CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The result of this work can be summarized as follows:

1. Increasing initial Cu^{2+}, Cd^{2+} and Pb^{2+} concentration and temperature increased biosorption capacities.
2. Increasing biosorbent dose decreased biosorption capacities but increased metals removal.
3. The optimum agitation rate was 150 rpm.
4. The sorption process of Cu^{2+}, Cd^{2+} and Pb^{2+} follows pseudo- second order reaction kinetics.
5. Isotherm of Cu^{2+}, Cd^{2+} and Pb^{2+} sorption fitted with Langmuir Isotherm.
6. The thermodynamic parameters of the sorption demonstrated that the biosorption process was spontaneous and endothermic under natural conditions.
7. Ion exchange was the main sorption mechanism for Cu^{2+} and Cd^{2+} at low initial concentration whereas at high concentration, other mechanisms such as adsorption-complexation played a more significant role in the sorption process. The sorption of Pb^{2+} was not mainly from ion exchange but also due to other mechanisms.

5.2 Contributions

This work described the biosorption of heavy metals (low strength, concentration < 100 mg l^{-1}) by the dried biomass of *Caulerpa lentillifera* which was a waste from a close loop shrimp farm. The various aspects of sorption detail were investigated. However, the use of this biomass in the actual application still needs further improvement regarding the sorption capacity. Table 5.1 reveals that the sorption capacity of this biomass for heavy metals was only on the average level, not as good as other biosorbents. The capacity enhancement techniques such as chemical treatments might be considered for a better sorption. Nevertheless, since this biomass is an unwanted material from aquacultural activities, the use of such material could pose some economical significance.

Table 5.1 Maximum capacity of natural biosorbent.

Biomass	Heavy metals: maximum capacity	Ref.
Sargussum sp.	Cd^{2+}: 0.04 mmol g^{-1}	Cruz et al., 2004
R.basilensis	Cu^{2+}: 0.10 mmol g^{-1}	Munoz et al., 2006
Wheat shell	Cu^{2+}: 0.10 mmol g^{-1}	Basci et al., 2004
Caulerpa lentillifera	Cu^{2+}: 0.19 mmol g^{-1} Cd^{2+}: 0.11 mmol g^{-1} Pb^{2+}: 0.18 mmol g^{-1}	This work
Chlamydomonas reinhardtii	Pb^{2+}: 1.50 mmol g^{-1}	Tüzün et al., 2005
Ecklonia maxima	Cu^{2+}: 1.48 mmol g^{-1} Pb^{2+}: 1.17 mmol g^{-1}	Feng and Aldrich 2004
Spirogyra sp.	Cu^{2+}: 2.10 mmol g^{-1}	Gupta et al., 2006