CHAPTER X

CONCLUSION AND RECOMMENDATIONS

10.1 Conclusions

In the investigation of the adsorption of basic dyes using *Caulerpa lentillifera*, it was found from the part of adsorbent characterization that the surface of algal sorbent contained many functional groups which played an important role in the adsorption behavior and at any pH higher than 2, the alga surface was negatively charged which attracted the basic dyes.

In batch study, it was found that, in the range of concentration employed in this work, the adsorption isotherms fitted with both Langmuir and Freundlich isotherm models. Increasing temperature increased the maximum sorption capacity (q_m) and the highest sorption capacity was obtained at 50°C. From thermodynamic point of view, the adsorption process was found to be endothermic in nature and spontaneous. Kinetic data corresponded well with the pseudo second-order kinetic model where the rate constants decreased as initial dye concentrations increased. The resultant desorption phenomenon observed in acidic solution might be attributed to ion-exchange type. This happened when H+ ion competed with the dye molecules for target functional groups on the algal surface. The pH of PZC could also be used to explain this. At the lower pH, the surface charge of the alga became less negative and the sorption was worse than at the higher pH. However, the use of water and high temperature could desorb small amount of dye. Hence, the combined ion-exchange and physical sorption phenomena might be possible during the dye-algal sorption.

The comparison study with activated carbon was done. The adsorption isotherms of all sorption systems were fitted with Langmuir isotherm model, which implied that the alga surface was homogenous and the there was monolayer coverage on its surface. From Langmuir model, it was found that the maximum sorption capacity (q_m) acquired for the sorption of MB onto *C. lentillifera* was 417 mg g^{-1} which was relatively high in comparison with the previous records and the equilibrium times of the algal systems were found to be shorter than that of activated carbon.

Batch type sorption is usually limited to the treatment of small volume of effluent, whereas fixed bed systems have an advantage over this limitation. Then the continuous flow experiment in the fixed bed column was conducted. It was found that the sorption capacity increased with increasing bed depth of the column or decreasing wastewater flow rate. BDST and Thomas models were well fitted with the data obtained from the continuous experiment. The concept of mass transfer zone index was introduced in this work and it was found that increasing bed depth and decreasing effluent flow rate decreased the mass transfer zone index, hence, increased the column efficiency. This tend agreed well with the result from Thomas and BDST model.

In the study of binary dye mixture, two patterns of spectral peak were observed. The mixture of Astrazon® Blue FGRL and Astrazon® Red GTLN (AB+AR) yielded single mount shape spectra, while te mixture of Astrazon® Blue FGRL and Astrazon® Golden Yellow GL-E (AB+AY) yielded double mount shape spectra. In case of AB+AR, the shifts of spectral peaks were observed when the composition of the mixture changed and the area beneath the light absorbance curve corresponded to the quantity of the dyes in the mixture. The proposed analytical method could be used as a simpler approach for the measurement of individual dye component in the mixture of two dyes. In the sorption of AB+AY mixture, the algal adsorbent had more affinity to Astrazon® Blue FGRL than AY particularly at low adsorbent dose. However, at high adsorbent doses, the removal percentage of AB and AY were not significantly different. In AB+AR mixture, C. lentillifera had higher affinity to AB than AR.

10.2 Contribution of this work

The work illustrated that *C. lentillifera* which is the fast-growing green macroalga, could be used as an adsorbent for the removal of basic dyes from synthetic wastewater. This algal biomass was particularly suitable for the adsorption of the commercial basic dyes Astrazon® Blue FGRL, Astrazon® Red GTLN, Astrazon® and methylene blue. Details on sorption equilibrium, kinetics, and thermodynamics were provided in this research. Complete investigations covering both batch and continuous adsorptions were provided which can be directly employed in further development of pilot scale examination of this application.

It is interesting to note that this alga has a much higher capacities than conventional, general-purpose sorbents like activated carbon which surely has much

higher surface area. The high affinity of this alga for basic dyes presents attractive solution to the historical wastewater treatment dilemma as this means that, eventually the effective treatment is potentially available with almost no extra cost.

10.3 Recommendations and suggestions for future work

Although this work had been designed to cover various aspects of the sorption of dyes with *Caulerpa lentillifera*, there are certain difficulties and limitations that still require further refinement. These include:

- Surface chemistry on the algal surface before and after being used as an adsorbent
- Adsorption of multi-component dyes
- Treatment of actual wastewater e.g. the design of pilot scale treatment system, the preservation of the algal sorbent in order to prolong its life time and the effect of preservation on the properties of alga, the combination of this technique with other conventional ones, and the disposal of used sorbent with economical and environmental friendly.