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Editorial

Biochars multifunctional role as a novel technology in the agricultural, environmental, and industrial sectors

1. Introduction

The utilization of biochar as an amendment to improve soil health and the environment has been a catalyst for the recent global enthusiasm for advancing biochar production technology and its management (Atkinson et al., 2010; Verheijen et al., 2010). This rapid rise in understanding biochar technologies is a pro-active response to the anticipated stresses of meeting future global nutrition demands while also sustaining environmental quality. Hearty research efforts using biochar are focusing on improving soil health characteristics to obtain higher crop yields. Moreover, there is increasing realization that sustainable food security will be difficult to maintain considering future climatic shifts and the impact on agronomic and environmental systems. Employment of biochar as a specialized soil amendment provides a practical approach to address these anticipated problems in the agronomic and environmental sectors (Mukherjee and Lal, 2013; Zhang and Ok, 2014).

Biochar is produced by thermal pyrolysis of organic feedstocks under a very low oxygen atmosphere (Laird, 2008) or through hydrothermal carbonization of wet organic material by high pressure and mild temperatures (Libra et al., 2011). The thermal and hydrothermal processes, respectively, results in a product referred to as biochar and hydrochar. Both of these materials are highly porous, carbon [C] rich solids that contain a myriad of organic structures as well as inorganic elements. Biochars have been characterized using ^{13}C nuclear magnetic resonance spectroscopy as having a high proportion of highly-condensed aromatic graphene-like structures (Baldock and Smernik, 2002; Novak et al., 2009; Cao et al., 2011), which are known to increase soil C sequestration because of their resistance to microbial oxidation (Glaser et al., 2002; Sigua et al., 2014). The inorganic chemical composition of the ash material is an important soil fertility characteristic since the ash is comprised of plant macro (e.g., N, Ca, K, P, etc.) as well as micro-nutrients (e.g., Cu Zn, B, etc.; Spokas et al., 2012; Ippolito et al., 2015). Besides boosting soil fertility conditions, biochar application to soils can increase their nutrient retention (Laird and Rogovska, 2015), improve water storage (Kinney et al., 2012; Novak et al., 2012), bind with pollutants (Uchimiya et al., 2010; Sun et al., 2011; Ahmad et al., 2014; Mohan et al., 2014), and mitigate greenhouse gas emissions (GHG; Cayuela et al., 2014). These reports demonstrate that biochar can have multi-functional roles in the agricultural and environmental sectors.

Meanwhile, other sectors (e.g., engineering, electronic and medical) have also conducted research to capitalize on the mechanical and electronic characteristics of biochars and char-like materials. Biochars have been investigated as a solid fuel source (Cao et al., 2007), building insulating material (Lin and Chang, 2008), and industrial sorbent (Liu et al., 2010) and as a novel carbon material (Titirici et al., 2007). Biochars have been used as a sorbent for toxins ingested by humans (Bond, 2002) and as composite material for advancing human embryonic stem cell differentiation (Chen et al., 2012).

The above narrative illustrates that biochars have a variety of applications in many sectors. To further identify and present salient examples highlighting biochars utility, two oral sessions and one poster session entitled “Biochar Soil Amendments for Environmental and Agronomic Benefits“ were held at the 20th World Congress of Soil Science in Jeju, Korea on June 8 to 13, 2014 (www.20wcss.org). In both oral sessions, 22 world experts were brought together to discuss their research results concerning biochar production and characterization, their reactions in soils, and involvement with various pollutants. Under the same scientific-umbrella, 169 poster presentations reported on the involvement of biochars in improving soil quality, sequestering GHG emissions from soils, and ameliorating contaminated soils and water. During both oral sessions, the size of the audience ranged between 250–300 participants and a very large number of visitors that engaged in vibrant discussions with poster presenters.

Based on the exuberance shown between conference attendees and biochar presenters, it was decided that a platform was needed to capture the knowledge presented and discussed during these sessions. Therefore, a special issue in *Chemosphere* was organized. The scientific themes of the special issue were selected to have a broad appeal to biochar stakeholders, industry, and academia in agriculture and the environmental sectors. Ergo, the special issue was entitled “Biochars multifunctional role as a novel technology in the agricultural, environmental, and industrial sectors”.

2. Contents of the first special issue

There were almost 40 manuscripts submitted to the editorial committee during the Winter of 2014 and into the Spring of 2015. Based on comments received from peer-reviews, the editorial committee approved the acceptance of 25 manuscripts by July 24, 2015. The editorial staff of *Chemosphere* recommended one special issue to coalesce all the accepted papers. This special issue contains 25 articles that were divided into three categorical areas and their contents are described below:

A. *Biochars compositional properties.* Characterization of the chemical and physical properties of biochar before application to soil is a fundamental primary step to investigate their

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performance as a soil amendment. Under this section, **Wang et al.**, characterized biochars pyrolyzed at different temperatures from sugarcane plant parts to demonstrate how pyrolysis conditions impact biochar characteristics and potential benefits as a soil amendment. Another characterization study by **Naser Khan et al.** reported on the chemical and physical impacts of three different biochars that were composted with chicken litter.

B. *Biochars interface with pollutants.* There were a total of nine articles grouped under this section. Two articles in this section are by **Wang et al.** that exemplifies biochars interaction with several forms of phthalates, which are common organic pollutants in soil. In their first article, biochar addition to phthalate-laced soil increased the retention of phthalates. There was also an influence of the native soil organic carbon, but they concluded that biochar can significantly decrease the potential risk of human uptake of phthalates. In the second article, a similar type of investigation was conducted in which they reported that bamboo biochar application enhanced soil sorption of the phthalate compound. They concluded that the adsorption capacity was dependent on the soil organic carbon levels and the aging characteristics of the bamboo biochar. **Kupryianchyk et al.** compared activated carbon and two different biochars for their sorption behavior of three forms of polyfluorinated compounds (PFC) and for their ability to remediate PFC contaminated soils. The activated carbon was capable of almost complete removal during laboratory sorption experiments and was effective at binding PFC in soils. In comparison, the biochar was comparatively a poor performer at binding the PFC compounds. The last two articles in this section, examined the ability of biochars to bind inorganic metals in soils. **Rinklebe et al.** reported that a biochar was capable of sequestering potential toxic elements (e.g., metals) in soil solutions under different redox conditions. Finally, **Morel et al.** examined the ability of a biochar to impact heavy metal uptake by three plant species in soils with two different pH values. They found that the biochar had an antagonist impact on plant metal uptake, but increased root proliferation especially in the alkaline soil. **Sun et al.** examined several biochar types for differences in sorption of propiconazole under three temperatues, mineral phases, and nano-porosity to ascertain binding mechanisms. They found that the sorption of propiconazole was related to the organic carbon-normalized surface area of the biochars and its aromaticity. Moreover, they reported that pore-filling in nanopores with aromatic carbon dominated this organic pollutants binding to these biochars. **Jiang et al.** examined copper and zinc adsorption by two types of biochars (hardwood and softwood) under elevated sulfate, salinity, and acidic conditions. They reported that the hardwood biochar adsorbed more copper than zinc. Adsorption of these two metals was not influenced by the elevated sulphate concentrations, and that reducing the matrix pH resulted in more copper and zinc adsorption. **Lee at al**. evaluated the impact of an activated carbon disk to bind with iodine in water samples using an advanced spectrometric method. The activated carbon disk was found to retain two iodine species in water samples and that the spectroscopic method produced good analytical results. **Park et al.** examined the competitive adsorption of several aqueous heavy metals onto biochar pyrolyzed from sesame straw. They reported that there were differences in sorption behavior among the pool of heavy metals possibility due to difference in competitiveness at the biochar surfaces.

C. *Biochars connection as a soil quality amendment.* This section was also a popular scientific theme with 14 articles grouped here. In the first article, **Ippolito et al.** reported on the ability of a hardwood biochar by itself, or co-applied with a manure to cause either a positive or negative priming effect in a calcareous soil. They reported that the hardwood biochar by itself caused a negative priming effect, but when co-applied with manure, the negative priming effect was eliminated. **Ro et al.** compared the abilities of a swine manure-based biochar and hydrochar to improve soil fertility while reducing nutrient movement in water leachate. They reported that both biochar and hydrochar were fully capable of increasing soil fertility characteristics. They also discovered the remarkable ability of the swine hydrochar to retain most of environmentally sensitive nutrients within soil matrix, not in leachates. This discovery suggested the potential use of swine hydrochar to improve both soil and ground water environments. **Smebye et al.** reported that biochar applied to an acidic soil resulted in a very large increase in dissolved organic matter (DOM) losses and also was capable of modifying the chemical composition of the DOM lost from the soil. **Xiaoyu et al.** examined the impacts of biochar applied with a balanced commercial fertilizer versus an unbalanced commercial fertilizer by itself on greenhouse gas emission and maize yields. They reported higher maize yields and a decrease in N_2O emissions in soils treated with balanced fertilizer and biochar compared to the unbalanced fertilizer treatment alone. **Stromberger et al.** conducted a study to determine if a hardwood biochar can influence the activities of extracellular enzymes. They reported that the hardwood biochar reduced the potential activity of certain soil extracellular enzymes, while other enzymes were not impacted. **Sanchita et al.** who investigated the impact of two biochars produced from poultry litter and macadamia nut on ammonia volatilization. They reported that ammonia volatilization was reduced by up to 70% after biochar addition compared to the control. **Jin et al.** conducted a micro-cosom study using biochar pyrolyzed from animal manure to determine if this material could serve as an alternate P source, but this required identification of P species and P-conversion enzymes. They reported that two P species were the dominant forms, and that the manure-based biochar had variable impacts on P-enzymatic activity. **Lim et al.** were concerned about predicting the impact of biochar additions on saturated hydraulic conductivity in four contrasting textured soils. The saturated hydraulic conductivity of the soils amend with biochars were significantly influenced by the rate and type of biochar and the soil particle size. Their results were employed in a model utilizing soil texture pedotransfer functions for predicting the biochars impact on the saturated flow as a function of soil texture. **Elzobair et al.** was concerned about the impact of biochar versus manure on soil microbial communities and certain enzyme activities in an Aridisol. They reported that, indeed, there were contrasting impacts of these two soil amendments on microbial biomass, community structure and fungi root colonization. **Kim et al.** had a very interesting reclamation study, whereby, a biochar was evaluated to reclaim tidal land with anticipation of improving soil quality for maize growth. They reported that application of rice hull biochar increased certain soil quality characteristics and that the maize crop responded with high yields in the reclaimed tidal marsh treated with the highest biochar application. **Novak et al.** evaluated different plant and manure-based biochars to determine if they could improve water infiltration through a hard-setting subsoil layer, while not degrading water quality from released soluble elements. Except for one biochar (poultry litter-based), all biochars initially improved water infiltration, but the rates declined with successive water leaching. Leachates were found to be enriched in soluble elements especially P from the poultry litter biochar. **Sigua et al.** contributed two articles concerning the ability of designer biochars to improve soil chemical properties of a hard setting subsoil layer and if the improvements were capable of increasing biomass and nutrient uptake of winter wheat. They reported that the designer biochars significantly improved the fertility of the hard setting subsoil layer and that the same engineered biochars significantly increased both above and below ground biomass and nutrient uptake of winter wheat. These are important results because the hard setting subsoil layer is a major impediment for crop growth and poor water availability for crop productivity in that region. Finally, **Zhang et al.** was concerned if a biochar under different fertilizer regimes (balance versus unbalanced NPK fertilizer) could enhance maize productivity and reduce greenhouse gas production from a nutrient-poor Inceptisol. Appling a balanced inorganic fertilizer (reduced N inputs, etc.) with the biochar was found to increase maize yields while reducing N_2O emissions relative to biochar and unbalanced fertilizer treatments. The authors concluded that applying biochar under a more-balanced fertilizer regime was a satisfactory management practice in this nutrient–poor soil.

The assortment of research articles published in this special issue reflects the multifunctional roles of biochars with respect to their utility in the agronomic and environmental sectors. It was a genuine pleasure to arrange this biochar special issue. We hope that you do enjoy this special issue published in *Chemosphere*.

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