CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This work proposed the method for the conversion of unwanted industrial materials, i.e. eucalyptus bark, to a useful activated carbon. The phosphoric acid activation was employed for this purpose where the optimal activation temperature was 500°C, the weight by volume ratio of eucalyptus bark and phosphoric acid (impregnation ratio) 1:1 and the activation time 1.5 h. This condition gave the highest iodine and methylene numbers, and also the highest BET surface area.

In the investigation of the batch adsorption of metals using activated carbon. It was found that the optimal pH for Cu(II) and Pb(II) adsorption on the activated carbon was pH 5. The adsorption reached equilibrium within 45 minutes for the whole range of concentration (0.1-10 mM) and the temperature range (25-60°C). The pseudo second order was best for the prediction of adsorption kinetics for both Cu(II) and Pb(II). Adsorption isotherms of Cu(II) and Pb(II) fitted well with Langmuir Isotherm. Activated carbon from this work could adsorb more Pb(II) than Cu(II) where the adsorptions occurred better at higher temperatures. The positive values of Ea and ΔH indicate the presence of an energy barrier in the adsorption process and endothermic process. The level of maximum adsorption capacity of this activated carbon was considered relatively high when compared with the reported values.

For the desorption study of single component systems, it was found that the desorption efficiency of the elution solutions could be ordered from most to least efficient as: citric acid > sulfuric acid > phosphoric acid for Cu(II), and citric acid > phosphoric acid > sulfuric acid for Pb(II). 1 N Citric acid was found to be most efficient with desorption efficiencies of 95.80 and 92.14% of Cu(II) and Pb(II), respectively. The time for desoption of the both metals was 60 min. The leaching temperature had significant effect on the recovery of the both metals.

For the binary desorption study of Cu-Pb mixture, it was found that there was potential in the recovery of each metal using 1N sulfuric acid as eluting agent. The recoveries of Cu(II) from binary component by 1 N sulfuric acid, giving the highest recovery of 69.35% when compared with phosphoric acid and citric acid solution. Pb(II) was only marginally eluted with sulfuric acid and therefore remained within the carbon matrix.

In fixed bed experiments, it was found that the sorption capacity increased with increasing bed depth of the column or decreasing the liquid flow rate. The BDST models were well fitted with the data obtained from the continuous experiment and this model illustrated that the maximum sorption capacity (N_0) decreased with an increase in flow rate. The concept of the number of transfer unit was introduced in this work and it was found that increasing bed depth and decreasing effluent flow rate increased the number of transfer unit, hence, increased the column efficiency. This agreed well with the results from the BDST model.

7.2 Contributions

The research shows that activated carbons could be well prepared from eucalyptus bark with chemical activation, and eucalyptus bark is actually one of the best precursors for the preparation of activated carbon. The chosen method was found to provide activated carbon product with reasonably high iodine and methylene blue numbers, along with high specific surface area. This activated carbon product performed well in the adsorption of heavy metals from the concocted waste solution. It was also illustrated that, for the binary mixture of Cu(II) and Pb(II), it was possible to recovery each individual metal from the solution simply by selecting a proper eluting/desorbing agent. In this work, 1N sulfuric acid was found to provide this separation quite satisfactorily. With further development of such technology, a more stable treatment and recovery technique should be ready for the scale-up. This work therefore contributes greatly to the actual industrial problems where the management of eucalyptus bark is a major concern as this "un-wanted" material could, in fact, be converted to a higher value product with a clear industrial application.

7.3 Recommendations / Future works

The investigation revealed some problems with the use of the activated carbon product for the adsorption of heavy metals. This involves the stability of such product after the regeneration with acidic agent. Further investigation on this point has not been conducted in this work and this is left as a future recommendation.

In addition, the use of chemical activation technique for the production of activated carbon might result in a large requirement of chemical which then poses some concerns regarding the quality of the wastewater effluent. Hence, it is either that the recovery of the activation chemical agent be developed or the use of other "low chemical requirement" method such as steam or hot gas should be investigated. This is to ensure industrial implication of such activation method.