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Surfactant-enhanced remediation of LNAPL contaminated porous medium

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1. Introduction

Currently, the remediation of groundwater from contamination with petroleum products is one of the most important areas of the global water protection. Mainly, it is occurred due to improper disposal of petroleum-containing wastes [1] after the oil processing, leads to a long-term source of groundwater contamination. In accordance with [2], the technology of surfactant-enhanced remediation (SER) is characterized by high efficiency of non-aqueous phase liquid (NAPL) removal in porous media compared to pump-and-treat method, that because of action of capillary forces can leave a considerable amount of residual petroleum contaminants within aquifers.

In [1] the authors consider the SER technology of contaminated groundwater, as it can lead to damage the tailing and rebound effects occurred due to action of capillary forces. Surfactant is heterogeneous molecule represented as monomer, which consists of hydrophilic (head) and hydrophobic (tail) groups composed of a long chain hydrocarbon [3]. According to [4] solubilization and mobilization are two main mechanisms of surfactants, allowing to enhance the removal of non-aqueous phase liquid (NAPL) in the porous medium. When increasing the number of surfactants monomers in considered solution, containing two immiscible fluids «NAPL-Water», system becomes saturated that leads to forming the surfactants micelles, under action of which the solubilization of non-aqueous phase is observed. It should be noted that during surfactant injection to contaminated porous medium the mobilization effect of light non-aqueous phase liquids (LNAPLs) is increased. This effect is occurred due to the decreasing in interfacial tension between two immiscible fluids contributes to reduction of capillary forces, which act to retain significant amount of LNAPLs as ganglia within porous medium of aquifers.

In this paper, the SER process of LNAPL contaminated porous medium is considered using magnetic resonance imaging (MRI). The main objective of this work is carrying out of experimental research of LNAPL displacement in vertical model of porous medium in two ways: by simple water flooding and by surfactant injection to evaluate the impact of surfactant on residual LNAPL removing from contaminated zones.

2. Results and discussions

From Figure 1 it was shown that surfactant-enhanced remediation method after water injection to porous medium in experiment №1 is more effective for residual LNAPL displacement compared to experiment №2 when surfactant water solution was injected at the beginning. In the case of experiment №1, approximately 11% of residual LNAPL from initial residual saturation was displaced. As for experiment №2, SER method is effective at the initial time moment and demonstrates more effects in area of higher saturation of LNAPL.

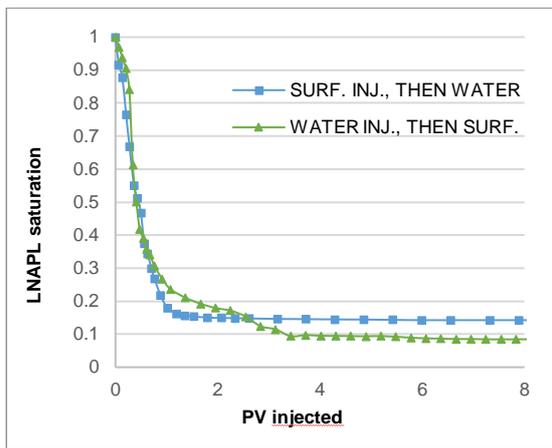


Figure 1: Comparisons of results between two experiments: green curve – experiment №1, blue curve – experiment №2.

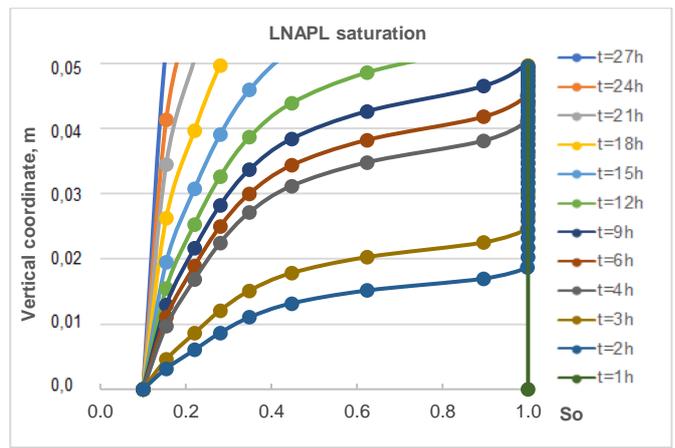


Figure 2: Changes in LNAPL saturation along vertical coordinate.

In experiment №1, at the beginning 100 ml of water solution was flooded to porous media that is corresponded to 3 pore volume (PV). After the end of water flooding 200 ml of surfactant water solution was injected for residual NAPL displacement in porous media. This case is corresponded to green curve from Figure 1. As for experiment №2, at the beginning 180 ml of surfactant water solution was used for immiscible fluid displacement in porous media that is corresponded to blue curve on Figure 1. The injection rate for two experiments was similar and equaled 0.16 ml/min.

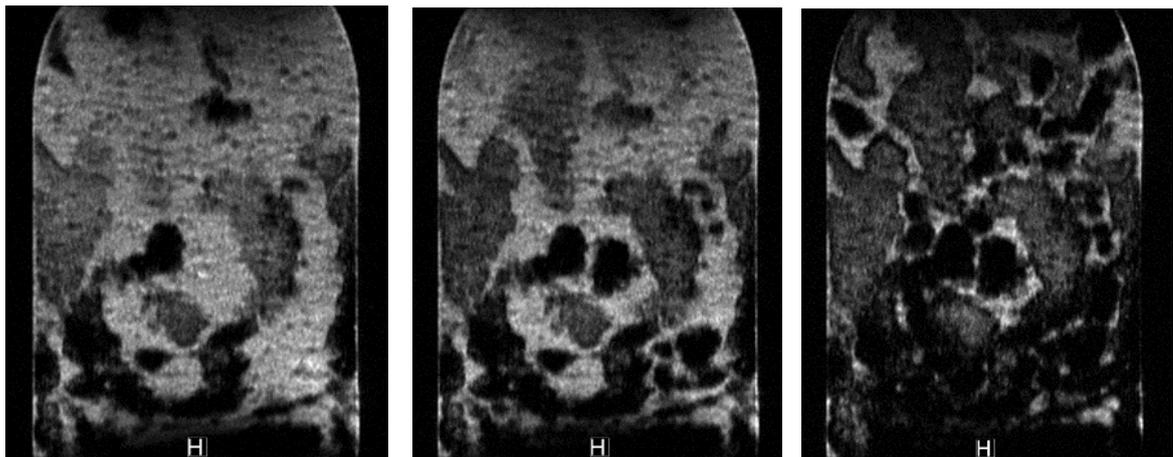


Figure 3: Consecutive MRI images of immiscible phase displacement.

As it was shown on Figure 2 the changes of LNAPL saturation along vertical coordinate approximately similar with changes in saturation of non-wetting phase without acting capillary forces. It is observed, that after surfactant water injection the residual LNAPL saturation decreases due to reducing of interfacial tension between two immiscible phases that leads to decreasing of capillary force value. Thus, experimental observations and compiled numerical model show the effectiveness of SER of LNAPL contaminated porous medium.

Reference

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