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Continuous monitoring of water flow and solute transport using vadose zone monitoring technology

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Groundwater contamination is usually attributed to pollution events that initiate on land surface. These may be related to various sources such as industrial, urban or agricultural, and may appear as point or non point sources, through a single accidental event or a continuous pollution process. In all cases, groundwater pollution is a consequence of pollutant transport processes that take place in the vadose zone above the water table. Attempts to control pollution events and prevent groundwater contamination usually involve groundwater monitoring programs. This, however, can not provide any protection against contamination since pollution identification in groundwater is clear evidence that the groundwater is already polluted and contaminants have already traversed the entire vadose zone. Accordingly, an efficient monitoring program that aims at providing information that may prevent groundwater pollution has to include vadose-zone monitoring systems. Such system should provide real-time information on the hydrological and chemical properties of the percolating water and serve as an early warning system capable of detecting pollution events in their early stages before arrival of contaminants to groundwater.

Recently, a vadose-zone monitoring system (VMS) was developed to allow continuous monitoring of the hydrological and chemical properties of percolating water in the deep vadose zone. The VMS includes flexible time-domain reflectometry (FTDR) probes for continuous tracking of water content profiles, and vadose-zone sampling ports (VSPs) for frequent sampling of the deep vadose pore water at multiple depths. The monitoring probes and sampling ports are installed through uncased slanted boreholes using a flexible sleeve that allows attachment of the monitoring devices to the borehole walls while achieving good contact between the sensors and the undisturbed sediment column.

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 in arid environments, land use impact on groundwater quality, and control of remediation process in a contaminated vadose zone. The data which is collected by the VMS allows direct measurements of flow velocities and fluxes in the vadose zone while continuously monitoring the chemical evolution of the percolating water.

While real time information on the hydrological and chemical properties of the percolating water in the vadose is essential to prevent groundwater contamination it is also vital for any remediation actions. Remediation of polluted soils and aquifers essentially involves manipulation of surface and subsurface hydrological, physical and biochemical conditions to improve pollutant attenuation. Controlling the biochemical conditions to enhance biodegradation often includes introducing degrading microorganisms, applying electron donors or acceptors, or adding nutrients that can promote growth of the desired degrading organisms. Accordingly real time data on the hydrological and chemical properties of the vadose zone may be used to select remediation strategies and determine its efficiency on the basis of real time information.