CHAPTER V

RESULTS AND DISCUSSION

This chapter collects all the result of copper-ion extraction. The results were divided to 2 section, once through mode and recycle mode. The parameters that affect to the copper ion extraction are studied. These parameters are initial copper ion concentration in feed solution, initial concentration of D2EHPA, volumetric flow rate of feed solution and hydrogen ions concentration in both side solutions.

5.1 The Once-Through Mode Operation

5.1.1 The effect of initial concentration of D2EHPA in membrane phase

The relationships between the concentrations of D2EHPA and removal efficiency of copper-ion in feed solution are indicated in Figure 5.1. In this Figure, The results that calculated from model are compared with measured, the effects of Δx used in model to calculated of removal efficient of copper-ion in feed solution are shown.

Table 5.1 shows the comparison of error percentage of removal efficiency of copper-ion extraction between calculation and experiment at various Δx. From this table, the best Δx to predict the removal efficiency of copper-ion extraction is 1 cm. The average error percentage and the standard deviation in this case are 12.76 and 14.07, respectively. Due to the best Δx was 1 cm hence this value were used to calculate the removal efficiency of copper-ion extraction in this work.

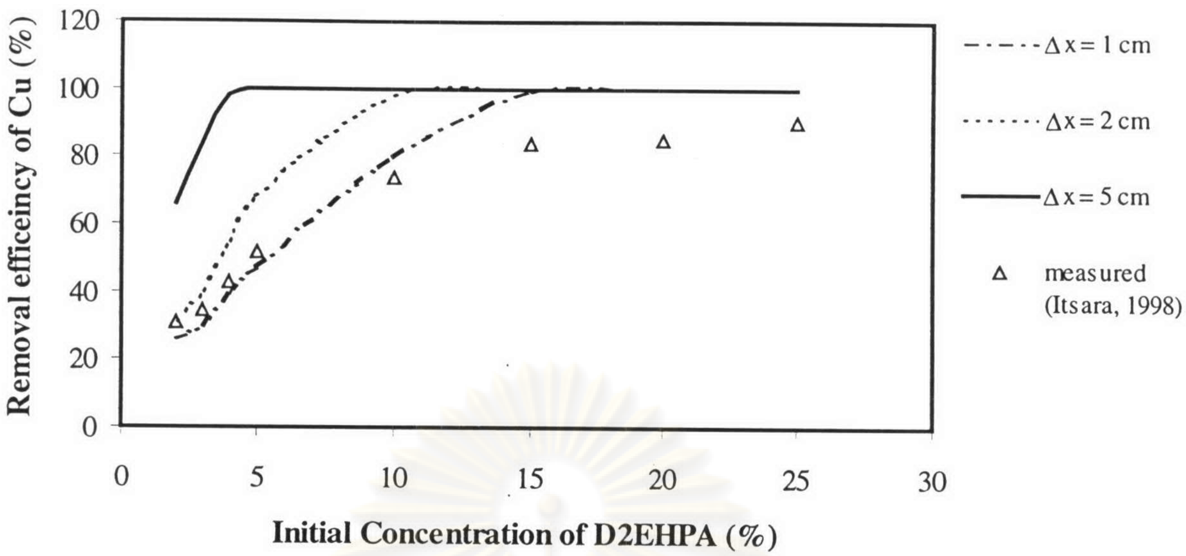

Figure 5.1 Effect of initial concentration of D2EHPA in membrane solution on removal efficiency of copper-ion at various Δx : C^f = 100 ppm, pH^f = 7, Q^f = 200 ml/min, Q^s = 200 ml/min, $[Cu^{2+}\}^f$ = 100 ppm.

Table 5.1 Comparison of percentage of error and standard deviation of removal efficiency of copper-ion extraction between calculation and experiment at various Δx (C^f = 100 ppm, pH^f = 7, Q^f = 200 ml/min, Q^s = 200 ml/min)

% D2EHPA(v/v)	% error (Δx = 1)	% error (Δx = 2)	% error (Δx = 5)
2	14.98	0.78	113.81
3	13.47	16.07	143.42
4	9.06	26.73	128.17
5	9.12	31.94	93.12
10	7.96	36.11	36.11
15	19.65	19.65	19.65
20	17.32	17.32	17.32
25	10.52	10.52	10.52
average	12.76	19.89	70.33
% SD	14.07	23.62	93.25

Figure 5.2 describes the effect of initial concentration of D2EHPA in membrane solution on removal efficiency of copper-ion at various initial concentration of copper ion in feed solution.

From Figure 5.2, the removal efficiency of copper-ion increases with the increasing of the initial concentration of D2EHPA in membrane solution. At low initial concentration of copper-ion in feed solution and initial concentration of D2EHPA, the removal efficiency increases quickly after then this efficiency approaches to 100 percent when the initial concentrations of D2EHPA more than 15 %. It can be explained that the concentration of D2EHPA exceed, hence the copper ion in feed solution are completely extracted.

For the high concentration of copper-ion in feed solution (500 and 1,000 ppm), the removal efficiency of copper ion in this case are smaller than the low initial concentration of copper-ion in feed solution. The increasing of removal efficiency of copper-ion increases in constant rate with increasing of the initial concentration of D2EHPA. The reason can be explained like these. The amount of copper ion in feed solution exceed when compare with the D2EHPA concentration, hence the amount of D2EHPA are not enough to extraction of copper ion in this case although the concentrations of D2EHPA increases.

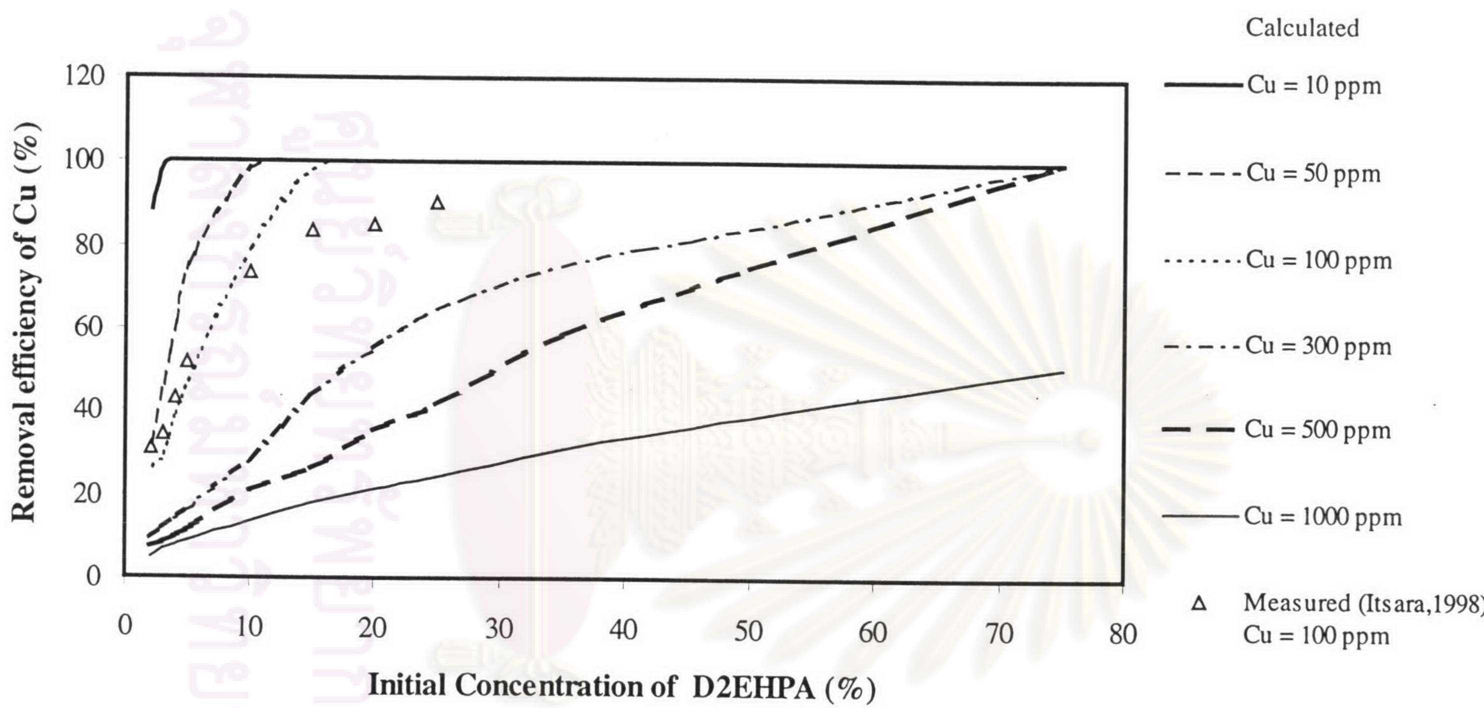

Figure 5.2 Effect of initial concentration of D2EHPA in the membrane solution on the removal efficiency at various initial concentration of copper-ion in feed solution : Δx = 1 cm, pH^f = 7, Q^f = 200 ml/min, Q^s = 200 ml/min, $[H^+]^s$ = 0.1 mol/l.

5.1.2 The effect of the initial copper ion concentration in feed solution

Figure 5.3 shows the relationship between copper-ion removal efficiency and initial concentration of copper-ion at various initial concentration of D2EHPA. As can be seen from this figure, at low concentration of copper-ion with copper ion concentration less than 200 ppm, The removal efficiency decreases rapidly. In the case of the concentration of copper more than 400 ppm and the concentration of D2EHPA less than 25 %, The removal efficiency decreases slowly. The reason can be explained that the amount of copper-ion increases while the amount of D2EHPA fix, there for the amount of D2EHPA are not enough to extract the copper-ion.

At the high concentration of D2EHPA (35, 50 and 75 %), the removal efficiency is separated to two period. At the first period, the removal efficiency of copper-ion remains constant. The removal efficiency of copper-ion decreases with the increasing of the initial concentration of D2EHPA in membrane solution.

The experimental results when initial concentration of copper-ion in feed solution is changed are also shows in figure 5.4. Close agreement between experimental and calculated results is obtained for the ranges studied (the average error percentage and the standard derivation, 10.21 and 12.41, respectively).

5.1.3 The effect pH in feed solution

Figure 5.4 illustrates the effect of pH on the removal efficiency of copper-ion. At the low pH (1-2), the removal efficiency of copper-ion in feed solution is very low. This is mainly because decreasing pH will increase the hydrogen ion in feed solution. Increasing the hydrogen ion in feed solution will resulted the higher reverse reaction rate and the lower forward reaction rate. The copper-ion complex decrease when the forward reaction rate decrease hence the removal efficiency of copper-ion is very low.

Increasing of pH will certainly increase the removal efficiency of copper-ion until pH in feed solution is equaled to 6, the removal efficiency of copper-ion remains constant although pH of feed solution increases. It can be explained that increasing pH will decease the hydrogen ion in feed solution and the copper complex formation rate increase when the hydrogen ion in feed solution increase and hence the removal efficiency of copper-ion increase. However, when pH is higher than 6, hydrogen ion concentration in feed solution is very low when compared with concentration of copper-ion and extractant hence hydrogen ion concentration has not effect to the copper complex formation rate. Therefore the removal efficiency of copper-ion is dependent of pH of feed solution in the lower pH region (pH = 1 – 5). Hence, for efficient extraction, pH in feed phase should be greater than 6.

The experimental results when pH in feed solution is changed are also shows in figure 5.4. A good agreement between experimental and calculated results is found for the ranges studied (the average error percentage and the standard derivation, 12.76 and 14.07, respectively).

5.1.4 The effect of the hydrogen ion concentration in stripping solution

The relationship between the hydrogen ion concentration and removal efficiency of copper-ion are depicted in Figure 5.5. At the low hydrogen ion concentration (lower than 0.0001 mol/l), the removal efficiency is nearly zero. This can be explained that decreasing hydrogen ion concentration in stripping solution extremely decreases the reverse reaction rate and hence the stripping rate and removal efficiency are nearly zero.

When hydrogen ion in stripping solution increases from 0.001 to 0.01 mol/l, the removal efficiency increases dramatically. This is mainly because increasing hydrogen ion in stripping phase increases the stripping reaction rate and hence the removal efficiency of copper-ion increase. However, when hydrogen ion in stripping solution is higher than 0.1 mol/l, the removal efficiency of copper-ion remains constant. This can be explained that the copper-ion complex sufficiently react with 0.1 mol/l of hydrogen ion in stripping phase, therefore the hydrogen ion exceed when its concentration is higher than 0.1 mol/l. Hence, for efficient extraction, hydrogen ion in stripping phase should be greater than 0.01 mol/l.

The experimental results when initial concentration of hydrogen ion in stripping solution is changed are also shows in figure 5.4. Close agreement between experimental and calculated results is obtained for the ranges studied (the average error percentage and the standard derivation, 12.76 and 14.07, respectively).

5.1.5 The effect of the volumetric Flow rate in feed solution

The effect of volumetric flow rate in feed solution on the removal efficiency is shown in Figure 5.6. The removal efficiency of copper-ion decreases with the increasing of volumetric flow rate. This can be explained that the increasing of volumetric flow rate will resulted the lower residence time and hence the formation rate of copper complex decreases. However, at the low volumetric flow rate of feed solution, the operating time is slowly than the high flow rate.

The experimental results when initial concentration of hydrogen ion in stripping solution is changed are also shows in figure 5.5. Close agreement between experimental and calculated results is obtained for the ranges studied (the average error percentage and the standard derivation, 12.76 and 14.07, respectively).

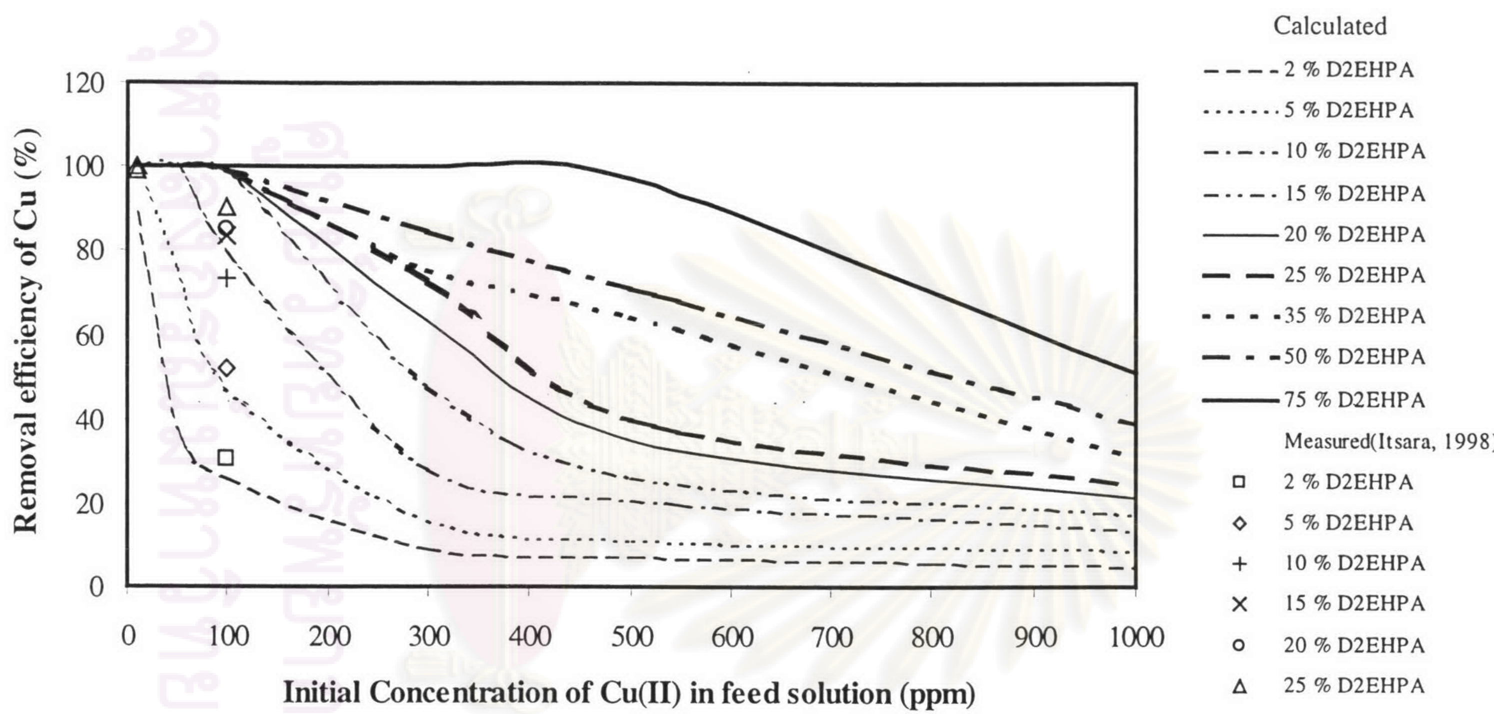

Figure 5.3 Effect of initial concentration of copper in the feed solution on the removal efficiency at various initial concentration of D2EHPA : $\Delta x = 1$ cm, $pH^f = 7$, $Q^f = 200$ ml/min, $Q^s = 200$ ml/min, $[H^+]^s = 0.1$ mol/l, $[Cu^{2+}]^f = 100$ ppm.

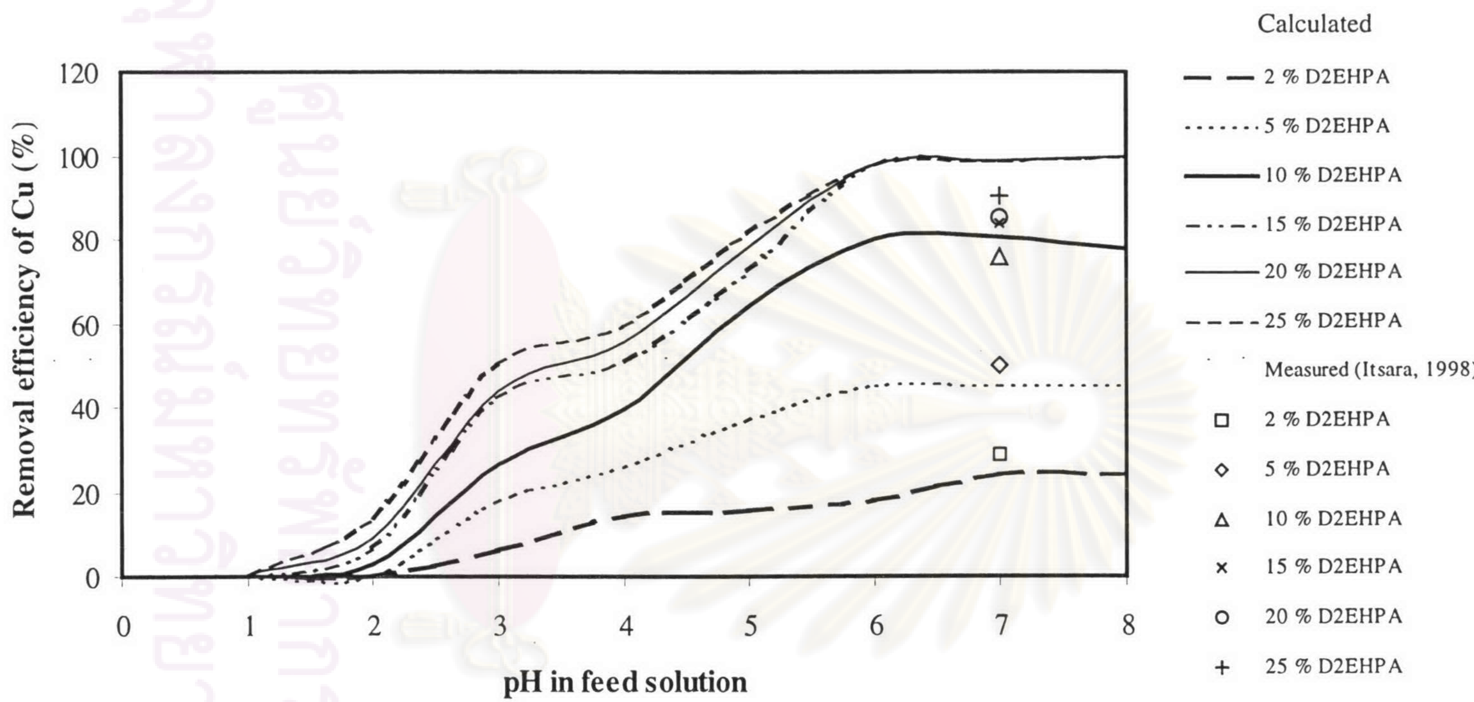

Figure 5.4 Effect of pH in the feed solution on the removal efficiency of copper ion at various initial concentration of D2EHPA : Δx = 1 cm, Q^f = 200 ml/min, Q^s = 200 ml/min, $[H^+]^s$ = 0.1 mol/l, $[Cu^{2+}]^f$ = 100 ppm.

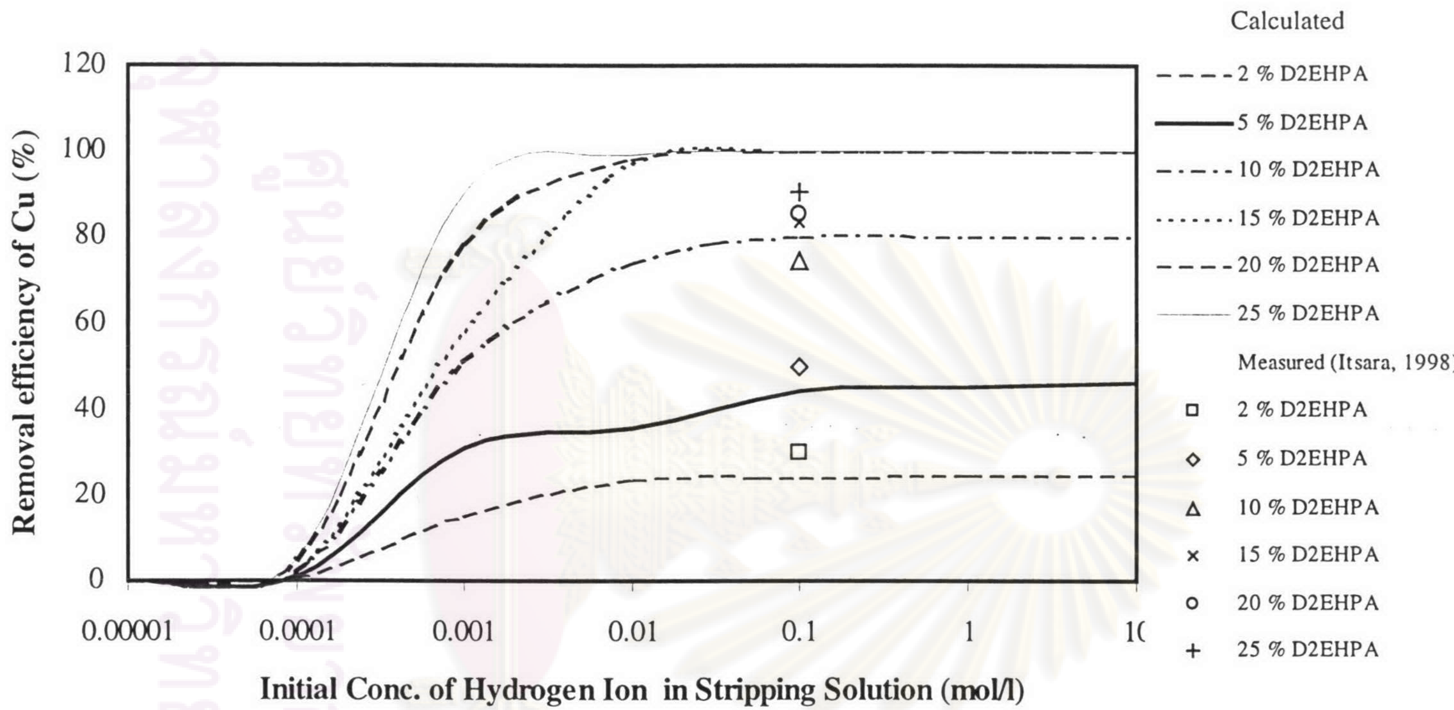

Figure 5.5 Effect of initial concentration of hydrogen ion in the stripping solution on the removal efficiency of copper ion at various initial concentration of D2EHPA : Δx = 1 cm, pH^f = 7, Q^f = 200 ml/min, Q^s = 200 ml/min, $[Cu^{2+}]^f$ = 100 ppm.

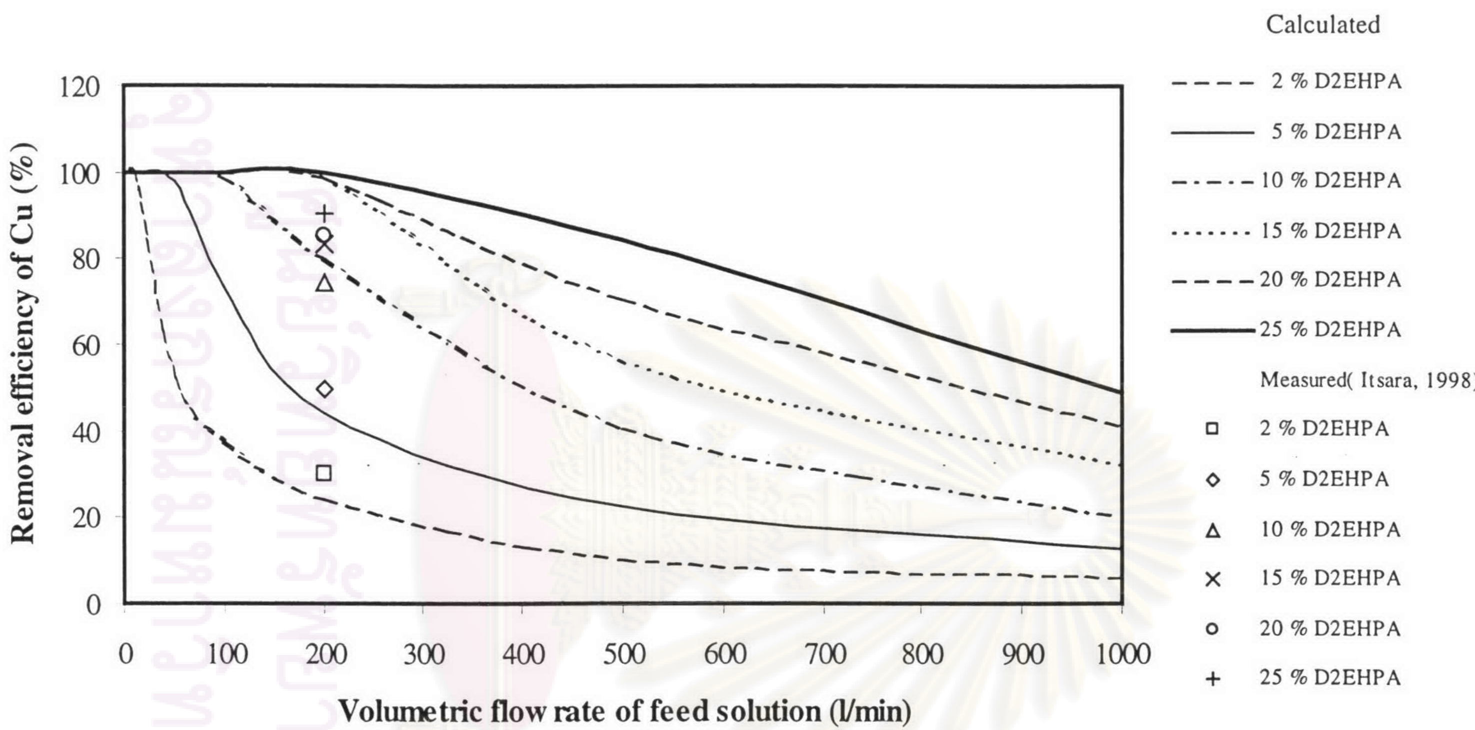

Figure 5.6 Effect of volumetric flow rate in the feed solution on the removal efficiency of copper ion at various initial concentration of D2EHPA : Δx = 1 cm, pH^f = 7, Q^f = 200 ml/min, Q^s = 200 ml/min, $[Cu^{2+}]^f$ = 100 ppm.

5.2 The Recycling Mode Operation

For the recycling mode, both feed solution and stripping solution are recycled. In this mode, the important parameters which will affect the copper-ion extraction are recycle time and circulation flow rate of feed solution.

Figure 5.7 shows effect of recycle time on the concentration of Cu^{2+} in feed solution at various circulation flow rate of feed solution.

The relationship between the removal efficiency and the circulation flow rate in feed solution are shown in Figure 5.8. At the low circulation rate of feed solution (less than 200 ml/min), the removal efficiency of copper-ion increase quickly after then this efficiency increase slowly when the circulation flow rate is higher than 200 ml/min. This can be explained that increasing circulation rate of feed solution will increases the mass transfer coefficient of copper-ion in aqueous feed solution and, consequently, the extraction rate increases. However, the contact time between copper-ion in feed solution and extractant in membrane solution decreases when increases the circulation flow rate and, subsequently, the formation rate of copper complex decreases and hence the removal efficiency of copper-ion increase slowly although the circulation flow rate increases.

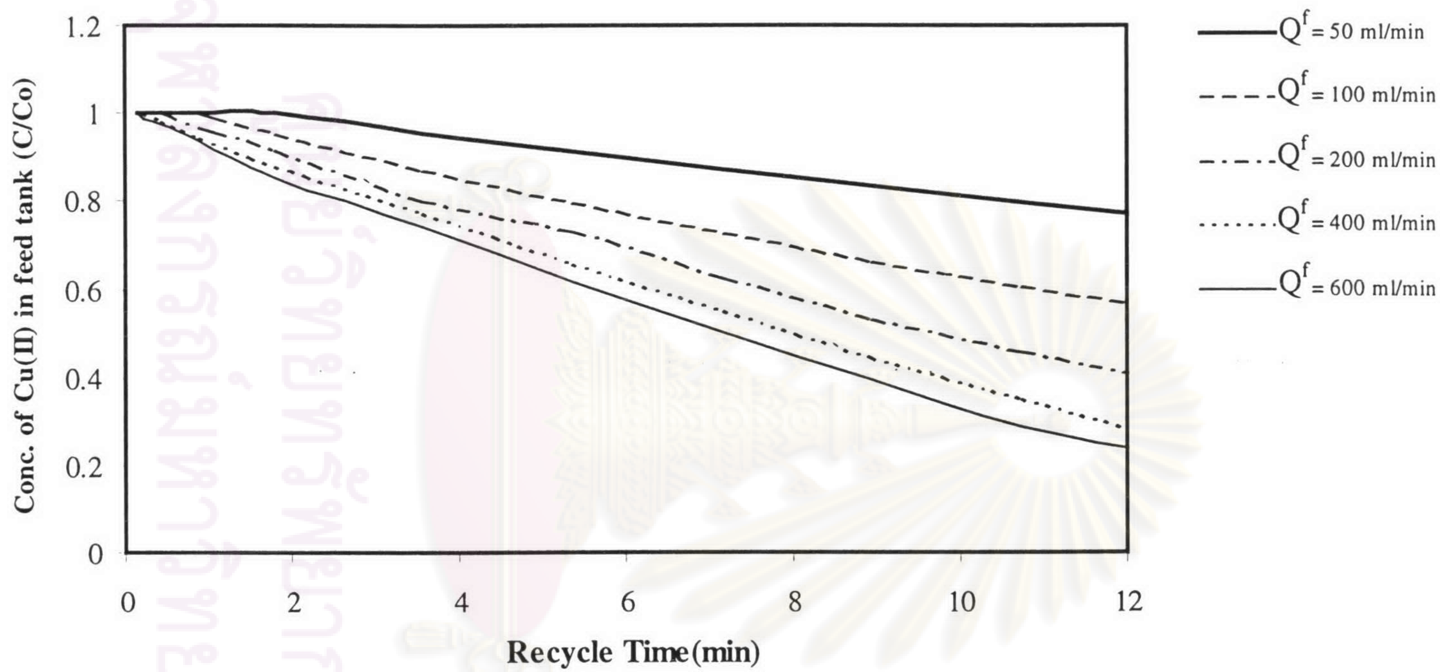

Figure 5.7 Effect of recycle time on the concentration of Cu^{2+} in feed solution at various circulation flow rate of feed solution : Δx = 1 cm, $pH^f = 7$, Q^s = 200 ml/min, $[H^+]^s$ = 1 mol/l, $[Cu^{2+}]^f$ = 300 ppm.

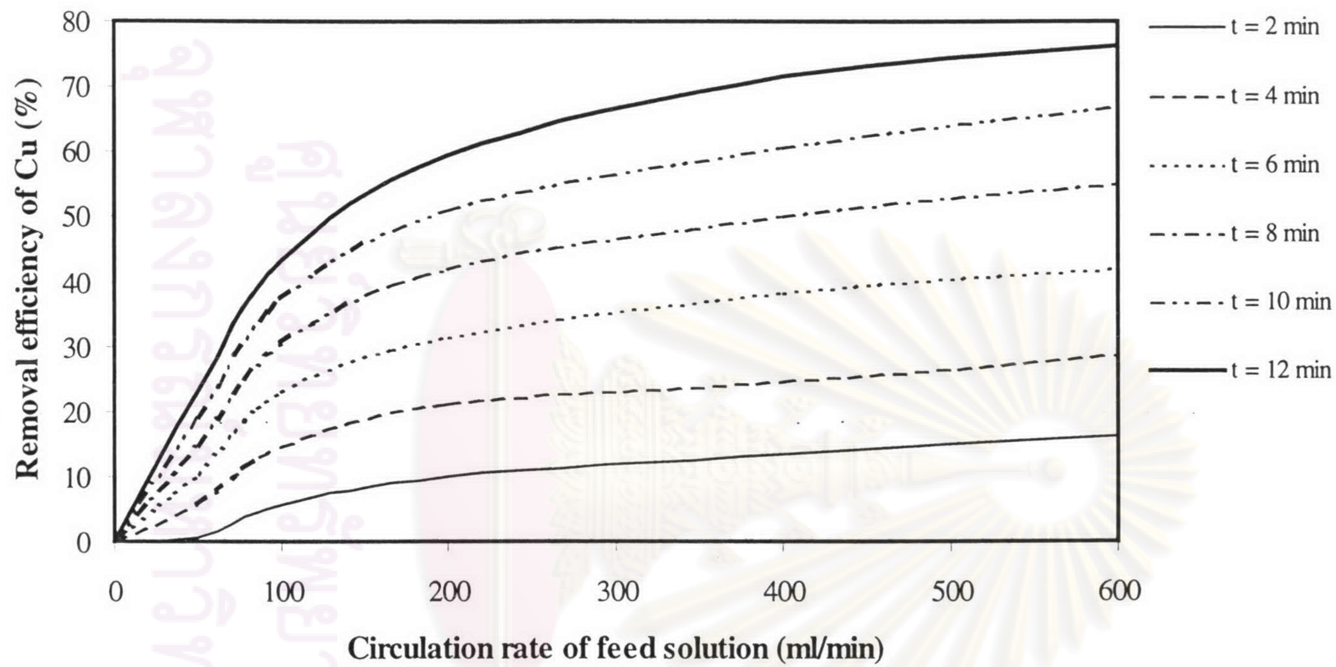

Figure 5.8 Effect of volumetric flow rate in the feed solution on the removal efficiency of copper ion at various recycle time : Δx = 1 cm, pH^f = 7, Q^s = 200 ml/min, $[H^+]^s$ = 1 mol/l ,$[Cu^{2+}]^f$ = 300 ppm.