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The counter-ion effect in surfactant-based remediation

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요 약 문

본 연구는 소수성 유기물로 오염된 지하수를 복원할경우, 식품등급의계면활성제와 NaOH 또는 NaCl 의 효과를 연구하기 위하여 주상실험을 실시하였다. 실험결과 계면활성제와 NaOH의 혼합 사용이 가장 효과적이었으며, Na+의 counter-ion 효과보다는 OH-의 pH효과가 더욱 중요한 인자가 됨이 밝혀졌다.

Key Word: Surfactant, Remediation, Groundwater, Counter-ion effect, Hydrophobic

1. Introduction

Removal of hydrophobic organics from contaminated groundwater is difficult because they possess low solubilities and high interfacial tensions. Extensive research has demonstrated that surfactant (surface active agents) flushing is a viable alternative for improving the efficiency of groundwater remediation (Lee et al., 2001, 2002). These studies showed that food-grade surfactant solutions significantly enhanced the removal of hydrophobic contaminants from groundwater. However, field test results by food-grade surfactants still have problems in removing hydrophobic organics in the groundwater.

Further, aqueous food-grade surfactant solutions are affected by environmental conditions such as pH, temperature, and the clay type and percentage etc. Lee et al. (2002) suggested that the effect of electrolyte of the remediation target area. The addition of NaOH for pH adjustment adds two ions, Na^+ and OH^-, to the surfactant solution. Changes in effectiveness for remediation could be caused either by pH changes or by changes on the counter ion Na^+. In order to determine whether OH^- or Na^+ was more effective in modifying surfactant effectiveness, experiments were performed with NaCl added to the surfactant solutions.

2. Materials and Methods

A Fruitfield Iowa sandy soil used for this study was obtained from Dr. Ukrainczyk of the Department of Agronomy of Iowa State University. The soils were air-dried and passed through a 2mm sieve. Organic matter of soil is low (0.2%).

1,2,4-trichlorobenzene (TCB) was chosen as the model hydrophobic substance because it frequently is detected in groundwater at industrial sites. Also, TCB proved suitable for further study because it showed good results in the previous research project (Lee et al.,

2002). 4%(v/v) Dowfax 8390 (anionic) was selected for this study. Dowfax 8390 chemicals have good solubilizing abilities for hydrophobic organic molecules (Rouse et al., 1993).

The glass column used in this study was 5 cm (O.D.) in diameter and 30 cm in height. This column was obtained from Supelco Company. Experimental methods and procedures were similar to those performed in prior research (Lee et al., 2001). Glass wool and glass beads were placed at the columns base, and 350 g of Fruitfield soil was placed over the beads. Compaction of the dry soil in 0.5 cm layers was standardized by tapping the side of the column 25 times. After a column was packed, deionized water was pumped at a rate of 3 mL/min into the column for three hours to saturate the soil. The contaminant (5 mL of TCB) was then injected by syringe into the middle of the column. Then 4%(v/v) surfactant solutions with/without 2% NaCl or deionized water was pumped into the columns top at a rate of 5 mL/min. The same number of Na^+ moles were added as those from NaOH in the pH experiments. The effluent was collected at each 250 mL interval. The analysis used solvent extraction and soxhlet extraction method. Gas chromatographic analysis on all the extracts of aqueous leachate samples were performed using a Hewlett Packard model 5890 series II gas chromatography with split/splitless injection system.

3. Results and Discussions

The addition of an electrolyte such as NaCl to an anionic surfactant solution can both increase the micelle aggregation number (size of micelle) and decrease the CMC (Critical Micelle Concentration), thereby modifying surfactant effectiveness for remediation (Harwell, 1992). Also Rosen (1989) showed that the addition of small amounts of pH neutral electrolyte to solution of ionic surfactants appears to increase the extent of solubilization of hydrocarbons that are solubilized in the inner core of the micelle. Increased binding of cations should cause the CMC of the surfactant to decrease and the aggregation number to increase with the stabilization of micelles. Therefore, experiments were conducted to examine the effect of cations in the removal TCB from the Fruitfield soil. Based on these experimental results, the effect of Na^+ was small, and was much less than that of pH (Table 1, 2). The effect of NaOH in changing effectiveness is not due to Na^+ effects, but rather to the OH^- as shown by these experimental results.

Table 1. The effect of 10% NaOH (2.5 M) in removal(%) of TCB

Surfactant	without NaOH	with NaOH	NaOH effectiveness
Dowfax 8390	79	92	16% INCREASE
Sandopan JA36 (Lee et al., 2002)	74	83	12% INCREASE
Triton X100 (Lee et al., 2002)	74	81	09% INCREASE

Table 2. The effect of 2% NaCl in removal(%) of TCB

Surfactant	without NaCl	with NaCl	NaCl effectiveness
Dowfax 8390	80	80	NO INCREASE
Sandopan JA36 (Lee et al., 2002)	75	79	05% INCREASE
Triton X100 (Lee et al., 2002)	75	76	01% INCREASE

4. Conclusions

Based on experimental results, the conclusions for this research are:

1) Much greater effectiveness was observed using surfactant solutions containing NaOH.

2) The effect of NaCl in changing effectiveness is less than that of NaOH.

3) The effect of NaOH in changing effectiveness is not due to Na^+ counter-ion effects, but rather to the OH^- based on experimental results.

5. References

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