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Review

Application of biochar for the removal of pollutants from aqueous solutions

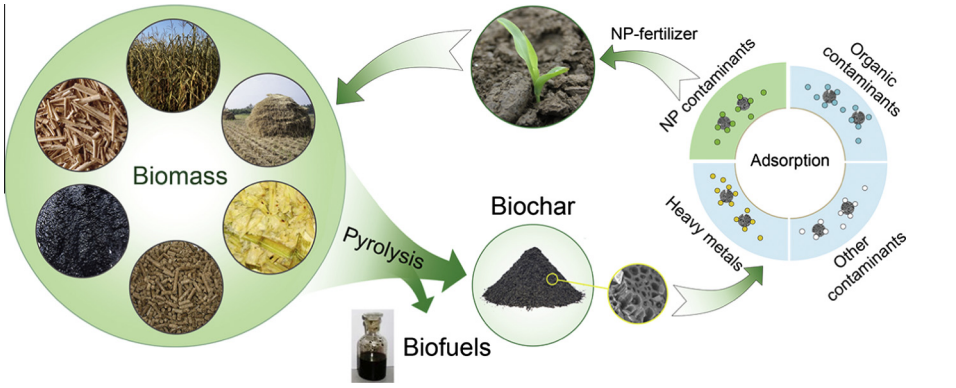
Xiaofei Tan [a,b], Yunguo Liu [a,b,*], Guangming Zeng [a,b], Xin Wang [c], Xinjiang Hu [a,b], Yanling Gu [a,b], Zhongzhu Yang [a,b]

[a] College of Environmental Science and Engineering, Hunan University, Changsha 410082, PR China
[b] Key Laboratory of Environmental Biology and Pollution Control (Hunan University), Ministry of Education, Changsha 410082, PR China
[c] College of Resources and Environmental Science, Hunan Normal University, Changsha 410082, PR China

HIGHLIGHTS

- This paper reviews recent findings on pollutants removal from water using biochar.
- Production and properties of biochar suggest that it can be a promising adsorbent.
- Biochar properties and circumambient conditions influenced the pollutants removal.
- Adsorption mechanisms depend on biochar properties and target pollutants.
- More studies are needed to close knowledge gaps before engineering application.

GRAPHICAL ABSTRACT



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ABSTRACT

In recent years, many studies have been devoted to investigate the application of biochar for pollutants removal from aqueous solutions. Biochar exhibits a great potential to efficiently tackle water contaminants considering the wide availability of feedstock, low-cost and favorable physical/chemical surface characteristics. This review provides an overview of biochar production technologies, biochar properties, and recent advances in the removal of heavy metals, organic pollutants and other inorganic pollutants using biochar. Experimental studies related to the adsorption behaviors of biochar toward various contaminants, key affecting factors and the underlying mechanisms proposed to explain the adsorption behaviors, have been comprehensively reviewed. Furthermore, research gaps and uncertainties that exist in the use of biochar as an adsorbent are identified. Further research needs for biochar and potential areas for future application of biochars are also proposed.

* Corresponding author at: College of Environmental Science and Engineering, Hunan University, Changsha 410082, PR China. Tel.: +86 731 88649208; fax: +86 731 88822829.
E-mail address: hnuliuyunguo@gmail.com (Y. Liu).

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Contents

1. Introduction

Biochar is a carbon-rich solid obtained by heating biomass, such as wood, manure with little or no oxygen (pyrolysis or "charring") (Sohi, 2012), which can be applied to soil for both agricultural gains and carbon sequestration. Biochar can slacken carbon release to the atmosphere from burning or degrading by carbon stabilization into a form resembling charcoal (carbon negative). By burying it in fields, it can store carbon in soil and improve soil properties. In addition, the bioenergy produced from pyrolysis process provides potential substitute for fossil fuels (carbon neutral) (Lehmann, 2007).

Publications which included the word "biochar" in the topic on indexed journals (according to ISI Web of Science™ from 2005 to 2013) have been growing steadily (Fig. 1), indicating a growing interest of the scientific community on biochar research. The increasing interest in biochar has inaugurated multidisciplinary areas for science researches and engineering applications. A large number of studies have highlighted the benefit of using biochar in terms of mitigating global warming, soil amendment, enhancing of crop yield and carbon storage (Whitman et al., 2011; Abit et al., 2012; Mao et al., 2012; Sohi, 2012; Khare and Goyal, 2013; Verheijen et al., 2014). Furthermore, there have also been considerable interests in using biochar to remove pollutants from aqueous solutions. The number of publications on indexed journals containing the keywords "biochar + water + adsorption" between 2005 and 2013 also increased notably, which accounts for approximately one-tenth of all "biochar" publications (Fig. 1).

The specific properties of biochar including large specific surface area, porous structure, enriched surface functional groups and mineral components make it possible to be used as proper adsorbent to remove pollutants from aqueous solutions. As an adsorbent, biochar has porous structure similar to activated carbon, which is the most commonly employed and efficient sorbent for the removal of diverse pollutants from water throughout the world (Faria et al., 2004; Nakagawa et al., 2004; Chen et al., 2007). Compared with activated carbon, biochar appears to be a new potential low-cost and effective adsorbent. The production of activated carbon needs higher temperature and additional activation process. Comparatively, production of biochar is cheaper with lower energy requirements (Cao et al., 2009; Zheng et al., 2010; Karakoyun et al., 2011; Ahmad et al., 2012; Lu et al., 2012). The feedstocks of biochar production are abundant and low-cost, which mainly obtained from agricultural biomass and solid waste (Shen et al., 2012; Yao et al., 2012; Qian and Chen, 2013; Xu et al., 2013b). In addition, converting invasive plant into biochar can improve the invasive plant management and protect the environment (Dong et al., 2013). Therefore, the conversion of biomass into biochar as a sorbent is a "win–win" solution for both improving waste management and protecting the environment (Cao et al., 2009; Zheng et al., 2010).

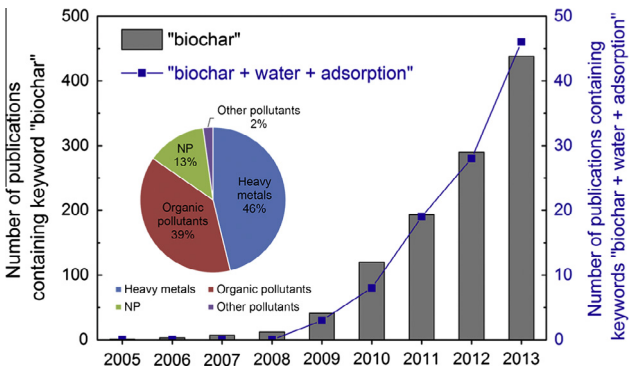

Fig. 1. Evolution of the number of publications on indexed journals containing the keywords "biochar" and "biochar + water + adsorption" between 2005 and 2013. The pie graph shows the percentage of the available scientific literatures which concerned the removal of different pollutants using biochar.