Hysteresis of Oil-Water Capillary Pressure-Saturation Relations in Oil-Contaminated Groundwater

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1. Introduction

An accurate description of the capillary pressure-saturation (Pc-S) and the relative permeability-saturation (kr-S) relations is essential to assess correctly the oil distribution in groundwater. Hysteresis is common in the Pc-S and kr-S relations. However, the hysteresis models developed have mostly been concerned about the water-wet media. A number of factors including variations in aqueous chemistry and mineralogy might affect the wettability change from water-wet to oil-wet media. Also, the wetting of porous media by oil could be fractional rather than uniform due to the heterogeneous nature of subsurface media. The objectives of this research are to conduct Pc-S measurements considering fractional wettability in the two-phase oil-water system and to analyze the hysteretic characteristics of the oil-water Pc-S relations in the consideration of fractional wettability.

2. Materials and Methods

The Pc-S measurements on two-phase oil-water system were implemented using the method by Lenhard and Parker (1988). The oil used was Soltrol 220. Porous media with fractional wettability was obtained by mixing different portions of silica sands that was untreated (water-wet) and treated (oil-wet) with octadecyltrichlorosilane (OTS). The fraction of OTS-treated sand among the porous medium was set by 25%, 50%, 75%, and 100%.

3. Results and Discussion

The observed oil-water Pc-S data showed that the more hydrophobic media had a lower Pc at a given water saturation, indicating that it is easier for water to be displaced by oil. Also, a wetting reversal distinctly occurred during imbibition

of water at OTS-treated sands. It seems that the media behaved as if they were water-wet during drainage and oil-wet during imbibition. When the OTS fraction of sands increased, the sands displayed relatively little spontaneous imbibition regions for water. This means that although the same water pressure (the same capillary pressure) is applied to imbibe water into a porous medium for the remediation techniques, such as pump-and-treat and soil washing, the amount of water imbibed may be very different according to fractional wettability characteristics of the porous medium. For example, when the OTS fraction of the sands increases, the amount of water imbibed would be smaller under the same capillary pressure.

In order to quantify the wettability of the porous medium, the United States Bureau of Mines (USBM) method was adopted. The USBM method is based on the fact that the work necessary for the wetting phase to displace the nonwetting phase from a core is less than the work required for the opposite displacement. According to the USBM wettability criterion, the media with 25% and 50% OTS were water-wet. The 75% and 100% OTS media could be classified as oil-wet. These results showed that the values of USBM wettability index can be positive even when the medium contains some portions ($\leq$50%) of the OTS sand.

4. References

1) Lenhard, R. J. and J. C. Parker, Experimental validation of the theory of extending two-phase saturation-pressure relations to three fluid phase systems for monotonic drainage paths. Water Resour. Res., 24(3):373-380, 1988.