INNOVATIVE SOIL MIX TECHNOLOGY CONSTRUCTED PERMEABLE REACTIVE BARRIER FOR GROUNDWATER REMEDIATION

ABSTRACT

A Permeable Reactive Barrier (PRB) is an in-situ permeable treatment zone designed to intercept and remediate a contaminant groundwater plume. Soil mix technology (SMT) PRB is a relatively new technique in which reactive materials are mixed in-situ with the native soil to remediate a contaminated groundwater. The current work is part of SMiRT (Soil Mix Remediation Technology) project; a real field remediation trial involves the execution of research field trials for the application of SMT in land remediation. It is aimed to investigate the relative efficiency of innovative reactive materials, namely natural zeolite (Zlt), granular organoclays (OCg) and inorgano-organo bentonites (IOBs) in remediating a severely contaminated groundwater as well as to develop a tool for real time groundwater quality monitoring using solid state sensor. IOB was synthesised using Alkylbenzydimethyl-ammonium chloride cationic surfactant to produce IOB1 and IOB2 while the non-ionic surfactant polypropylene glycol (PPG) was used to produce IOB3. Aluminium chlorohydrate 50% aqueous solution pillaring agent was used to prepare all IOB materials. The reactive materials represented six different PRB walls containing IOB1, IOB2, IOB3, IOB2OCg, IOB2-Zlt and IOB2-OCg-Zlt. The performance of these materials was evaluated in both laboratory and field scales using both site groundwater and model contaminants. Model contaminants included toluene, ethylbenzene, xylene (TEX) and dodecane ($C_{12}H_{26}$). The treatment process associated with these materials is sorption and their high sorptive capacity and ability to deal with a range of contaminants make them ideal for use in PRB systems. The reactive materials were characterised using thermo-gravimetric analysis (TGA), X-ray diffraction (d-spacing changes), and scanning electron microscopy (SEM). Results confirmed the intercalation of the different surfactants and the pillaring agent within the bentonite layers where the d-spacing increased in the order of IOB1>=IOB2>IOB3. Batch test results showed that the materials had approximately three times higher affinity to the real contaminated groundwater (~60mg/g) than the TEX model

contaminants. The material sorptive capacities towards TEX corresponded to molecules solubility and octane number with a preference order of X> E> T. Combined mixed materials showed greater sorptive capacity than single materials and the materials preference order was IOB2-OCg-Zlt >= OCg > IOB-OC>> IOB1 >IOB2> IOB3>= IOB2-Zlt. The adsorption data of TEX fitted well to both Langmuir and Freundlich isotherms, suggesting both surficial and partitioning effect with relatively high adsorption capacity compared with the existing natural materials. Desorption test results confirmed irreversible adsorption, where the material hysteresis was maximum for IOB2-OCg followed by IOB2-OCg-Zlt. The materials showed even greater adsorption capacity towards dodecane, with OCg had greater sorptive capacity than pillared IOB. The order of dodecane adsorption was OCg > IOB-OCg > IOB2-OCg-Zlt> IOB1> IOB2> IOB2-Zlt >IOB3> Zlt IOB2-OCg with average minimum sorption of ~ 450mg/g.

The column test performed to simulate the real flow conditions showed similar materials preference order and the TEX uptake was in the order of T<E<X for all the reactive materials. Groundwater desorption results indicated that IOB2-Zlt had the lowest holding capacity and materials desorption was in the order of IOB2-Zlt > IOB2-OCg-Zlt IOB2-OCG > IOB3 >IOB1 >IOB2.Materials showed slight to no effect on aquifer hydraulic conductivity when compared with a control sample.

Site cores from within the PRB walls suggested good materials' mixing quality and consistency down to the groundwater level. It was not possible to form a comprehensive conclusion about the materials' performance in the field due to the relatively insufficient amount of groundwater being permeated through the PRB walls where more pumping work still needs to be done. In-situ hydraulic conductivity test showed one to two orders of magnitude higher than the laboratory values, reflecting the scaling factor and the confined laboratory test conditions. Leachibility results of non-volatile organics suggested site heterogeneity with varied leaching values over the core profile. IOB3 showed maximum leaching capacity of 20mg/g. Analysis of core materials also showed site heterogeneity where it was not possible to examine the quality of the mixture using the traditional microstructural analysis and more work need to be done for materials characterisation.

A solid-state sensor was developed to facilitate the real time groundwater monitoring. Laboratory scale results using MTBE and toluene model contaminant solution showed that the sensor has a good response to a range of concentrations. Sensor step curve with MTBE

and toluene showed good response under different UV light conditions with a concentration of 100 ppm. Results indicated that sensors response time depends on material fabrications and temperature. Further work is needed towards compounds selectivity.