CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Removal Study

The objectives of removal studies were utilization of bagasse and bagasse fly ash as removal materials for lead and chromium. The following conclusions have been drawn from the above investigations:

1. The efficiencies of lead adsorption onto bagasse and bagasse fly ash were found to be between 0.05 to 95.6 % and 25.7 to 99.5 %, respectively.

2. Contact time, initial concentration, solution pH, and adsorbent dose affected lead removal efficiency. Lead removal efficiency increased with increasing contact time, solution pH, and adsorbent dose but decreased with increasing initial concentration. In addition, they were affected lead adsorption capacity, adsorption capacity increased with increasing contact time, solution pH and initial concentration but decreased with increasing adsorbent dose.

3. The maximum lead removal efficiency occurred at initial concentration of 5 mg/L at solution pH 6, it was 95.6 and 99.5% for bagasse and bagasse fly ash, respectively. The maximum lead adsorption capacity was achieved at initial concentration of 80 mg/L at solution pH 6, it was 4.1 and 7.9 mg/g for bagasse and bagasse fly ash, respective.

4. At condition of solution pH 6 and initial concentration was 80 mg/L, the lead removal efficiency became almost constant at 10 g/L for both adsorbents.

5. Lead adsorption isotherm can be described by Freundlich equation. The recommended equation, $\log x/m = 5.43 \log Ce - 7.53$ and $\log x/m = 0.85 \log Ce + 1.03$ for bagasse and bagasse fly ash, respectively. In practice, Pb removal reactor can be designed using this equation.

6. Bagasse fly ash was a better lead adsorbent comparing to bagasse. It may be due to higher porosity, pore specific volume, and specific surface area of bagasse fly ash. These characteristics affected the removal efficiency and adsorption capacity in such a way that high value cause high removal efficiency and capacity.

7. The removal of Cr(VI) by bagasse and bagasse fly ash may involved two processes, namely, reduction of Cr(VI) to Cr(III) and adsorption of Cr(VI) and Cr (III). Bagasse can remove Cr(VI) more than bagasse fly ash but, it can remove total Cr less than bagasse fly ash. Bagasse can remove Cr(VI) via reduction more than adsorption. On the other hand, bagasse fly ash can remove Cr(VI) by adsorption more than reduction. The hydroxyl groups in cellulose structure of bagasse was found may be the main reduction site for Cr(VI) species.

8. Contact time, initial concentration, solution pH, and material dose affected total chromium and Cr(VI) removal efficiency. Total chromium and Cr(VI) removal efficiency increased with increasing contact time and adsorbent dose but decreased with increasing initial concentration and solution pH.

9. The efficiencies of Cr(VI) removal by bagasse and bagasse fly ash were found to be between 80 to 100 % and 0.5 to 93 %, respectively. For total chromium removal efficiencies were found to be between 7.3 to 20.8 % and 0.2 to 79.5 % by bagasse and bagasse fly ash, respectively.

10. At condition of solution pH 1 and initial concentration was 80 mg/L, bagasse doses of more than 20 g/L were enough to complete the removal of Cr(VI) within 60 min but bagasse fly ash was unable to remove Cr(VI) completely and more than 25 g/L dosage was required.

11. The Cr(VI) removal reaction can be described by Langmuir-Hinshelwood model. The reaction rate (r) was $r = -0.023\ C / 1 - 0.2035\ C$ and $r = 0.0037\ C / 1 - 0.1315\ C$ for bagasse and bagasse fly ash, respectively. In practice, Cr(VI) removal reactor can be designed using this reaction rate.

5.1.2 Solidification/Stabilization Study (S/S Study)

The S/S studies can conclude as follow:

1. The Portland cement hydration is inhibited by bagasse and bagasse fly ash which adsorbed or non-adsorbed heavy metal.
2. Compressive strength was not effect by type of bagasse and bagasse fly ash (adsorbed or non-adsorbed heavy metal). Meanwhile, w/c ratio and percent replacement effect compressive strength.
3. The compressive strength and relative compressive strength decrease with increasing of percent replacement of bagasse or bagasse fly ash.
4. The optimal values of w/c ratio for compressive strength were 0.4-0.5 and 0.4-0.6 for bagasse and bagasse fly ash replacement, respectively.
5. The compressive strengths increased with hydration time and after a 3-day curing time, compressive strength were enough to meet the land filling standard (3.5 ksc) for 5 and 10% replacement with bagasse and bagasse fly ash, respectively.
6. This process is strongly immobilized of lead and chromium. Concentration of lead and chromium in leachate were below the limits (5 mg/L) established by the Ministry of Industries No.6, B.E. 2540 (1997).

5.1.3 Construction Material Study

The objectives of construction material study were utilization of bagasse fly ash (adsorbed and non-adsorbed) as partial cement replacement material. The conclusions as follow:

1. The proportion 1 : 1.1 : 1.9 of cement : sand : crushed stone gave the highest compressive strength (400 ksc).
2. Compressive strengths of concrete were affected by percentage of replacement, w/c ratio, and curing time. Compressive strength increased with decreasing percent replacement, and curing time and highest at w/c ratio of 0.4.

3. Concentrations of lead and chromium in leachate were below the limits (5 mg/L) established by the Ministry of Industries No.6, B.E. 2540 (1997). This process accomplishes this task while at the same time help to provide a safe sound method of disposing heavy metal hazardous waste.

4. The relationship between percent replacement, w/c ratio, and compressive strength can be described by Gaussian equation. The percent of error of recommend Gaussian equations showed a good agreement between predicted strength and actual strength, less than 10 % error in range of 0-15 % replacement.

5.1.4 Economic Benefit Study

1. The operation cost of acid treated bagasse by 0.1M HCl was 0.012 Baht/g of bagasse. Wastewater of solution pH 2, 1 m^3 adjusted by 6N NaOH to pH 6 use 57.6 Baht. In real practice, commercial-grade HCl may be used instead in order to save the cost of chemical.

2. The cost of cement was 18.36 and 4.7 Baht for 10 and 30% replacement with bagasse and bagasse fly ash 1 kg, respectively which solidified product can disposed via landfilling (compressive strength more than 3.5 ksc). The cost of concrete block decreased with increasing partial cement replacement with bagasse fly ash.

3. Pb removal in wastewater from Factory A that 30 mg/L of Pb and solution pH of 6, operation cost of conventional process (precipitation by pH adjustment by NaOH and H_2SO_4) was lower than alternative process (adsorb by bagasse or bagasse fly ash). However, the alternative process is one of choice for lead removal. Waste treatment by other waste from other factory is challenging and should be sustainable development.

4. Waste removal from sugar Factory AA, the alternative process, bagasse fly ash was used as adsorbent for lead acetate and used the spent material as concrete block which partial cement replacement up to 30%. In addition, residual bagasse fly ash was not transfer to fill on earth or plantation; they were used as concrete block. At least, factory AA will save approximately 40,250 Baht/year.

5.2 Recommendations

1. Effect of mixture of various heavy metals on removal efficiency, adsorption capacity, and compressive strength of mortar and concrete should be further studied.

2. All condition of construction material study should be repeated for tests of durability, tensile strength, elastic modulus, and modulus of rupture.

3. In the section on construction material study, more variation of percent replacement, predicted compressive strength, and w/c ratio should be studied to further refine the equation.

4. Long-term leaching test should be performed on solidified products to ensure that heavy metals will not become mobile once alkalinity is leached out.

5. Effect of temperature in boiler on physical characteristic of bagasse fly ash, removal efficiency and compressive strength of mortar or concrete should be further studied.