CHAPTER - V

CONCLUSION

Utilization of the conventional methods for the removal of dye from their respective wastewater are not appropriate to the Indian context due to their practical difficulties and high cost. Adsorption of pollutants (especially pollutants dissolved in waster) using activated carbons have been extremely successful as a promising solution. The great advantages of the adsorption using activated materials are due to their high surface area and excellent adsorption capacity. In addition to the above said advantages, the usage of biologically derived materials as a precursor for the preparation of ACs is eco-friendly and renewable one. Compared to granular or powdered activated carbons, nano sized fullerene like carbons have higher surface area, excellent adsorption–desorption kinetics and lower resistance to bulk flows.

Textile processing industry in India is facing a threat of closure owing to the high initial and operating costs for the installation of proper effluent treatment systems. Though adsorption using activated charcoal is a good technology in terms of efficiency, but they are exorbitantly costlier. Therefore, textile dyestuff from the processing industry (especially dyeing industry) lets their wastewater into the fresh waterways. With an environmental point of view and also economical point of view, it is proposed to help the processing industry with a new technology or method of effluent processing is highly warranted.

Exploration of materials in the nano scale has great advantages like high surface area, uniform properties, excellent process ability etc. Carbon in nano scale has some exciting morphologies like nanotubes, nano spheres like fullerenes, single layered nano sheets and so on. Synthesis of nano sized carbon materials using biologically renewable precursor or environmentally unimportant materials will certainly be beneficial for the environment as well as the society. The usage of nano carbon materials for the adsorptive removal of pollutants has some limitations like floating on the surface of water and easy leaching with water owing to their small size and low density. In-order to overcome these sort of difficulties, the carbon is immobilized with some magnetically active nano materials like Fe, Ni oxides, which will certainly enhance the recovery of the spent carbon.

The conclusions of the present investigations are:

- ✓ Nano Sized Carbon Balls (NCB) with a uniform size of 40 to 80 nm are successfully synthesized from *Madhuca longifolia* oil as a precursor oil.
- ✓ The multi-metal catalyst derived from *Alternanthera sessilis* stem ash helps the formation of strings of carbon balls.
- ✓ The SEM images of pure carbon indicated that the nano carbon balls with extremely uniform size of 40 to 80 nm were formed.
- ✓ There is a uniform distribution of Fe_3O_4 on the surface of carbon without much agglomeration.
- ✓ The lower bulk density values indicated that, the synthesized carbon balls are very small in size with some hollowness inside the balls.

- ✓ The XRD pattern of NCB and its composite has a broad pattern at 25°, which is generated due to the reflections of (002) graphitic plane, this is a typical pattern of amorphous structure with a d_{002} of 0.036 nm.
- ✓ The immobilization of Fe_3O_4 on the graphitic layer does not show much influence of d_{200} spacing as indicated by the position of XRD peak at 25.0°.
- ✓ The formation of NCB is also analysed and bubble growth mechanism is proposed.
- ✓ The magnetically immobilized NCB has great potential for the removal of Methylene blue, Acid Green 25 and Direct Red 81 dyes under batch and column mode of adsorption.
- ✓ The maximum removal of MeB by Fe_3O_4@NCB achieved at a pH of 8.0 was 96.5% for an initial MeB concentration of 50 mg/L.
- ✓ Maximum desorption of MeB was achieved at a pH of 2.0, at lower pH, the cationic dyes are easily removed by the competitive protons.
- ✓ The amount of MeB removed at equilibrium increased from 25.0 to 89.74 mg/L on increasing the concentration from 25 to 100 mg/L.
- ✓ The MeB uptake by Fe_3O_4@NCB composite was decreased from 48.78 to 45.12 mg/g on increasing the temperature from 30 to 45°C.
- ✓ The regression coefficient of pseudo-second order is quite lower than that of pseudo-first order depicts that the adsorption follows pseudo-

first order during the beginning of adsorption and in the later stages, it follows pseudo-second order kinetics.

- ✓ The Intra-particle diffusion studies prove that the micropores along with mesopore play a major role in the adsorption during the adsorption of MeB onto Fe_3O_4@NCB.
- ✓ The monolayer adsorption capacity of MeB calculated using Langmuir model increases from 192.31 to 277.78 mg/g on increasing the temperature from 30 to 45° C.
- ✓ Freundlich model is more appropriate to express the adsorption of MeB with high correlation co-efficient than Langmuir model.
- ✓ On increasing the initial MeB concentration from 25 to 75 mg/L, the MeB uptake increased from 65.61 to 118.78 mg/g under column mode adsorption studies.
- ✓ Yoon-Nelson model though the r^2 is good but the calculated adsorption capacity show large deviation when compared with the Thomas model for the column adsorption of MeB.
- ✓ The percentage of AG25 removed at a pH of 2.0 is 90.4%, when the solution pH exceeds 7.0, there is a drastic decrease in the adsorption and finally at a pH of 12.0, the adsorptive removal of AG25 decreased to 38.8%.
- ✓ The AG25 adsorption by Fe_3O_4@NCB increased from 24.22 to 81.77mg/g on increasing the initial AG25 concentration from 25 to 100

mg/L and it decreased from 46.17 to 43.33 mg/g on increasing the system temperature from 30 to 45°C.

- ✓ The pseudo -first order expression hold good during the initial stages of adsorption of AG25 and in the latter stages, it follows pseudo-second order.

- ✓ The adsorption data of AG25 fitted reasonable well for the Elovich model, indicated that chemisorption also plays a significant role and the surface also energetically heterogeneous.

- ✓ The adsorption of AG25 follows both film diffusion (due to surface functionalities) and pore diffusion (due to the porosity of carbon) are operating simultaneously.

- ✓ The correlation co-efficient (r^2) for the Freundlich model is little higher than Langmuir model, substantiated that surface heterogeneity of Fe_3O_4@NCB composite adsorbent and Freundlich model is more appropriate to describe the adsorption of AG25 with high r^2 value.

- ✓ On increasing the AG25 concentration from 25 to 75 mg/L, the breakthrough volume decreased from 2450 to 1600 mL and AG25 dye removed per gram of the adsorbent increased from 55.43 to 108.60 mg/g on increasing the initial concentration from 25 to 75 mg/L.

- ✓ Thomas model though has low r^2 but the standard deviation of the adsorption capacity of AG25 with that of experimental value is less. On contrary, Yoon-Nelson model though the r^2 is good but the calculated adsorption capacity show large deviation when compared with the Thomas model.

- ✓ The adsorptive removal of DR81 initially increases from 77.8 to 84.84% on increasing the pH from 2.0 to 6.0, when the pH exceeds 7.0 the adsorption of DR81 start to decrease and it becomes 41.7% at a pH of 12.0.
- ✓ On increasing the initial dye concentration from 25 to 100 mg/L, the quantity of DR81 adsorption increases linearly from 25.00 to 92.80 mg/g.
- ✓ The decrease of adsorption of DR81 at high temperature indicates that, the adsorption accompanied by heat release (exothermic).
- ✓ Therefore, this adsorption system consists of DR81 and Fe_3O_4@NCB was not a first-order reaction at all initial concentrations and temperature ranges studied.
- ✓ The pore diffusion plays a significant role for the adsorption DR81 onto Fe_3O_4@NCB.
- ✓ The Freundlich equation predicts that the DR81 concentration on the Fe_3O_4@NCB surface will increase so long as there is an increase in the DR81 concentration in the liquid side.
- ✓ The Fe_3O_4@NCB column reached a saturation at 2300, 1800 and 91500 mL of throughput volume for an initial DR81 concentration of 25, 50 and 75 mg/L respectively.

- ✓ Among the two mathematical models tested for the adsorption of DR81 onto Fe_3O_4@NCB column, the YN model provided an excellent fitness with low standard deviation of $1.11 < sd < 4.24$.

- ✓ The treatment of the effluent samples indicated that there is a good amount of dissolved solids were removed from the effluent samples as indicated from the TDS values.

- ✓ While analyzing the cost, adsorption using Fe_3O_4@NCB is more economical than commercial charcoal for the treatment of $100M^3$ of effluent and the dye removal using Fe_3O_4@NCB is the cheap on comparison with commercial charcoal.

RECOMMENDATIONS FOR THE FURTHER STUDY

1. The efficiency of the prepared nano carbon adsorbent in the removal of other pollutants like heavy metals, phenols and other toxic metals can be studied.

2. Large scale treatment of the dye house effluent can be tried in batch and column mode.

3. The treatment of mixed effluent (the effluent sent to common treatment plant) can be tested in batch and column mode.

4. The prepared nano carbon balls can be doped with photocatalysts and photocatalytic decomposition of dyes can also be tried in large scale operations as well as it can be tried for various other categories of dye molecules.