6.1 Conclusions of the Thesis

The batch study on heavy metal removal by adsorption using mango peel and *Alisma plantago aquatica* were carried out in batch shake flasks. The major findings of the study are discussed in this section.

- Batch studies on cadmium, lead, zinc, chromium and copper removal showed significant effects of the variables adsorbent dose, contact time, initial metal concentration, pH etc. The results provide a good indication of the different operating conditions that would be required for efficient removal of each heavy metal from aqueous solution.

- pH is a significant factor in adsorption processes since it causes electrostatic changes in the solution. The maximum removal efficiency for Cd(II) is 96.24% at pH 6, 95% for Pb(II) at pH 4, 85% for Zn(II) at pH 7, 99.8% for Cr(III) at pH 6 and 76.7% for Cu(II) at pH5 were obtained for *Alisma plantago aquatica*. Removal of metal were 83.47% Cd(II) at pH 6, 94.93% Pb(II) at pH 4, 86.69% Zn(II) at pH 7, 79.32% Cr(III) at pH 6 and 82.82% Cu(II) at pH5 for mango peel.
Langmuir, Freundlich and Dubinin-Radushkevich (D-R) isotherms were observed to fit the equilibrium data and the model parameters were calculated at various temperatures using linearized equations.

Langmuir isotherm model ($R^2 \approx 1$) is in good agreement with the experimental data as compared to Freundlich and D-R models.

Kinetics data were best modeled by a pseudo second order kinetics equation.

The desorption study was also carried out and showed that the hydrochloric acid (HCl) 0.1N is the best extractant.

The thermodynamic constants, $\Delta G$, $\Delta H$ and $\Delta S$ of the adsorption process showed that adsorption of Cd(II), Pb(II), Zn(II), Cr(III) and Cu(II) were endothermic and spontaneous.

The breakthrough curves for packed column adsorption of zinc ions by *Alisma plantago aquatica* were plotted at various flow rates. The results showed that the adsorption of zinc is dependent on flow rate. The zinc removal yield decreased with increasing flow rate.

The Adams – Bohart and Wolborska models were applied to experimental data obtained from dynamic studies performed on fixed column to predict the breakthrough curves and to determine the column kinetic parameters. The region of the breakthrough was defined by the Adams – Bohart and Wolborska model at all flow rates. The model constants belonging to each model were determined by linear and non-linear regression techniques and were proposed for the use in column design.
6.2 Scope for Future Research

The technology, which uses locally available plant waste material like mango peel, and *Alisma plantago aquatica* is extremely low cost, effective and viable.

Following are the scope for future research:

- To explore the possibilities, modifications / pretreatment of adsorbent to improve its adsorption capacity.
- Studies with actual industrial wastewater to evaluate parameters for field applications.