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Monitoring of organic contaminants in sediments using low field proton nuclear magnetic resonance

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The effective monitoring of soils and groundwater contaminated with organic compounds is an important goal of many environmental restoration efforts. Recent geophysical methods such as electrical resistivity, complex conductivity, and ground penetrating radar have been successfully applied to characterize organic contaminants in the subsurface and to monitor remediation process both in laboratory and in field. Low field proton nuclear magnetic resonance (NMR) is a geophysical tool sensitive to the molecular-scale physical and chemical environment of hydrogen-bearing fluids in geological materials and shows promise as a novel method for monitoring contaminant remediation. This laboratory research focuses on measurements on synthetic samples to determine the sensitivity of NMR to the presence of organic contaminants and improve understanding of relationships between NMR observables, hydrological properties of the sediments, and amount and state of contaminants in porous media. Toluene, a light non-aqueous phase liquid (LNAPL) has been selected as a representative organic contaminant. Three types of porous media (pure silica sands, montmorillonite clay, and various sand-clay mixtures with different sand/clay ratios) were prepared as synthetic sediments. NMR relaxation time (T_2) and diffusion-relaxation ($D - T_2$) correlation measurements were performed in each sediment saturated with water and toluene mixed fluid at assorted concentrations (0% toluene and 100% water, 1% toluene and 99% water, 5% toluene and 95% water, 25% toluene and 75% water, and 100% toluene and 0% water) to 1) understand the effect of different porous media on the NMR responses in each fluid mixture, 2) investigate the role of clay content on T_2 relaxation of each fluid, 3) quantify the amount hydrocarbons in the presence of water in each sediment, and 4) resolve hydrocarbons from water in $D - T_2$ map. Relationships between the compositions of porous media, hydrocarbon concentration, and hydraulic properties of sediments will be presented and discussed. A minimum toluene detection limit has been established, and influences on NMR signals from increasing contaminant concentration have been investigated as well. It is evident in our data that the dominant control of porous media on NMR responses relies on clay content in the sand-clay mixture.