PREFACE

Due to the fast-growing population, technological development and advancement in the living standard of the people, the requirement for energy as well as the price of fossil-derived fuels like petrol and diesel are increasing. The global energy demand has increased from 49 in 2015 to 328 Million Tonnes of Oil Equivalent in 2018. Fossil fuels are predominantly used to fulfil these skyrocketing global energy demands. But major concerns associated with these fossils are that these are neither sustainable nor cleaner energy source. Uses of these fossil fuels release enormous amount of pollutants such as NO_X, SO_X, particulates and CO_2. In light of this, there is a need to develop an alternative renewable energy source for partial fulfilment of required energy demand. Among the available renewable sources of energy, incidentally, biomass has gathered significant attention due to its plentiful amount, low market value, and carbon neutrality.

So, the research objective was decided to perform the pyrolysis of sagwan sawdust for bio-energy generation. The complete research work is summarized in different chapters.

Chapter 1 explains current energy scenario, energy related environmental issues, biomass as a solid waste and also as a source of energy. At present, around 90 % of the energy consumption in developing countries is fulfilled by fossil fuels (coal, petroleum and natural gas). The technological developments, on the other hand, are responsible for depleting the limited fossil fuel reserves along with the release of toxic effluents. The growing demand for energy and environmental concerns have shifted the alertness of researchers to find out a substitute renewable, sustainable, environmental friendly and cleaner energy source for the coming generation. Sagwan wood is used by different industries, especially paper and furniture industries, as it is light wood and has high durability. According to the Food and Agricultural Organisation of the United States

(FAO), after processing only around 28 % of the tree becomes timber and rest is residue. These residues are disposed of to the open atmosphere with no economical value. Every year huge amount of sagwan sawdust is produced and so for its proper utilization, pyrolysis can be performed. This chapter also explains the origin of the problem and objectives of the research work.

Chapter 2 summarizes the literature review associated with the research work. The study includes the selection criteria and feasibility analysis of biomass for pyrolysis as well as the concerned reaction mechanism involved with the pyrolysis process available in literature. The chapter also explains the kinetic and thermodynamic parameters involved in the pyrolysis process. The effect of pyrolysis process parameters on product yield and characteristics were reviewed. Finally, review was done for the utilization of biochar for Cr (VI) removal.

Chapter 3 explains the kinetic and thermodymic studies of sagwan sawdust pyrolysis for its bio-energy potential. TGA of sagwan sawdust was performed at the heating rates of 5, 10 and 20 ˚C/min to study its degradation behaviour. Utilizing the TG and DTG data, kinetic and thermodymic parameters were evaluated using iso-conversional models. The reaction mechanism for the degradation was studied using Z-master plot.

Chapter 4 describes the pyrolysis of sagwan sawdust for the product yield and characterization. The effect of process variables i.e. temperature, fixed bed height, sweeping gas flow rate and particle size on product yield were investigated. Temperature had the most significant role in the pyrolysis process. Characteristics of biochar, bio-oil and pyrolytic gas were studied using different characterization techniques. The pyrolysis of sagwan sawdust is effective in waste treatment, waste minimization as well as in energy generation.

Chapter 5 describes the product distribution and optimization of pyrolysis process variables for maximum bio-oil and minimum biochar yield. The optimization study was performed employing response surface methodology through box-behnken design. The study reports the interaction effect among the process variables for the product yield. The products obtained were also characterized using various characterization techniques.

Chapter 6 describes the utilization of obtained biochar after SS pyrolysis as an adsorbent for Cr (VI) removal from aqueous solution. The study was performed in batch mode varying different parameters i.e. solution pH, initial Cr(VI) concentration, adsorbent dose/Cr(VI) concentration, time and temperature. Further optimization of the process parameters were also done employing response surface methodology through box-behnken design. The kinetics, isotherms, thermodynamics and mass transfer involved in the adsorption process had also been described. The possible reaction mechanism for the adsorption process had also been explained. The regeneration and reusability of the adsorbent had been done in the study.

Chapter 7 describes the summary and future recommendations drawn on the basis of results obtained out of this research work. The results describe sagwan sawdust has the potential to be used as precursor for pyrolysis. In addition, it also helps in waste minimization and waste utilization. Biochar as adsorbent is also in adsorbing Cr(VI) from aqueous solution. In addition, there are certain recommendations that will help in future research work.

CHAPTER 1

Introduction

1.1 Energy scenario

Energy availability is directly or indirectly related to the growth, economical development and social prosperity of the nation. According to the statistics provided by the United Nations, the population of the world was 7.2 billion in the year 2013 and it is expected to increase by 33% in the year 2050 (Tripathi et al., 2016). With such high rate of increase in the population, demand in every aspect (food, shelter, energy, etc.) is becoming higher continuously. Energy plays a very crucial role in every sector such as transportation, agriculture, industry, power generation and many others. The global consumption of fuel has increased from 84319.17 Twh in 1980 to 161471.36 Twh in 2018 as shown in Fig. 1.1 and at the same time the change in energy demand has also increased from 49 Mtoe in 2015 to 328 Mtoe in 2018 as shown in Fig. 1.2.