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Biochar application strategies for polycyclic aromatic hydrocarbons removal from soils

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are known as a hazardous group of pollutants in the soil which causes many challenges to the environment. In this study, the potential of biochar (BC), as a carbonaceous material, is evaluated for the immobilization of PAHs in soils. For this purpose, various bonding mechanisms of BC and PAHs, and the strength of bonds are firstly described. Also, the effect of impressive criteria including BC physicochemical properties (such as surface area, porosity, particle size, polarity, aromaticity, functional group, etc., which are mostly the function of pyrolysis temperature), number of rings in PAHs, incubation time, and soil properties, on the extent and rate of PAHs immobilization by BC are explained. Then, the utilization of BC in collaboration with biological tools which simplifies further dissipation of PAHs in the soil is described considering detailed interactions among BC, microbes, and plants in the soil matrix. The co-effect of BC and biological remediation has been authenticated by previous studies. Moreover, recent technologies and challenges related to the application of BC in soil remediation are explained. The implementation of a combined BC-biological remediation method would provide excellent prospects for PAHs-contaminated soils.

1. Introduction

1.1. Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs), as nonpolar and hydrophobic organics (Zama et al., 2018), could be originated from anthropogenic activities such as incomplete combustion or pyrolysis of organic materials (Ma et al., 2015), coal processing, coke oven plants, created gas plants, and coal tar pouring regions (Viglianti et al., 2006). PAHs are generally classified into two categories based on the number of benzene rings; 1) low molecular weight (2-3-4 ringed) compounds (LMW-PAHs), and 2) high molecular weight (5–6 ringed) compounds (HMW-PAHs) (Li et al., 2020b), and typically considered as soil contaminants when their concentration is over 0.2 mg/kg (Maliszewska-Kordybach et al., 2009). PAHs can be hazardous and toxic pollutants in the soil environment (Li et al., 2014) owing to their ecotoxic, carcinogenic, and mutagenic impacts (Chai et al., 2012; Li et al., 2019). Only freely dissolved PAHs (C_{free}) and bioaccessible concentration (C_{bioacc}) of PAHs, not the total content of PAHs, are responsible for their toxic effects in soils (Kołtowski et al., 2017b). The bioavailable and bioaccessible PAHs in soils could conveniently be assimilated via plants, worms, and microbes based on their lipophilic features (Ogbonnaya et al., 2014a), thereby readily entering into food chains and causing drastic jeopardies to biota (Kong et al., 2018) and human health (Zhang et al., 2018c). Schematic structures of some typical types of PAHs in soil are shown in Fig. 1.

Several physicochemical techniques for PAHs-contaminated soils, such as solvent extraction (soil washing), electrokinetic remediation, photocatalytic oxidation, thermal treatment, and chemical oxidation, have been propounded to eliminate PAHs from polluted soils (Oleszczuk et al., 2019). Solvent extraction, mostly using surfactant as a solvent, has been proven as an efficient technique to remove PAHs from contaminated soils, but the surfactant expense might attribute to 50% of the total

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