CHAPTER VI
OVERALL CONCLUSIONS

6.1 Overall conclusions:

“All is Well That Ends Well”. This is the title of a Shakespearean Comedy. No other statement befit is as befitting as this to my concluding remarks at the end of my thesis.

The bio-waste materials used were collected locally, carbonized and treated with nitric acid. After the preparation the carbons named as NCDC, NCMC and NCAC (collectively named as Kaza’s carbons) using peels of Citrus documana, Citrus medica and Citrus aurantifolia respectively. Physico-chemical characteristics of these adsorbents studied are good and comparable with other adsorbents. Boehm titration reveals that presence of basic groups is more when compared to acidic group in these carbons and pH < pHZPC. These conditions favor the adsorption anionic sorbates.

The liquid phase oxidation of prepared carbons with HNO3 results in the formation of surface oxygen functional groups and amine groups which are retained from the source materials are also observed in FT-IR analysis and results are supplemented by thermo gravimetric analysis. Loose packing of the aromatic sheets called turbostratic structure is identified in these carbons in XRD analysis which facilitate the adsorption process. The findings in XRD analysis are supported by the SEM studies, in which random arrangement of dispersed carbon flakes with porous
nature is observed. Surface ablation of the carbons is clearly observed in the morphological studies. Elemental composition of carbon and oxygen on the carbon’s surface of the three carbons is provided by the EDAX analysis.

The optimum conditions for achieving the maximum adsorption of reactive dyes on to NCDC, NCMC and NCAC was investigated by batch mode adsorption studies. 3 g of the each carbon is fixed as optimum adsorbent dosage and optimum contact time of 60 min for Blue MR and 50 min for Red M5B dyes. At neutral pH, at room temperature (25±2°C) and at 20 mg l⁻¹ initial concentration of each dye, the maximum percent removal capacity of these adsorbents observed is 89% for NCDC, 82% for NCMC and 80% for NCAC in case of BMR and 91% for NCDC, 87.2% for NCMC and 85% for NCAC in case of RMB. Surface morphological changes of adsorbents are observed in SEM images and dye loading is observed in EDAX analysis.

The percent removal of dye increased with increase of adsorbent dosage and contact time. These carbons showed good adsorption capacities in acidic medium rather than alkaline medium. However, these adsorbents effectively worked up to pH 8. The percent removal decreased with increase in initial concentration of dye and with increase in particle size of the adsorbents. 20 mg l⁻¹ initial concentration of dye and 45 µ size of carbons are considered as optimum parameters. The dye loaded carbons tried for regeneration by varying pH (3.0–12.0) solution but regenerated carbons showed poor efficiency in further decolorization process that may indicate that dye is strongly bound to the adsorbent surface and the availability of number of
active sites are not much increased during regeneration. However as these adsorbents prepared from bio-waste materials, regeneration may not be an economical limiting factor.

There is no significant effect of ionic strength in adsorption of dyes onto the prepared activated carbons. In presence of chloride ion the adsorption capacity has not significantly influenced for each adsorbent, but in presence of sulphate ion, little increase in adsorption capacity was observed in both BMR and RMB dye cases.

Adsorption equilibrium isotherms *viz.*, Freundlich, Langmuir, Temkin and Dubinin- Radushkevich are applied and on the basis of correlation co-efficients and chi-square analysis, it is observed that Langmuir isotherm best fitted followed by Temkin and Dubinin–Radushkevich isotherms for adsorption of both BMR and RMB dyes onto NCDC, NCMC and NCAC. This suggests that dye adsorption is limited with monolayer coverage and the surface is relatively homogeneous in terms of active sites.

Out of five applied kinetic models applied, *viz.*, pseudo first-order, pseudo second-order, Weber and Morris intraparticle diffusion model, Bangham’s pore diffusion model and Elovich equations and by the assessment of SSE values of these models, it is identified that the adsorption process is following pseudo-second-order rate. The good fitting of kinetic data to pore diffusion and Elovich equations indicate that pore diffusion plays a vital role in controlling the rate of the reaction.
The adsorption process is temperature dependent and it is observed that percent removal increased with increase on temperature. The endothermic nature of adsorption is indicated by the positive value of $\Delta H^0$ and the spontaneous nature of sorption process is identified by the negative values of $\Delta G^0$. The entropy value $\Delta S^0$ is positive for all the three sorbents i.e., the sorption process is possibly irreversible and stable. The amine groups present on the adsorbent surface are believed to be the binding sites for both the dyes.

Textile effluents are collected from Sri Sai Ram textile industry in Mangalagiri, Guntur district, Andhra Pradesh, India. The effluent samples are colored. COD and BOD are high. The suitability of the prepared activated carbons for the removal of color from textile mill effluent was examined. Textile effluents are treated with NCDC, NCMC and NCAC separately for a contact time of 60 min. It is observed that besides removal of color, there is concurrent reduction of COD, BOD and pH of the effluents. The effluent was treated until the acceptable limit of 7, 5 and 3 m$^{-1}$ absorbance reached at the standard wavelengths of 436, 525 and 620 nm respectively.

The suggested carbons are effective in decolorizing effluents. Since these carbons are prepared from bio-waste materials and the method of treatment of textile effluent is simple, they can be implemented in industries to save the environment from pollution.