Chapter 7

Conclusions and Recommendations

7.1 Conclusions

The main conclusions of present investigations are

1. The agro-residues need to be characterized before proposing to use them for energy carriers through the process of pyrolysis/gasification/combustion. Those agro-residues having a high percentage of V.M., less percentage of ash are appreciably good for their use in gasifiers and combustors for energy generation. In this study, all agro-residues/biomass have an almost same quality of volatiles.

2. Low ash percentages are desired for any thermochemical operations. Accordingly, babool (acacia nilotica) branches, berry branches, corn cob and cotton stalk are the most desirable ones. It has been confirmed that all biomass are having comparable GCV. This concludes the fact that all of them are good as fuel. Coconut coir and corn cob are least desired agro-residues to be considered for combustion and gasification purposes due to their ash fusion temperature less than even 1200°C.

3. A high percentage of fixed carbon (F.C.) is preferred for charring operation through Pyrolysis. Agro-residues having the high percentage of F.C. i.e., babool (acacia nilotica) branches, cotton stalk, groundnut shell and rice-husk can be utilized for conversion to char and can be further treated thermally and chemically to get activated carbon for the study of sorption of phenol.
4. The activated PBAN is a quite good adsorbent for adsorption of phenol compared to PBAN. Langmuir isotherm fitted quite well the experimental data for activated PBAN for the entire concentration range of phenol under study. This confirmed that activated PBAN had monolayer adsorption of phenol. The value of $R_L$ was between 0 and 1 indicating favorable adsorption of phenol towards activated PBAN. All adsorption isotherms confirmed that phenol had a very good affinity towards activated PBAN.

5. For activated PBAN, kinetics of adsorption was best explained by pseudo-first-order-kinetics. Hence by activating the powder of acacia nilotica branches thermally by treating at 500 °C for 3 hrs in addition to treatment with H$_3$PO$_4$ at 35° C for 4 hours the char proves to be quite an appropriate adsorbent for removal of toxic phenol from effluents and water bodies.

6. When PBAN was thermally treated at 600°C for 3hrs in addition to its chemical treatment with H$_3$PO$_4$ for 4hrs, the char resulted in CANBI which is quite an improved adsorbent compared to activated PBAN. The physical and chemical characteristics of this char are comparable to a good commercial adsorbent.

7. SEM analysis of CANBI confirmed the highest BET surface area of 403m$^2$/g. This fact has also been verified by its high adsorption capacity of 250mg/g of CANBI which is higher compared to other adsorbents, PBAN and activated PBAN.

8. FT-IR analysis of CANBI shows the presence of hydroxyl group along with an indication of adsorption of phenol. Phenol adsorption on CANBI was via "donor-acceptor complex mechanism" in which oxygen atom of carbonyl group acted as the electron donor and the aromatic ring of phenol molecule as the electron acceptor.
9. Adsorption study on CANBI indicates that Freundlich isotherm fitted quite well the experimental data for the almost entire concentration range of phenol under study.

10. Effect of time on adsorption of phenol on CANBI was better explained by pseudo-second-order kinetics.

11. Thermodynamic study on adsorption of phenol on CANBI indicated that the process was feasible and endothermic in nature.

### 7.2 Recommendations for Further Study

1. Other characterized biomass as indicated in Table 4.1, having very high F.C. like berry branches which is abundantly available in SLIET, is recommended for the study of adsorption of phenol from aqueous solutions.

2. Closed loop engineering is proposed to be applied on the application of activated PBAN and CANBI for sorption of phenol from aqueous solutions.

3. Process optimization will be attempted for large scale production of activated PBAN and CANBI.

4. Various scenarios for cost effective adsorption of phenol out of aqueous solutions will be studied.