CONCLUSION

After investigating the orthophosphate adsorption on natural adsorbents of natural zeolite, diatomite, perlite, kaolin, and ball clay, natural zeolite showed the highest % adsorption among the others. The structure of natural zeolite used in this work was identified its structure and composition. The XRD results showed the structure of mordenite, (Ca, Na_2, K_2) $Al_2Si_{10}O_{24}.7H_2O$, and the structure tended to change to aluminum silicate (Al_2SiO_5) of kyanite and silicon oxide (SiO_2) at the calcination temperature of 900ºC. For surface characterization, after increasing calcination temperature, it was indicated that surface area at multiple point of mordenite tended to decrease from 126.20m^2/g for one without calcination to 2.66 m^2/g for one calcined at 900ºC. SEM was not able to inform the difference in morphology after calcination at various temperatures. The chemical composition on surface obtained from EDS for all calcination temperatures, before and after adsorption, had 60-80%wt SiO_2, approximately 10%wt Al_2O_3, and 10%wt of other metal oxides. These results indicated that SiO_2 was the major composition and Al_2O_3 was the minor one on surface. Moreover, there were also traces of metal oxide (Ca^{2+}, Fe^{2+}, Na^{+}, K^{+}) on their surface.

In the orthophosphate adsorption study, the results showed the maximum adsorption on the calcined mordenite at 750ºC. The equilibrium adsorptions were 1, 2, 4, and 5 hr at initial orthophosphate concentration of 5, 10, 20, and 30 mg-P/L, respectively. The orthophosphate adsorption capacity of the calcined mordenite at 750ºC was 91, 93, 92, and 89% per 1g mordenite for initial orthophosphate concentration of 5, 10, 20, and30 mg-P/L, respectively. The adsorption results were fitted with Langmuir

isotherm with R^2 = 0.8532 giving the maximum adsorption of 769.23 mg-P/Kg adsorbent. Therefore, the behavior of orthophosphate adsorption in this work was monolayer. The adsorption occurs on specific sites with chemical adsorption and the orthophosphate molecules cannot migrate across the surface or interact with adjacent molecules.

To explain the orthophosphate adsorption behavior, FTIR was used to investigate the bonding between orthophosphate and the surface of mordenite. The FTIR results showed Si-O, Al-O, SiO-H, and Si(OH)Al bonds on mordenite and there were PO_4^{3-}, $H\ PO_4^{2-}$, and $H_2\ PO_4^-$ at the surface. However, the results could not inform the site where orthophosphate was bound to. Therefore, zeta potential measurement was used to further observe the adsorption behavior.

The zeta potential results could give the information on adsorption behavior at the surface on the uncalcined mordenite and the calcined ones at some temperatures. The results indicated that the high dissolution of Ca^{2+} in the acidic solution and the high dissolution of Fe^{2+} in basic solution had an effect on the orthophosphate adsorption.

At the surface, the dissolved Fe^{2+} could help Al and Si to adsorb orthophosphate by coordination adsorption and the Ca^{2+} could increase the orthophosphate adsorption by electrostatic adsorption. On the surface of the uncalcined mordenite, the zeta potential showed that the Si-OH was dominated and the orthophosphate adsorption was occurred at Si-OH sites. After the mordenite was calcined, the zeta potential of the calcined mordenite at 600 and 750ºC clearly showed the increase in Al-O groups at the surface. At the calcination temperature of 750ºC, orthophosphate could adsorb not only on

Si-O sites but also on Al-O sites which significantly increased the adsorption capability. With the presence of Fe^{2+}, the zeta potential of the calcined mordenite at 750ºC showed the highest orthophosphate adsorption capability which agreed to the results from orthophosphate adsorption experiment.

At the calcination temperature of 900ºC, the structure of mordenite was changed and the surface properties were altered. The zeta potential showed that the adsorbed orthophosphate groups were attracted by electrostatic adsorption in the distance to the surface. The information from zeta potential could be used to propose the adsorption behavior on the uncalcined mordenite and the calcined ones at 450, 600, 750, and 900ºC. However, the results could not clearly explain the adsorption of the calcined mordenite at 150 and 300ºC. There should be further investigations on surface adsorption behavior in order to clarify the adsorption behavior of the calcined mordenite at 150 and 300ºC.