ABSTRACT

Title: Engineered production of Single-Use Plastic – Eucalyptus Biomass char composites and their application in mine waste dump remediation and olericulture

Single-use plastics (SUP) have been one of the chief contributors to the global plastic waste problem due to their low product life span and technoeconomic complexities in their recycling. The inherent advantages of co-pyrolysis in recovering value added by-products from plastic waste makes it's an economically environmentally viable process. In the current research, the prospects of the char composite recovered from the co-pyrolysis of Eucalyptus biomass (EuBm) and single-use plastics (Polystyrene (PS), Low density polyethylene (LDPE)) as a soil amender in mine soil reclamation and as a co-supplement in olericulture are explored. It was observed that the inhibitory effect of liquefied plastic coating has resulted in the formation of an energy dense char composites suitable for fuel applications. However, at temperatures above the degradation of plastics the synergistic effect between the feeds during co-pyrolysis has resulted in the formation of a dense, carbonaceous, and ash-rich char composite suitable for application in soil amendment. The physicochemical characteristics of SUP-EuBm char composites depicting for its best properties as soil amender like plant extractable nutrient concentrations, electric conductivity, cation exchange capacity, were observed to be highest at temperatures around 400 °C (PS), 500 °C (LDPE). Apart from temperature, the influence of other process parameters (residence time, and proportion of feed) also had significant influence on the char's characteristics. The optimized process parameters of 415 °C – 125 minutes - 0.325 (w/w) (PS), 510 °C – 119 minutes - 0.32 (w/w) (LDPE) were determined through multiple regression modelling. The life cycle assessment of the production of chars revealed combustion unit to have most prominent of environmental hazards, which could be attributed to the flue gas emissions. Moreover, in comparison to biochar produced from biomass pyrolysis, char composites had higher environmental impacts due to their relatively lower product yields and higher pyrolytic gaseous emissions, Also, the life cycle costing (LCC) depicted a negative net LCC for BC (₹ –2.26 lakh) as compared to the positive net LCCs (BP: ₹ 5.3 lakh; BL: ₹ 5.45 lakh) of char composites. With a potential technological shift like replacing combustion with electricity and recovery of liquid and gaseous by-products from the process, the economic and environmental sustainability of the process could be improved. The improved plant growth, plant productivity, and fruit quality in bell pepper and tomato species with the co-application of chars and organic fertilizers depicts the positive implications of char composites application for olericulture. This could be attributed to the improved nutrient retentivity against leaching and nutrient use efficiency as observed with the leaching column experiment. The highest improvements of 84 -112 % in plant productivities as compared to application of organic fertilizer alone and 198 – 238 % as compared to the non- supplemented soil were observed with the integrated application of manure and single-use char composites (10 t/ha^{-1}). On the other hand, application of char composites in mine soil reclamation in addition to phytoremediation was found to substantially improved the immobilization of toxic heavy metals in the soil. The pot culture and field studies determining the effects of char application rate, type of chars, and the addition of top soil to remediate contaminated mine dump soil revealed an improved soil fertility index (270 – 495 %.) with addition of chars and improved remediation with top soil addition and rate of application of char. Along with the increase in total heavy metal contents in the soil with char application rate, there was significant reductions in the metal concentrations in plant root and shoots. These are representative of the higher immobilization of these metals and reduced bioavailability and phytoavailability in the soil. So, the recovery of char composites from co-pyrolysis and its application in the fields of mine soil reclamation and olericulture could be sustainable techniques of plastic waste management, while solving the challenges associated with sustainable agriculture and surface mining.

Keywords: Co-pyrolysis, Char composite, Mine soil reclamation, Sustainable agriculture, and Life cycle assessment