CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In this research, a continuous multistage ion foam fractionation column with bubble-cap trays was employed to remove cadmium ions from simulated wastewater having cadmium ions at a low level (10 mg/L). In this study, sodium dodecyl sulphate (SDS) was used to generate the foam. This study demonstrated the ability of multistage ion foam fractionation to remove Cd^{2+} ions from simulated wastewater at a very low feed Cd concentration of 10 mg/L. The effects of the operational parameters (feed SDS/Cd molar ratio, foam height, air flow rate, feed flow rate, and feed Cd concentration) on the separation performance of continuous multistage ion foam fractionation were investigated in this study. An increase in feed SDS/Cd molar ratio enhanced the removal of Cd. This is due to an increase in the ability for foam formation, and the adsorption density of Cd-SDS complex at the bubble surface. However, the SDS concentration above a certain level resulted in wetter foams, leading to having a high volume of generated foam that lowered both the enrichment ratio and separation factor of the Cd. The SDS recovery tended to increase with increasing feed SDS/Cd molar ratio. The molar ratio of SDS/Cd in foamate was found to be close to the theoretical adsorption molar ratio of 2/1 on the air–water interface of foam when the system was operated at a feed SDS/Cd molar ratio in the range of 2/1 to 7/1.

An increase in foam height, which reduces liquid hold-up in the generated foam, resulted in the enhancement of the enrichment ratios of both SDS and Cd while the removal and residual factor of Cd showed insignificant change. An increase in air flow rate increased the foam generation rate and foamate volumetric ratio, leading to decreasing the enrichment ratios of both SDS and Cd, but increasing Cd removal. The separation factors of both SDS and Cd decreased with increasing feed flow rate because of the increases in both SDS and Cd input rates and foamate volumetric ratio. An increase in feed Cd concentration increased % SDS removal but decreased the enrichment ratios of both Cd and SDS because of the increasing foamability. In the low Cd range of 10–30 mg/L, the studied unit of multistage ion foam fractionation was demonstrated to provide a very high cadmium removal greater than 99.5 %.

The effectiveness for Cd removal is reduced with the addition of salt due to the reduced ability of Cd^{2+} to adsorb at the air–water interface of foam. A cation counterion derived from the added salt can compete with Cd ion for the interface at a certain concentration, depending on the ability of counterions to penetrate the adsorption layer (Stern layer). The effect of added cations on the reduction of Cd removal was in the following order: $Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$ whereas the added anions had a little effect. The effect of added anions on the reduction of Cd removal was in the following order: $SO_4^{2-}\approx Cl^{-}>NO_3^{-}$. The SDS recovery was found to improve, depending on type of added salt because the repulsion force between the head groups of SDS is greatly reduced by the counterions from added salt, leading to increasing SDS adsorption at the air–water interface of foam. In order to obtain high removal efficiency of Cd, it is important to reduce concentration of any counterions which can compete with Cd^{2+} for the adsorption onto the bubble surface. The highest separation efficiency (Cd removal = 99.7%; residual factor of Cd = 0.003; and enrichment ratio of Cd = 95) of the studied continuous multistage ion foam fractionation column was achieved at an air flow rate of 60 L/min, a feed flow rate of 40 mL/min, foam height of 90 cm, the number of trays equal to 5, a feed SDS/Cd molar ratio of 8/1, and an added $NaNO_3$ concentration of 0.5 mM.

6.2 Recommendations

The recommendations for future work are as follows:

1. To investigate heavy metal removal from real wastewater having a low heavy metal concentration such as electroplating wastewater.

2. To use renewable-based surfactant, such as methyl ester sulfonates instead of synthetic surfactant to make this process more environmental friendly
3. To study on heavy metal recovery from foamate in order to make ion foam fractionation to be more economically feasible.
4. To investigate the removal of mixed heavy metals by continuous multistage foam fractionation.