CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, natural zeolite, clinoptilolite, was modified by using cationic surfactant (CTAB) and various anionic surfactants with different molecular structure such as head group (mono and twin head group) and tail group (short and long, and straight and branch chain). A simple two-step surface modification technique was employed using cationic surfactant (CTAB) to form a monolayer and anionic surfactant (DOWFAX 8390, DOWFAX 2A1, and SDBS) to form a bilayer. The resulting surfactant-modified zeolite (SMZ) adsorbents were then evaluated for their ability to remove heavy metals (cadmium and lead) and organic compound (toluene).

The results showed that the adsorption of both cadmium and lead could be described by the Langmiur isotherm. SMZs prepared with different anionic surfactant were shown to have nearly the same ability to adsorb Cd^{2+} and Pb^{2+} when compared to unmodified clinoptilolite. Among the two model metal ions, SMZs could adsorb cadmium more effectively than lead in both single- and mixed-metal systems. In contrast, lead was adsorbed more than cadmium in the case of clinoptilolite but clinoptilolite has low affinity toward lead and cadmium. As a result, a high adsorption capacity can be achieved at very low metal concentrations. This could be explained by the hard-soft acid base (HSAB) principle (Shawabkeh *et al.*, 2004). In the mixed-metal system, the competitive adsorption of Cd^{2+} and Pb^{2+} on SMZs and clinoptilolite was noticed which follows $Pb^{2+} > Cd^{2+}$. Such behaviors are determined by the hydrated ionic radii and the hydration energies of the heavy metal ions. For the adsorption of an organic compound, SMZs adsorb toluene significantly greater than unmodified clinoptilolite and the adsorption affinity appears to be dependent on the molecular structure of the surfactant used. The toluene adsorption exhibits a linear-type isotherm and the extent of the adsorption follows the order of SMZ-DOWFAX 8390 > SMZ-DOWFAX 2A1 > SMZ-SDBS > unmodified clinoptilolite. Thus, this research clearly demonstrated that the surfactant-modified zeolite, particularly when modified using long alkyl chain length of surfactant, could

be considered as potential adsorbents for heavy metal and organic contaminant removal from wastewater.

5.2 Recommendations

This research work focused on study the structure of surfactant is impact on the preparation of the surfactant-modified zeolite (SMZ) by using cationic and anionic surfactant modified surface of natural zeolite in following a simple two-step surface modification technique. The molecular structure of anionic surfactants is an important factor in preparing SMZ. The adsorption ability for the simultaneous removal of heavy metal and organic contaminants of SMZ depends on molecular structure of adsorbed surfactant. Again the study in this effect as structure of surfactant, future study can be done to investigate removal the other organic contaminants such as benzene, ethylbenzene, and naphthalene by using SMZ. For the removal heavy metals, it would be of great interest to study the kinetic effect of the adsorption of heavy metal ions.