing essential information for the comprehension of the mentioned processes occurring in the rocky unsaturated zone. The integration of such data and numerical and/or stochastic approaches is strategic for the development of predictive models of flow and transport, making them an effective real-time alert tool in the context of water and environmental emergency management.

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