Use of Oil-in-Water Emulsions to achieve Stable Displacement of Soil Pollution

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Résumé

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1 Introduction

Soil pollution is undeniably a global problem that impacts the lives of many people and affects biodiversity (1). Contamination by non-aqueous phase liquids (NAPLs) is particularly difficult to treat or remove because of their high viscosity and low aqueous solubility (2). At present, waterflooding is commonly used to obtain in situ remediation of the NAPLs-polluted sites. However, the generation of preferential fluid paths as a consequence of soil heterogeneity leads to low efficiency of this method. Emulsions are colloidal systems of two immiscible liquids, where one liquid is dispersed in the other one, stabilized by emulsifiers such as surfactants, solid particles or polymers (3). Emulsions develop high viscosity and can be used to enhance the mobility of the pollutant during their flow through micron-sized pores. In the present study, oil-in-water emulsions with high viscosity were used to displace a model pollutant in a microfluidic device, obtaining significant reduction in residual pollutant saturation as compared to water-flooding. Moreover, the emulsions distributed evenly over the whole porous medium. This provided good contact with the pollutant, which is suitable for the prospective use of emulsions as carrier fluids to deliver reagents that reduce pollutant toxicity in soils.

2 Materials and experimental methods

The porous medium was a transparent microfluidic chip having a permeability of 1.73 Darcy. The pores had a size distribution with mean diameter of 157μm and minimum and maximum value of 10μm and 940μm respectively. Monodisperse oil-in-water emulsions with average size of 10μm and water were used as displacing fluids and light mineral oil was used as model organic pollutant. The fluids were injected with a pressure-controlled pump. An optical microscope equipped with a high-resolution camera was used to monitor the position of all phases in the micromodel. The fluids were died with different colours to improve visualization in the microchip. A four-step strategy was devised to emulate real conditions: water

*Intervenant

saturation, oil drainage, water imbibition and emulsion flooding. Pressure drop in the microchip and flow rate were continuously measured in order to evaluate relative permeabilities of the liquid phases. Images of the phase distribution at the end of each stage were acquired. Post-treatment and analysis of the acquired images was conducted using ImageJ open software, allowing for the quantification of residual pollutant saturation.

The distribution of the different phases in the micromodel after each stage are shown in Figure 1. The residual oil saturation (SOR) after water imbibition experiment was 42% while it was only 15% after emulsion displacement. In addition, the emulsion was evenly distributed throughout the medium and displacement was stable. This is a consequence of the higher dynamic viscosity of the emulsion as compared to light mineral oil, producing favourable displacement conditions. Moreover, the emulsion-water interfacial tension was lower than that the interfacial tension between oil and water. This increased the value of capillary number and resulted in a better mobilization of the pollutant.

3 Conclusions and prospects

Under the present experimental conditions, oil-in-water emulsions proved to be efficient mobility control agents offering a better performance than water for flooding-based remediation. These results must now be extended to other emulsion formulations and boundary conditions. Although the invasion front was homogeneous, some ganglia of trapped pollutants were still present after emulsion injection. Based on the present experiments, the use of stable emulsions as carrier fluids to deliver reagents capable of reducing the toxicity of the remaining ganglia seems a promising remediation strategy. Indeed, the emulsion was efficiently put in contact with the pollutant throughout the sample, with no unswept zones.

References

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