MEK SEPARATION FROM ITS AQUEOUS SOLUTION BY MEMBRANE CONTACTOR

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ABSTRACT

Separation of MEK(methylethylketone) was carried out experimentally by a flat membrane contactor using a variety of extracting organic compounds. A correlation equation of Sherwood number was determined in terms of Reynolds number and Schmidt number for the flat membrane contactor system. This correlation equation was applied to get theoretically the overall mass transfer coefficient of MEK: it was compared to the experimental one. It was found that they are in good agreement.

INTRODUCTION

MEK, one of a typical VOC, has been used as a solvent in many industries for manufacture of tapes, electronics, paints, adhesives, polyurethane, etc. To separate MEK from its aqueous solution, many studies have been reported using various methods such as distillation, adsoption, absorption and membrane technologies. In this work, a membrane contactor was investigated if it could be an feasible alternative to the conventional liquid – liquid extraction technology for the separation of MEK from wastewater. The tortuosity of porous PVDF (polyvinylidenedifluoride) membrane was measured using a diffusion cell where toluene, which has the known value of its diffusivity in hexane, was used as a solute. A correlation equation of Sherwood number was experimentally derived in terms of Reynolds number and Schmidt number using an experiments of phenol separation from its aqueous solutions. The extraction of MEK was carried out by dodecane and TMP(trimethyl-pentane) as a extractive strip solvent in a membrane contactor and the experimental overall mass transfer coefficient of MEK obtained was compared to the theoretical overall mass transfer coefficient.

THEORY

The tortuosity(τ) of a polymeric porous membrane (PVDF, Millipore) was measured using the following equation:

$$\ln\left(\frac{C_{f,0}-C_{s,0}}{C_f-C_s}\right)=\frac{2\varepsilon A}{\tau\delta V}D_{AB}t \tag{1}$$

For the system shown as Fig.1, the equation of the relation between overall mass transfer resistance, individual mass transfer resistances of feed, membrane and strip side can be derived as a following equation.

$$\frac{1}{K_{overall}}=\frac{1}{k_{aq.1}}+\frac{1}{K_D k_m}+\frac{1}{K_{aq.2}} \tag{2}$$

If sodium hydroxide solution is used as a strip solution, the concentration of phenol in a strip side is zero. Then the equation (2) can be expressed simply as follows:

$$\frac{1}{K_{overall}} = \frac{1}{k_{aq.1}} + \frac{1}{K_D k_m} \tag{3}$$

where K_D is a distribution coefficient and k_m is an individual mass transfer coefficient in the membrane defined as :

$$K_D = \frac{C_{or.eq}}{C_{aq.eq}} \tag{4}$$

$$k_m = \frac{D_{PhOH}\varepsilon}{\tau L} \tag{5}$$

The overall mass transfer coefficients of the system can be derived from the differential mass balance equation.

$$-\frac{V}{A}\frac{dC_{aq.1}}{dt} = K_{overall}C_{aq.1} \tag{6}$$

The integration of equation (6) with proper boundary conditions is resulted as follows:

$$\ln\left(\frac{C_{aq.1}}{C^0_{aq.1}}\right) = -\frac{K_{overall}A}{V}t \tag{7}$$

Sherwood number can be expressed as a function of Reynolds number and Schmidt number.

$$N_{Sh} = aN^b_{\mathrm{Re}}N^{1/3}_{Sc} \tag{8}$$

The exponent of Schmidt number was taken from the reference[1]. The constants a and b in equation (8) can be calculated from a logarithmic plot of various Reynolds number with proper impeller speeds, Sherwood number obtained from equation (3) and (7) and Schmidt number.

For the membrane contactor system shown in Fig.2, the equation of the relation between overall mass transfer resistance, individual mass transfer resistances can be written as a following equation:

$$\frac{1}{K_{overall}} = \frac{1}{k_{aq}} + \frac{1}{K_D}\left(\frac{1}{k_m} + \frac{1}{k_{or}}\right) \tag{9}$$

The mass transfer coefficient in an organic side can be calculated from the equations (8) for a feed and a strip side.

$$k_{or} = k_{aq}\frac{D_{MEK,or}}{D_{MEK,aq}}\left[\left(\frac{\nu_{or}}{D_{MEK,or}}\right)\Big/\left(\frac{\nu_{aq}}{D_{MEK,aq}}\right)\right]^{1/3}\left(\frac{N_{\mathrm{Re},or}}{N_{\mathrm{Re},aq}}\right)^b \tag{10}$$

For a membrane contactor system, the overall mass transfer coefficient can be derived from the following differential equation.

$$-\frac{V}{A}\frac{dC_{b,aq}}{dt} = K_{overall}(C_{b,aq} - C^*_{b,aq}) \tag{11}$$

where $C_{b,aq}^*$ is the concentration of MEK in an aqueous phase corresponding to the concentration of MEK in an organic phase. $C_{b,aq}^*$ can be expressed as follows:

$$C^*_{b,aq} = \frac{C_{b,or}}{K_D} \tag{12}$$

With proper boundary conditions, equation (12) can be integrated as a following equation:

$$\ln\left[\left(\frac{1}{1+K_D}\right)\frac{C_{b,aq}}{C^*_{b,aq}}-\frac{1}{K_D}\right]=-K_{overall}\left(\frac{1}{1+K_D}\right)\frac{A}{V}t \tag{13}$$

The experimental overall mass transfer coefficient obtained from equation (13) can be compared with the theoretical overall mass transfer coefficient which can be calculated using equation (9).

RESULTS AND DISCUSSION

The tortuosity of the PVDF membrane was measured as 3.05. A logarithmic plot of Sherwood number, Reynolds number and Schmidt number is shown in Fig.3. From Fig.3, the constants a and b in equation (8) were calculated as follows:

$$N_{Sh}=(5.3583\times10^{-4})N_{\mathrm{Re}}^{0.958}N_{Sc}^{1/3} \tag{14}$$

The concentration profile of MEK in feed phase is shown in Fig.4 when dodecane was used as an organic phase. The separation ability of dodecane could be maintained until after 6 hours since the concentration of MEK was decreased linearly with time.

The theoretical and experimental overall mass transfer coefficients are illustrated in Fig.5. Dodecane or TMP was used as an organic phase. As both the theoretical and experimental value have the same order of 10^{-4}, it can be said that a theoretical value is in a good agreement with an experiment one even though experimental values are 1.5~2 times higher than theoretical values. Theoretical overall mass transfer coefficients might be smaller than experimental ones due to the effect of diffusivity, density, viscosity of solutions as well as the error of the tortuosity of pores in membrane.

CONCLUSIONS

The theoretical overall mass transfer coefficients could be obtained using the local mass transfer resisatances existed in aqueous and organic phases and the membrane resistance. The correlation between Sherwood number, Reynolds number and Schmidt number was derived from a batch flat type membrane contactor, in which a porous membrane was installed. The experimental overall mass transfer coefficients of MEK was found to be in good agreement with the theoretical overall mass transfer coefficients in a membrane contactor. Also it was found that the membrane contactor could be an alternative technology to the conventional liquid-liquid extraction.

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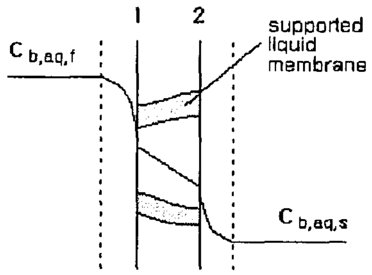

Fig. 1. Concentration profile for phenol separation

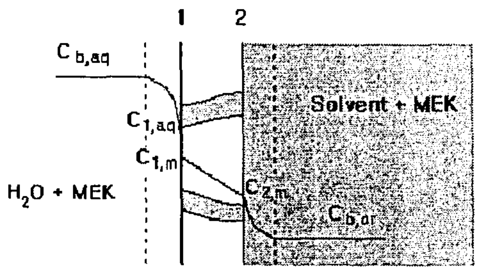

Fig. 2. Concentration profile for MEK separation

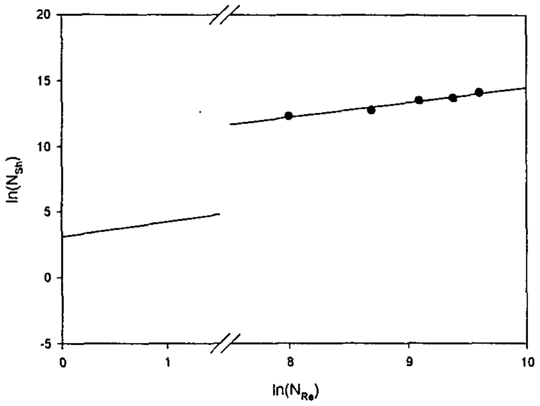

Fig. 3. Plot of ln N_{Sh} vs. ln N_{Re}

3,000 < NRe < 15,000

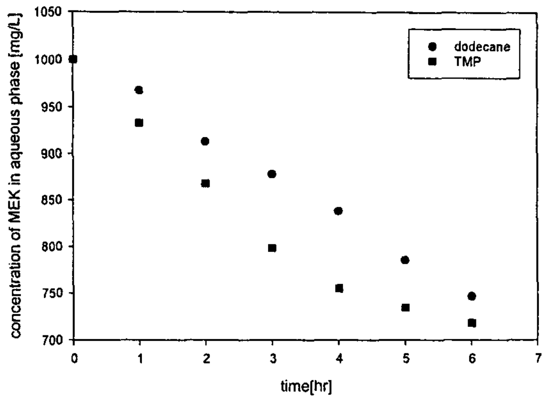

Fig. 4. Concentration of MEK in aqueous phase as a function of time with two different organic phases.

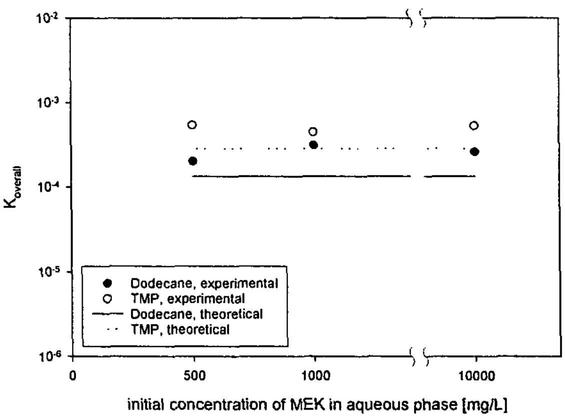

Fig. 5. Comparison of overall mass transfer coefficients