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Optimization of remediation strategies using vadose zone monitoring systems

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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 results 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 and gas at multiple depths. 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.

Up-to-date the system has been successfully implemented in several studies on water flow and contaminant transport in the unsaturated zone including enhanced bioremediation of contaminated deep vadose zone (40 m depth). Manipulating subsurface conditions for enhanced bioremediation was demonstrated through two remediation projects. 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. In both cases temporal variation of the sediment water content as well as the variations in the vadose zone chemical and isotopic composition allowed real time detection of water flow velocities, contaminants transport rates and bio-degradation degree. Results and conclusions from each wetting cycle were used to improve the following wetting cycles in order to optimize contaminants degradation conditions while minimizing leaching of contaminants to the groundwater.