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Real Time In-situ Measurements of Water Flow and Solute Transport in Deep Vadose Zone

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Assessment of water percolation and solute transport in the vadose zone is considered a major challenge in hydrologic sciences. It is often characterized by unstable flow that is highly sensitive to hydraulic conditions. In laboratory experiments where the flow characteristics through a well-defined medium may be controlled, close predictions may be achieved. Nevertheless, in natural field conditions the lithologic heterogeneity as well as the erratic nature of hydraulic conditions increase flow instability and imposes a great obstacle to proper prediction. Often conventional models relay solely on parameter that are measured on the domain boundaries, with no direct validation in time and dimension scales that correspond with actual flow dynamics in the modeled domain.

A vadose-zone monitoring system (VMS), which was developed recently, allows continuous monitoring of the hydrological and chemical properties of percolating water in the deep vadose zone. The data which is collected by the system allows direct measurements of the water percolation and detect the chemical evolution of the percolating water across the entire unsaturated domain. Up-to-date the system has been successfully implemented in several studies on water flow and contaminant transport in various hydrological and geological setups. These include floodwater infiltration and groundwater recharge, agriculture impact on groundwater quality, evolution of land fill leaches, and control of remediation processes in contaminated sites.

Direct observations on flow and transport processes which were measured in a variety of natural deep vadose zone under various hydraulic conditions allowed evaluation of few assumptions that are commonly used in vadose zone modeling. For example, water percolation in natural vadose zone occurs as wetting waves through a relatively narrow range of water content amplitudes that does not exceed field capacity values, even if land surface is flooded with high water head for long periods (weeks to months). This phenomenon greatly influence solute and contaminate transport in unsaturated conditions. Percolation under low water content that never reach saturation does not allow complete leaching of solutes from the unsaturated zone. Moreover, it allows salinity/contaminant accumulation in sections of the porous domain that never gets fully saturated even in relatively homogeneous domain such as sand dunes. The incomplete leaching creates major differences between the chemical composition of sediment sample extracts and mobile water phase. Evidences to this phenomenon were observed over a wide range of geological and hydrological scales. Apparently this phenomenon impacts flow and transport models that use chemical composition of sediment samples for calibration and validation process. Another example is related to transport in unsaturated clay sediments. Direct measurements of water percolation velocities showed that percolation rates in unsaturated clay are several orders of magnitude faster compare to any other natural sediment, such as sand or alluvium (natural gravel). It has been found that fast water percolation velocities were related directly to desiccation cracks that form naturally in unsaturated clay. Apparently these observations contradict common notion that attribute lower sensitivity to aquifers underlying clay soils.