CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, the surfactant-modified zeolite (SMZ) adsorbents with various metal ligand to surfactant loading ratios were prepared and evaluated for their capability in adsorbing heavy metal (cadmium) and organic (toluene) contaminants in both single- and mixed-solute systems. In addition, used SMZ which contains adsorbed heavy metal and organic contaminants was regenerated by using simple regeneration techniques and then reused in order to compare the adsorption efficiency to its original capacity.

The results obtained in this study clearly demonstrated that the adsorption of heavy metal such as Cd^{2+} ions and organic compound such as toluene by SMZ was greatly improved by the surface modification technique to form a bilayer of cationic surfactant (CTAB) and metal ligand (palmitic acid or PA) on natural zeolite surface. From the equilibrium adsorption study, the results showed that the amount of metal ligand (PA) loading on SMZ had significant effect on the metal adsorption of SMZ. The cadmium uptake by SMZ increased significantly with increasing metal ligand to surfactant loading ratio in the range of 1:1 to 4:1. Increasing the metal ligand loading on SMZ beyond this range had insignificant effect on the cadmium adsorption by SMZ. In addition, the sorption of cadmium on SMZ was shown to be through the complexation between cadmium ions and the carboxylic functional group of PA on SMZ. For organic adsorption, increasing metal ligand loading on SMZ resulted in a slight decrease in the amount of toluene adsorbed on SMZ which is believed to be attributed to the tighter packing of the interlayer of PA and CTAB adsorbed on SMZ surface, thus reducing effective volume of the hydrophobic core of the mixed bilayer for toluene. In mixed-solute system, the presence of toluene did not show any effect on the adsorption of cadmium by SMZ whereas the presence of cadmium was found to enhance the adsorption of toluene. The results obtained from the regeneration studies clearly demonstrated that used SMZ containing heavy metal could be regenerated by using low pH solution to desorb sorbed metal ions on SMZ.

On the other hand, used SMZ containing toluene could be easily and fully regenerated by simple air purging. All sorbed toluene was stripped out from SMZ and regenerated SMZ could be reused after the regeneration. It can be concluded that SMZ can be regenerated and reused for multiple adsorption cycles.

5.2 Recommendations

This research work focused on three parts: the preparation of the surfactant-modified zeolite (SMZ) with various metal ligand and surfactant loading ratios by using a simple two-step surface modification technique, the adsorption of heavy metal and organic contaminants as a function of metal ligand loading ratio, and the regeneration and reuse of SMZ. Although this work studied the simultaneous removal of heavy metal and organic contaminants, the scope of the study was limited to only one species of heavy metal and organic contaminants which was cadmium and toluene, respectively. It would be of great interest to expand the study to a variety of heavy metals and toxic organics. For example, other heavy metals such as Pb^{2+} and Hg^{2+} could be used in the future study whereas benzene, ethylbenzene, and naphthalene could be used as model organic contaminants. Moreover, other types of metal ligands should also be used in the preparation of SMZ such as anionic surfactant.