Agronomic and Environmental Remedial Benefits of Biochar: Current Challenges, and Future Perspectives

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Abstract: A significant interest in biochar applications has opened many multidisciplinary research areas in science. Extensive research has been carried outon the potential of biochar for its agronomic uses such as soil fertility improvement and carbon sequestration because ofbiocharmineralogical composition and long-term stability in the soil. Also, the application of biochar for environmental remediation is recognized recently as a promising area of research due toits unique physiochemical characteristics, redox potential, and adsorption reactions.

Research on biochar started due to various sources such as (a) research on Amazonian terra preta soils from the twentieth century (the pioneering work of Sombroek), (b) significant efforts during the 1970sand 1980s on research related to charcoal applications on plant and soil (c) research on the characteristics of naturally occurring charcoal and black carbon and (d) research development on biomass pyrolysis and gasification.The conversion of biomass to biochar on one side manage waste pollution load along with the additional benefit to the environment such as climate change mitigation. Furthermore, biocharhas been widely usedin soil amendment, carbon sequestration, and pollutants remediation. However, through carbon sequestration, the soil application of biochar has been recommendedas the best way for climate change mitigation. The atmospheric emissions of carbon dioxide (CO_2) are highly affected due to the long-term biochar stability in soil. Recent research studies on soil application also declared that biochar affected both abiotic and biotic processes and reduced the emissions of methane (CH_4) and nitrous oxide (N_2O).

Biochar can be producedthrough pyrolysis that is a process of biomass decomposition at a temperature range from 150 to 900 °C in an oxygen deficient condition. Depending on the temperature and residence time, pyrolysis is categorizedintoa slow, intermediate and fast pyrolysis.Pyrolysis of biomass has the dual benefit of managing waste along with the production of carbonaceous material that has a wide range of soil and environmental application. In addition to carbon sequestration, soil application of biochar affect both abiotic and biotic process reduce the emissions of CH_4 and N_2O. Similarly, through biotic and abiotic pathways biochar can also transfer, donate or accept an electron to the surrounding environments through its redox potential. However, there are still exists a gap in understanding the critical parameters for the production and application that affect its agronomic and environmental application. Hence, significant work is required to produce biochar with a specific activity and long-term stability for its agronomic and environmentalapplication.

The published reviews on biochar applicationsprimarilyexplain only the agronomic and environmental applications with little information on various mechanisms involved in the biochar applications. This review aimed to examine the influence of biochar synthesis controlling parameters such as pyrolysis temperature, residence time and types of feedstock on the characteristics of biochar with the mechanisms explaining the potential of biochar for the environmental and agronomic applications. Furthermore, thisreview highlighted the challenges in biochar production and its field applications for agronomic and environmental remediation. Severalfuture research recommendations were givenon the production of biochar with high redox functional groups and sorption potential along with understanding the behavior of biochar under natural field conditions.

Keywords: Biochar; Resource recovery; Soil fertility, Environmental remediation