Geophysical Research Abstracts
Vol. 13, EGU2011-475, 2011
EGU General Assembly 2011

Continuous monitoring of the vadose zone hydraulic and chemical properties as a tool for optimization of remediation strategies

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In-situ bio-remediation of the vadose zone depends mainly on the ability to change the subsurface hydrological, physical and chemical conditions in order to enable development of specific, indigenous, pollutants degrading bacteria. As such the remediation efficiency is much dependent on the ability to implement optimal hydraulic and chemical conditions in deep sections of the vadose zone. These conditions are usually determined in laboratory experiments where parameters such as the chemical composition of the soil water solution, redox potential and water content of the sediment are fully controlled. Usually, implementation of desired optimal degradation conditions in deep vadose zone at full scale field setups is achieved through infiltration of water enriched with chemical additives on the land surface. It is assumed that deep percolation into the vadose zone would create chemical conditions that promote biodegradation of specific compounds. However, application of water with specific chemical conditions near land surface dose not necessarily result in promoting of desired chemical and hydraulic conditions in deep sections of the vadose zone.

A vadose-zone monitoring system (VMS) that was recently developed allows continuous monitoring of the hydrological and chemical properties of deep sections of the unsaturated zone. The VMS includes flexible time-domain reflectometry (FTDR) probes which allow continuous monitoring of the temporal variation of the vadose zone water content, and vadose-zone sampling ports (VSPs) which are designed to allow frequent sampling of the sediment pore-water at multiple depths. The monitoring system is permanently installed through uncased slanted boreholes using a flexible sleeve that allows attachment of the monitoring devices to the borehole side walls.

Implementation of the vadose zone monitoring system in sites that undergoes active remediation provides real time information on the actual chemical and hydrological conditions in the vadose zone as the remediation process progresses. Such information is critical for proper assessment of the remediation strategies and evaluation of the efficiency of the actions that take place on the land surface.

Up-to-date the system has been successfully implemented in several studies on water flow and contaminant transport in various hydrological and geological setups including control of remediation process in a contaminated vadose zone. Manipulating subsurface conditions for optimal bioremediation is demonstrated through two different remediation projects at two sites. One site is characterized by 20 m deep vadose zone that is contaminated with gasoline products and the other is a 40 m deep vadose zone that is contaminated with perchlorate. The vadose zone monitoring system that was installed at each site allowed accurate monitoring of the wetting cycles, including: (1) wetting front propagation velocities, (2) temporal variation of the sediment water content, (2) chemical and isotopic composition of the percolating water, (3) variations in nutrient concentration, and (5) variations in the vadose zone redox potential. Results from each wetting cycles were used to improve the following wetting cycles in order to optimize the vadose zone conditions for microbial activity while minimizing leaching of contaminants to the groundwater.