Solubilization Characteristics of trichloroethylene(TCE) in nonionic surfactants

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<Abstract>

Solubilization isotherms of TCE in the nonionic surfactants were studied. In this research, the maximum solubilization of TCE in the micelle was observed at the HLB of approximately 15. Increasing carbon number, solubilization of TCE was enhanced with the same ethoxylated alcohols number in brij surfactants.

key words : solubilization, TCE, nonionic surfactant, carbon number, HLB

1. Introduction

Contamination of groundwater by non-aqueous phase liquids (NAPLs) is a serious concern all over the industrial world. NAPLs are classified into DNAPLs and LNAPLs by their density comparing that of water. DNAPLs have higher density than that of water so they can easily penetrate into subsurface and contaminate groundwater. DNAPLs are volatile so that they continuously diffuse into groundwater as a form of pool above the aquitard.

TCE widely used as industrial solvents, degreaser and dry cleaning agent. Spilling TCE causes severe contamination of aquifer as a DNAPL and should be treated. Conventional pump-and-treat method has been limited because of relatively low water solubility of TCE. To enhance the effectiveness and efficiency of subsurface remediation contaminated by DNAPLs like TCE, surfactant enhanced subsurface remediation (SESR) can be applied[1]. Surfactants form micelles above critical micelle concentration (CMC) and solubilize TCE in hydrophobic core in aqueous stream. The final goal of this research is the removal of TCE solubilized micelles which are large enough to be rejected by ultrafiltration, which called micellar enhanced ultrafiltration(MEUF).

Solubilization isotherm of was investigated to design the MEUF and expect the removal efficiency. In addition, the effects of hydrophile-lipophile balance(HLB) and number of carbon on the solubilization of TCE in nonionic surfactants were studied.

2. Materials and Method

2.1 Materials

Trichloroethylene(TCE) was purchased from Aldrich Chemical(USA) and all surfactants which were used in the experiment were purchased from Sigma(USA). Properties of TCE and surfactants were summerized in Table 1 and Table 2.

Density	Log Kow	Log 1/H	Solubility
1.463g/mL	2.38	0.384	1099mg/L

Table 1. The properties of TCE at 25℃

where (a) POE=polyoxyethylene, (b)u=unsaturated

Name	MW	HLB	Carbon No.
POE(a)(20) sorbitan monolaurate	1128	16.7	12
POE(20) sorbitan monopalmitate	1284	15.6	16
POE(20) sorbitan monostearate	1312	14.9	18
POE(20) sorbitan monooleate	1310	15	18(u)(b)
POE(4) lauryl ether	362	9.7	12
POE(10) lauryl ether	626	14.1	12
POE(10) cetyl ether	683	12.9	16
POE(10) oleyl ether	708	14.9	18(u)
POE(20) cetyl ether	1124	15.7	16
POE(23) lauryl ether	1198	16.9	12
Tergitol 15-S-7	515	12.4	11-15

Table 2. The properties of surfactants

2.2 Experimental Method

2.2.1 TCE solubilization

10mL surfactant solution was added into 20mL vial. TCE was injected and promptly sealed with teflon-coated septum. Samples were shaken at 25℃ for overnight. Head space of $100\mu\ell$ was sampled with a gas tight syringe and immediately injected into the GC injector.

2.2.2 Analysis of solubilization isotherm [1]

Mole fraction of TCE in the micelle was obtained from mass balance:

$$M_{TCE-m} = M_{TCE-i} - M_{TCE-w} - M_{TCE-v}$$

$$X_{TCE-m} = \frac{M_{TCE-m}}{M_{TCE-m} + (M_a - M_o)}$$

where M_{TCE-m}, M_{TCE-i}, M_{TCE-aq}, M_{TCE-v} are the amount of TCE solubilized in micelle phase, initially added, in aqueous phase and in the vapor phase.

Solubilization equilibrium constant (K) and percent solubilization was definded by

$$K = \frac{X_{TCE-m}}{C_{TCE-f}}$$

$$\textbf{Solubilization}\,(\%) \quad = \quad \frac{\textbf{M}_{TCE-m}}{\textbf{M}_{TCE-i}} \times 100$$

3. Results

3.1 Effect of HLB on TCE solubilization

Figure 1. shows the amount of TCE as miligram per surfactant as milimole when initial TCE concentration was 5.5mM. The solubilized TCE increased until HLB was near 15 and show the maximum solubilization of TCE and decreased. Fountain et al.[2] also investigated that TCE exhibited maximum solubility at an HLB of 15.
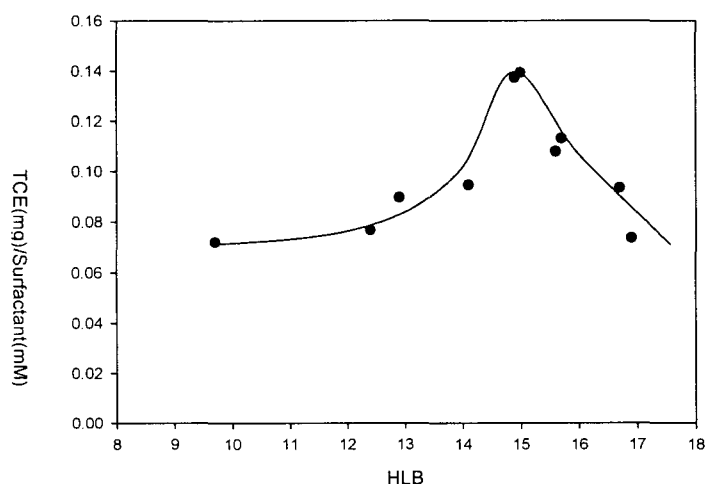

Figure 1. TCE(mg) in the micelles per surfactant(mM) as a function of HLB

3.2 Effect of Carbon number on TCE solubilization

Surfactants that have same POE number of 10 were used in order to investigate the effect of carbon number of the nonionic surfactants on TCE solubilization. With the increase in carbon number of surfactant from 12 to 18 the molar fraction of TCE in the micelles increased(Figure 2).

The solubilization equilibrium constant was demonstrated in Figure 3. The solubilization equilibrium constant exhibits the distribution of TCE between micelle phase and aqueous phase. The higher solubilization equilibrium constant was observed in higher carbon number surfactant solution. Solubilization capacity is correlated with micelle core volume, which can explain these phenomena because core volume generally increases as carbon number increases[1].

Figure 4 shows percent solubilization of TCE. The minimum removal efficiency of TCE in MEUF process can be expected by the percent solubilization. The highest solubilization was obtained with highest carbon number and its average removal efficiency was 65%.
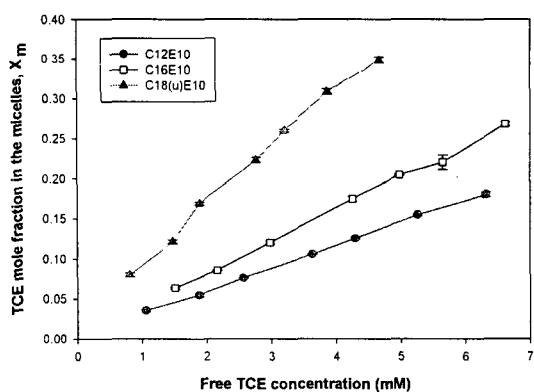
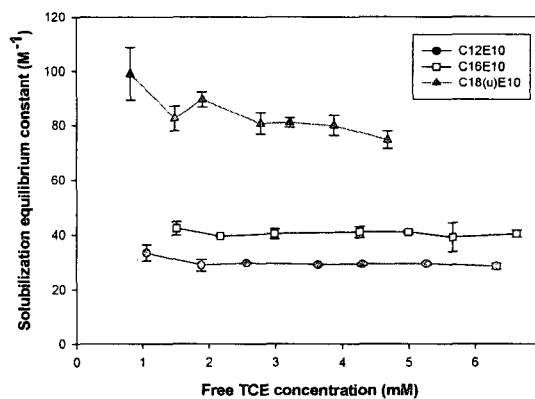Figure 2. Mole fraction of TCE in the micelle
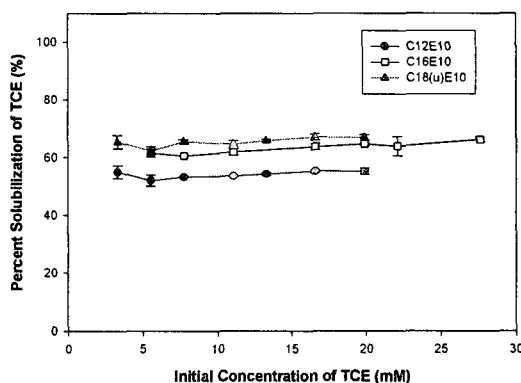

Figure 3 Solubilization equilibrium constant

Figure 4. Percent solubilization of TCE

4. Conclusions

The maximum solubilization of TCE in the micelle was observed at the HLB of approximately 15. As carbon number increased the more TCE was solubilized in the surfactant micelles as well as the higer solubilization equlibrium constant was obtained due to the increase of micelle core volume.

Ackowledgement

References

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