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# Combined in situ bioremediation treatment for perchlorate pollution in the vadose zone and groundwater

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Perchlorate (ClO-4) is considered environmental pollutant which may spared rapidly in the saturated and unsaturated zone due to its chemical stability and low sorptivity to soil. In Israel, it found in high concentration at the vadose zone (up to 30,000 mg/l) and groundwater (up to 750mg/l) underlying former industrial waste lagoons. Nevertheless, perchlorate is biodegradable by native microbial community in presence of electron donor under anaerobic conditions in the polluted soil. Previous studies, on the site remediation, exhibited a significant difficulty in introducing the essential electron donor to the deep unsaturated zone. It has been found that any attempt to increase deep vadose zone water content led to substantial displacement of perchlorate into the groundwater. Moreover, it was also found that the biodegradation potential of the top soil is significantly higher compared to the deep vadose zone. These findings led to the development of an alternative method for simultaneous treatment of the unsaturated zone and the groundwater. The method utilizes the high degradation potential of the shallow soil layers along with the high mobility of the perchlorate. The combined treatment method includes recurrent pumping of contaminate groundwater and application of the polluted groundwater amended with electron donor to the shallow soil layers. As a result, perchlorate is bio-degraded in the upper soil layers and the treated water continues to flush down the rest of the deep layers, while displacing the pollution into the groundwater, where it is instantly pumped back to surface for further treatment. The entire process is monitored and controlled by the VMS (Vadose zone monitoring system), which allows continues measurements of the pollutants concentrations and transport processes along the vadose zone.
Evaluation of the method efficiency was done in a pilot-scale field experiment carried out over nine months. Full reduction of perchlorate concentration (<10 mg/l) after application of contaminated groundwater (750mg/l ClO-4) across the upper 13m has been regarded as proof of concept for the alternative method.
During field experiments, changes in soil chemical and microbial properties were examined; trace experiment was carried out in order to track and predict perchlorate and water transport; an unexpected decline in perchlorate degradation rate (180 days from experiment initiation) was examined through laboratory experiments; and as a results a strong correlation between excess of electron donor, decrease in buffer capacity of the soil and the occurrence of competitive reduction process was found during the experiment. Those conclusions provide essential information regarding the optimal operation conditions required for the treatment.