Chapter 2
Preparation and Application of Biochars for Organic and Microbial Control in Wastewater Treatment Regimes

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ABSTRACT

Biochars have been extensively applied in soil remediation, carbon sequestration, and in climate change mitigation. However, in recent years, there has been a significant increase in biochar research in water treatment due to their stupendous adsorptive properties for various contaminants. This is attributed to their large surface areas, pore structures, chemical compositions, and low capital costs involved making them suitable candidates for replacing activated carbons. This chapter discusses the preparation methods and properties of biochars and their removal efficacy for organic contaminants and microbial control. Factors affecting adsorption and the mechanisms of adsorption of organic pollutants on biochars are also concisely discussed. Biochars present environmentally benign and low-cost adsorbents for removal of both organic pollutants and microbial control for wastewater purification systems.

INTRODUCTION

Biochar, according to the International Biochar Initiative (IBI), is a solid material obtained by carbonization of biomass (IBI, 2013). Biochar is therefore a carbon-rich solid material derived by heating biomass, under limited or no oxygen (pyrolysis or carbonization) conditions (Sohi, 2012), with possible application

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in soil for carbon sequestration and as an adsorbent. The varied conditions of carbonization of different parent feedstock materials result in infinite brands of biochars with significantly varied properties primarily intended for agricultural use such as soil remediation and the aforementioned carbon sequestration (Lehmann, 2007; Lehmann et al., 2011). Since 2005 to the present there has been a steady increase in the number of multi-disciplinary scientific publications with the word "biochar" as a key word. This is a testament on the increased biochar research within the scientific community. However, while a large portion of the publications relate to application of biochars as soil amendments, carbon storage agents and in mitigation of climate change, a significant fraction, around one-tenth of the publications between 2005 and 2013, relate to the use of biochars as environmentally benign adsorbents for removal of contaminants from water (Tan et al., 2015). This is attributed to their high surface area, presence of numerous functional groups, porous network and their mineral components which imbues the materials with high adsorptive properties. These attributes make biochar a potentially low-cost and effective adsorbent and a suitable alternative to activated carbons which are widely applied in conventional wastewater treatment regimes worldwide. In terms of capital costs involved, activated carbons require high preparation temperatures including activation steps whereas biochars require relatively lower temperatures hence reduced energy and infrastructural requirements besides being a renewable resource (Ahmad et al., 2012; Lu et al., 2012). Agricultural biomass and other solid wastes such as manures, sawdust, waste tyres, water hyacinth etc which form the precursor materials for development of biochar can be readily obtained in abundance. Furthermore, biochar synthesis adds economic value to these otherwise waste materials and would potentially eliminate their negative environmental impacts. Hence there is a synergistic "win-win" relation between environmental management and environmental protection (Dong et al., 2013). This chapter discusses the preparation methods and properties of the resulting biochars, the adsorptive potential of biochars for organic pollutants, factors affecting adsorption processes and the adsorption mechanisms of organic pollutants onto biochars. Application of biochars for microbial control is also discussed. The chapter demonstrates that biochars present an environmentally benign technology for water and wastewater treatment.

PREPARATION METHODS AND PHYSICOCHEMICAL PROPERTIES OF BIOCHARS

Biochar, as earlier defined, is a porous material produced through thermochemical conversion of biomass in a minimally oxygenated high temperature environment (IBI, 2013). The production utilizes organic materials such as wood (Schimmelpfennig & Glaser, 2012; Liu et al., 2010), animal manure (Park et al., 2011) and agricultural waste (Demirbas, 2004). Most of these starting materials are readily available and quite often the choice of biomass will depend on the most abundant one in a given area.

Due to the diversity of these organic materials, field and laboratory studies have shown that the yielding biochars have different properties such as composition, porosity, BET surface area and total pore volume (Ozcimen and Ersoy-Mericboyu, 2010). Apart from the choice of initial feedstock biomass, the physicochemical properties of the final biochar product are also determined by preparation conditions such as heating temperature and reaction duration and activation methods applied (Onay, 2007). These properties play a vital role in determining their performance and application in the environment. The preparation methods used for biochar production include; pyrolysis, gasification and hydrothermal carbonization (HTC)