STUDY ON PYROLYSIS OF SAGWAN (*TECTONA GRANDIS*) SAWDUST AND USE OF BIOCHAR FOR AQUEOUS Cr(VI) REMOVAL

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by

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CHAPTER 7

Summary and Future recommendations

On the basis of work carried out, results obtained and discussion presented in the previous chapters, the following conclusions can be drawn:

- High VM, higher HHV, low AC and MC affirm SS is suitable for biofuel and chemical production through pyrolysis.
- TGA results revealed the maximum devolatilization took place in the temperature range from 210 to 480 ˚C and increased heating rate shifted the DTG peak to higher temperature, showing decrease in the heat transfer efficiency at higher heating rate.
- The Change in the E with increasing conversion indicated multistep kinetics of SS degradation and the average E as calculated from FWO, KAS and Friedman models were 143.55, 145.78 and 142.78 kJ/mol, respectively.
- The lower A and E suggested easier degradation of SS towards bioenergy generation. Thus these results will be helpful in the design and development of thermochemical processes for the utilization of waste SS to energy source.
- Bio-oil yield increased upto 600 ˚C and then decreased; biochar yield decreased continuously whereas pyrolytic gas yield increased continuously with increase in

temperature. The maximum bio-oil yield of 48.80 wt. % was obtained at temperature 600 °C, nitrogen flow rate 150 mL/min, packed bed height 8 cm and particle size range 0.18-0.25 mm.

- Pyrolysis process was further spastically optimized using RSM through BBD to maximize bio-oil and minimize biochar yield. The Optimized condition for the process was temperature 640 °C, nitrogen flow rate 180 mL/min and packed bed height 8 cm. Bio-oil and biochar yield at optimized condition were 48.71 and 25.56 wt. %, respectively.
- Physicochemical characteristics of bio-oil suggested its utility as synthetic fuel after up gradation or as source of valuable chemicals. FTIR and GC-MS analysis marked the presence of aliphatic, aromatic and oxygenated hydrocarbon in the bio-oil.
- Proximate and ultimate analyses exhibited increased carbon content in the biochar showing its use as electrode or catalyst. The HHV of the biochar increased with increase in pyrolysis temperature and obtained values were in the range of Indian coal.
- SEM analysis described the porous nature of biochar and EDS analysis marked the presence of valuable inorganic elements in it.
- BET analysis showed pores were mesoporous and maximum surface area for the biochar was 281.8140 m^2 g^{-1}, obtained at 640 °C. High BET surface area suggested its application as adsorbent in waste stream purification.
- Pyrolytic gas had appreciable amount of H_2, CH_4, CO and CO_2 that could provide good combustion properties.
- The biochar obtained at optimized condition was used for the treatment of Cr(VI) from aqueous solution in batch mode.

- Adsorption equilibrium time was achieved within a short period of 60 min and maximum Cr(VI) removal was found to be 98.37 % at adsorbent dose of 5 g/L, pH 2 and temperature 30 °C.
- The pH_{zpc} for the biochar was 8.4. FTIR study showed functional groups like C-H, O-H, C-O, C=O, etc. were involved in the adsorption process and XPS analysis affirmed the reduction of Cr (VI) to Cr (III).
- The adsorption process followed second order kinetics and Langmuir isotherm fitted well with the experimental data. The maximum adsorption capacity of 9.62 mg/g was achieved at 30 °C.
- Thermodynamic parameters indicated the spontaneous and exothermic nature of Cr(VI) adsorption onto SS biochar. Film-diffusion was found to be the rate-limiting step for Cr(VI) adsorption from bulk of the liquid to the surface of the adsorbent.
- The adsorption mechanism for Cr(VI) onto SS biochar was proposed using the results from FTIR, XPS and SEM-EDS analyses. Adsorption occurred via electrostatic and physical attraction, reduction and complexation.

Recommendations for Further Study

- The co-pyrolysis of SS with other biomass can be performed which may provide better yield and quality of bio-oil.
- The pyrolysis of SS can be performed in different modes of reactor using different catalysts.
- The complete pyrolysis experiments were performed at laboratory scale reactor; it should also be evaluated in a reactor at industrial level for commercialization.
- Study on enrichment of pyrolysis products can also be done.
- Finally, the SS biochar can also be used for the treatment of wastewater containing other heavy metals or dyes.

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