Abstract

Title: Development of waste to biochar pyrolysis unit and study of the use of the biochar for reclamation of mine-soil

Continuous exploitation of coal mine generates a huge volume of rock materials, laden with mineral, salts, and heavy metals, are known as 'mine spoils', which are dumped in the form of overburden dumps. Poor physicochemical properties and eminent level of heavy metals in the mine-soil/spoil pose a threat to the environment and human health. Such risks can be reduced by reclamation of the mine soil; however, the vegetation growth over such mine-soil is very limited due to having poor physicochemical properties of the soil. Use of various soil ameliorant for the reclamation of such contaminated and degraded soils has been mooted in the earlier studies. Among them, biochar is of particular importance due to having beneficial soil properties, functionality, low cost, and easy availability.

The objectives of this research work were to develop a slow pyrolysis unit to produce biochar from the biomass waste (Rice straw and *Eucalyptus* wood), evaluating the effect of pyrolysis conditions on the biochar properties, and to study the effect of biochar in the reclamation of the mine-soil collected from the coal mine overburden dump. The first two chapters of the thesis include the introduction and literature review on the subject and rest of the work divided into four chapters that would explain the work carried out.

In this research work, the author has indigenously designed and developed a slow pyrolysis facility and utilized it for the production of biochar from rice straw and *Eucalyptus wood* waste. The author has evaluated the thermal efficiency and indoor air quality of the developed slow pyrolysis unit. The economic analysis of the biochar production using slow pyrolysis unit was also evaluated. Moreover, the effect of pyrolysis temperate and heating duration the properties of rice straw and *Eucalyptus wood*-derived biochar was studied and optimized for its application in mine-soil. Besides, the author has also developed a potassium-iron rice straw biochar composite using a modified chemical method and evaluated its effectiveness in the sorption of the applied nutrients in the soil. Finally, the author has evaluated the effectiveness of the *Eucalyptus wood* biochar produced at two different temperatures (400 and 600 ºC), as well as the biochar-fertilizer mixture in the reclamation of the mine soil collected from the Bera coal mining area, Dhanbad,

Jharkhand, India using the two developed index viz. soil fertility index and mine soil quality index.

The results in chapter 3 demonstrated that the slow pyrolysis unit showed an overall thermal efficiency of 40 % for biochar production. Further, the indoor air quality index developed for the pyrolysis unit indicated that working around the unit would be harmful to the person having the respiratory disease. The economic analysis of the biochar production showed that the unit price of the biochar came around 460.76 USD per ton, which is very less compared to the reported production price of the biochar. The results in chapter 4 indicated that the properties of biochar primarily controlled by the temperature and heating duration of the pyrolysis. The optimized pyrolysis conditions for the rice straw biochar and *Eucalyptus wood* biochar for application in the soil were 500 ºC for 80 min and 468 ºC for 180 min, respectively. The results of chapter 5 showed that the potassium-iron biochar composite had a large surface area, carbon content, and oxygen-containing functional groups compared to the pristine rice straw biochar. The sorption capacity of potassium-iron biochar composite for NO_3^-, PO_4^{3-}, and NH_4^+ was higher compared to the pristine rice straw biochar. Moreover, the amendment of potassium-iron biochar composite in soil column test significantly ($p < 0.05$) reduced the leaching of the nutrients through the column compared to the pristine biochar and increased the soil fertility index. The results of chapter 5 showed that the application of both biochar and biochar-fertilizer mixture significantly ($p < 0.05$) improved the physicochemical properties of the mine soil, and simultaneously reduced the metal toxicity through metal adsorption in the biochar-soil matrix. Biochar and biochar-fertilizer mixture application in the soil also significantly ($p < 0.05$) improved the soil fertility index and mine-soil quality index as compared to the controlled study (only mine soil), indicating that biochar could be an effective soil ameliorant for the reclamation of the mine soils.

Keywords: soil fertility index, mine soil quality index, pyrolysis, mine soil, and adsorption