CHAPTER V

CONCLUSIONS

In this work, TiO_2 nanoparticles with good catalyst properties (high surface area, small nanocrystal size, high porosity, and proper crystal structure) and high photocatalytic activity in chromium (VI) removal were successfully synthesized. Two types of TiO_2 with different additives, DEG and PEG 600, were investigated in comparison with TiO_2 without any additive.

5.1 Nanocrystal TiO_2 with DEG

In summary, the major findings include:

- DEG delayed the phase transformation from anatase to rutile phase from 450 °C for TiO_2 without any additive to 600 °C with DEG stabilizing agent.
- DEG exerted the pronounced effect on reducing of nanocrystal size and consequently increasing the surface area of TiO_2 crystals. The size of TiO_2 with DEG is relatively smaller than that of TiO_2 without any additive.
- Adsorption of chromium (VI) onto TiO_2 surface followed the Langmuir adsorption isotherm better than the Freundlich adsorption isotherm. The adsorption isotherm equation is:

  $$\frac{C_e}{(x/m)} = 0.9164C_e + 30.495$$

  where the Langmuir constants Q_0 and b were found to be 1.09 mg/g and 0.030 L/mg, respectively.
- Photocatalytic reduction of chromium (VI) using TiO_2 with DEG followed the zero-order kinetic pattern at the initial concentration of chromium (VI) less than 50 mg/L and then the kinetic pattern changed to follow pseudo first order when initial concentration of chromium higher than 50 mg/L.

- The intrinsic kinetic values of TiO_2 with DEG were calculated following Langmuir-Hinshelwood equation and the values of the adsorption equilibrium constant (K_{Cr}) was found to be 0.287 L/mg and the second-order rate constant (k_c) was 0.168 mg/L-min.

5.2 Nanocrystal TiO_2 with PEG 600

In summary, the major findings include:

- PEG delayed the phase transformation from anatase to rutile phase from 450 °C for TiO_2 without any additive to 500 °C with PEG stabilizing agent.
- PEG exerted the pronounced effect on reducing of nanocrystal size and consequently increasing the surface area of TiO_2 crystals. The size of TiO_2 with PEG is relatively smaller than that of TiO_2 without any additive.
- Adsorption of chromium (VI) onto TiO_2 surface followed the Langmuir adsorption isotherm better than the Freundlich adsorption isotherm. The adsorption isotherm equation is:

$$\frac{C_e}{(x/m)} = 0.7477C_e + 30.749$$

  where the Langmuir constants Q_0 and b were found to be 1.34 mg/g and 0.024 L/mg, respectively.
- Photocatalytic reduction of chromium (VI) using TiO_2 with DEG followed the zero-order kinetic pattern at the initial concentration of chromium less than 50 mg/L and then the kinetic pattern changed to follow pseudo first order when initial concentration of chromium higher than 50 mg/L.
- The intrinsic kinetic values of TiO_2 with DEG were calculated following Langmuir-Hinshelwood equation and the values of the adsorption equilibrium constant (K_{Cr}) was found to be 0. 0.480 L/mg and the second-order rate constant (k_c) was 0.220 mg/L-min.

5.3 Role of DEG and PEG 600 on nanocrystal TiO_2

- When compare the effect of short chain DEG and long chain PEG 600 on forming of the nanocrystal TiO_2, PEG accelerated the formation of rutile at lower calcination temperature than the short chain of DEG.
- The crystallite size and surface area of TiO_2 increased with increasing of molecular weight of PEG as the PEG 600 enhanced the smaller size of TiO_2 than DEG.
- The pore volume and pore diameter increased with increasing molecular weight of PEG.
- The long chain of PEG 600 can agglomerate the nanocrystal TiO_2 better than the short chain of DEG. Thus, with the linkage particles, PEG 600 can accumulate the anatase and transform from the anatase to rutile phase in the lower temperature comparing to DEG, i.e. 600 °C for PEG 600 and 800 °C for DEG.
- Upon photocatalytic reduction of chromium (VI), the TiO_2 with PEG 600 provides the highest efficiency among three types of TiO_2 (TiO_2 with PEG, TiO_2 with DEG and TiO_2 without additive). This behavior was revealed by the highest value of K_{cr} representing the highest in chromium (VI) adsorption on the surface of titania and the highest value of k_r corresponding to the highest reaction rate in photocatalytic reduction of chromium (VI) upon irradiation process.

5.4 Outcomes from this research

- Better understanding of the effects of DEG and PEG 600 on properties of nanoparticle TiO_2
- Better understanding of the effects of mole ratios of TTiP:DEG or TTiP:PEG 600 on properties of nanoparticle TiO_2
- Better understanding of the effects of calcinations temperatures on properties of nanoparticle TiO_2 with DEG or PEG

From the above knowledge, the proper nanocrystal TiO_2 can be synthesized and used for applications in heavy metal removal as presented in this work. The synthesized

TiO_2 nanoparticles were tested and they successfully removed chromium (VI) from synthetic wastewater.

5.5 Further research suggestions

- Developing new type of TiO_2 with specific properties such as mesoporous by using other types of stabilizing agents
- Investigating possibilities of applying this synthesized TiO_2 with DEG or PEG 600 for organic contaminant removal
- Applications of this synthesized TiO_2 with DEG or PEG 600 for cleaning air pollution
- Applications of this synthesized TiO_2 with DEG or PEG 600 for soil remediation