



CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, Hexagonal Mesoporous Silicate (HMS) and three types of HMSs grafted with organic functional groups were synthesized and their physicochemical properties were characterized by several techniques. Selective adsorption phenomena of Cd(II), Cu(II), Methylene blue and TX-100 on the HMSs surface were investigated in both of single and bi-solute, comparing with powdered activated carbon (PAC).

Physicochemical characteristics of these materials were investigated and the effects of pH on adsorption mechanisms were also discussed. The adsorption experiments were performed under batch condition at low Cd(II) and Cu(II) concentration of 1-20 ppm, low Methylene blue (MB) concentration of 5-150 ppm and high TX-100 concentration of 50-600 ppm.

This investigation presented that the XRD patterns of functionalized HMSs exhibited very broad peak, indicating that the mesostructure of functionalized HMSs was less order. The specific surface areas of functionalized HMSs were decreased due to increasing of amino functional group. PAC has the small average pore size, but HMS and functionalized HMSs have average pore sizes in the range of mesopore scale. In addition, presence of organo-functional groups might deform hexagonal mesostructure which might cause increasing of average pore size. The FT-IR spectra of HMS and functionalized HMSs exhibit O-H stretching band at wavenumber of 3400-3500 cm^{-1} , indicating that they still have silanol groups on surface, particularly in HMS. C-H stretching and C-H bending bands of CH_2 -methylene group appeared in functionalized HMSs, in spite of disappearance in HMS. Moreover, two N-H stretching bands of A-HMS indicate the presence of NH_2 but mercapto-functional groups (SH) in M-HMS could not be identified. However, they could be investigated by elemental analysis which confirmed that amino and mercapto functional groups presented on the surface of functionalized HMSs. pH_{ZPC} of HMS,

A-HMS, M-HMS, OD-HMS and PAC was found to be 5.5, 9.5, 6.2, 4.4 and 9.5, respectively. The presence of amino-functional groups on HMS gave a higher pH_{ZPC} than HMS, despite that M-HMS did not change significantly at pH in range of 4-6.

Adsorption kinetic follows the pseudo-second-order model for Cd(II), Cu(II), MB and TX-100 adsorption on all adsorbents, indicating that the adsorption step may involve chemisorption. The calculated q_e values agree well with the experimental q_e values.

Chemical reaction between metal ions and surface functional groups was suggested to be an important factor for adsorption of heavy metals. Adsorption capacities of synthesized HMSs except M-HMS were lower than PAC. Moreover, silicate crystalline structure, pore size and surface area did not affect to adsorption capacities of Cd(II) and Cu(II) on silicate surface significantly. From these results, it might be indicated that adsorption capacity of Cd(II) and Cu(II) adsorbed on hydrophobic functionalized HMSs (M-HMS, OD-HMS and PAC) are greater than hydrophilic functionalized HMSs (A-HMS) at high level concentration.

Van der Waals interaction, which is caused by hydrophobicity, was suggested to be an important factor for adsorption of ionic dyes. OD-HMS had the strongest van der Waals interaction caused the highest adsorption capacity of MB. On the contrary, A-HMS has positive surface charge, which explains the lowest adsorption of MB. Hydrogen bonding between amino-group of A-HMS and MB did not increase the adsorption capacity of MB. PAC had the highest MB adsorption capacity. PAC has a higher surface area than all HMSs, and the surface of PAC is highly heterogeneous with different organic groups. Effect of positive surface charge of PAC on positive charge MB can be neglected.

Adsorption capacities of TX-100 on synthesized HMSs were higher than PAC, except A-HMS. Adsorption capacities of TX-100 depend on many factors such as pore size, surface area and surface hydrophobicity. Hydrophilic adsorbents had higher TX-100 adsorption capacities than hydrophobic adsorbents. That can be explained by complete aggregation on external surfaces of hydrophilic adsorbents. On the contrary hydrophobic surfaces can support only semi-aggregation.

Correlation coefficients of Langmuir and Freundlich isotherm calculated by linear regression were not different significantly. And effects of pH on adsorption capacities of studied heavy metals, methylene blue and TX-100 were related to electrostatic interaction caused by changing of surface charge type and density.

In bi-solution, all of adsorbents have high selectivity for heavy metals both of Cd(II) and Cu(II) in a mixture with TX-100, which is caused by changing surface characterization of adsorbents by TX-100 and different interactions between HMSs and adsorbates; namely HMSs and TX-100 interact by hydrogen bonding or van der Waals force of TX-100 on surfaces whereas HMSs and Cd(II) or Cu(II) interact by chemical bonding.

Moreover, all of adsorbents have lower selectivity for heavy metals both of Cd(II) and Cu(II) in a mixture with MB, which is caused by different interactions between HMSs and adsorbates; namely HMSs and MB interact by electrostatic force whereas HMSs and Cd(II) or Cu(II) interact by chemical bonding.

Functionalized HMSs except amino-groups grafted HMS (A-HMS) have high selectivity for TX-100 in a mixture with Methylene blue (MB), which is caused by different interactions between HMSs and adsorbates; namely HMSs and TX-100 interact by hydrogen bonding or van der Waals force of TX-100 on surfaces whereas HMSs and MB interact by van der Waals interaction.

5.2 Recommendations

- 1.) Study effects of other co-existing matter and electrolytes that might affect to selective adsorption capacity and mechanism in real textile wastewater.
- 2.) Study adsorbents regeneration and/or chemicals recovery method and efficiency of HMS and functionalized HMSs, including effect of those methods on physico-chemical characteristics, affected to re-used adsorbents adsorption efficiency.