Biochar for Wastewater Treatment

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Biochar as a stable carbon-rich material shows incredible potential to handle water/wastewater contaminants. Its application is gaining increasing interest due to the availability of feedstock, the simplicity of the preparation methods, and their enhanced physico-chemical properties. The efficacy of biochar to remove organic and inorganic pollutants depends on its surface area, pore size distribution, surface functional groups, and the size of the molecules to be removed, while the physical architecture and surface properties of biochar depend on the nature of feedstock and the preparation method/conditions. For instance, pyrolysis at high temperatures generally produces hydrophobic biochars with higher surface area and micropore volume, allowing it to be more suitable for organic contaminants sorption, whereas biochars produced at low temperatures own smaller pore size, lower surface area, and higher oxygen-containing functional groups and are more suitable to remove inorganic contaminants. In the field of water/wastewater treatment, biochar can have extensive application prospects. Biochar have been widely used as an additive/support media during anaerobic digestion and as filter media for the removal of suspended matter, heavy metals and pathogens. Biochar was also tested for its efficiency as a support-based catalyst for the degradation of dyes and recalcitrant contaminants. The current review discusses on the different methods for biochar production and provides an overview of current applications of biochar in wastewater treatment.

Keywords: Biochar ; thermal conversion ; modification ; adsorption ; wastewater treatment

1. Introduction

The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants such as dyes, heavy metals, surfactants, pharmaceuticals, pesticides, and personal care products from industries and municipalities into water bodies [1]. Most of these pollutants are highly persistent in nature and are otherwise convert into recalcitrant form [2]. The uncontrolled discharge of these pollutants is a concern because of their suspected negative effects on ecosystems [1][3][4]. Several conventional technologies are applied worldwide for the removal of wastewater pollutants including coagulation-flocculation, adsorption, membrane filtration, reverse osmosis, chemical precipitation, ion-exchange, electrochemical treatment, solvent extraction and flotation for the removal of inorganic pollutants [5][6][7][8]. However, these technologies suffer from a range of disadvantages stretching from inefficiency to remove pollutants at low concentration and to completely convert pollutants into biodegradable or less toxic byproducts, high energy and chemicals consumption, process complexity, high maintenance and operation costs, etc. [9][10][11]. An efficient and viable treatment process should meet both economic and environmental requirements to be marketed and applied in large scale. The incorporation of low-cost and available materials in different treatment processes could decrease the global treatment cost and increase the process efficiency.

2. Influence and application

Biochar as an eco-friendly and low-cost material generally produced from organic wastes such as agricultural wastes, forestry residues and municipal wastes has attracted increasing attention evidenced by its increasing use in different environmental applications. Organic wastes could be converted into char by different techniques including pyrolysis, hydrothermal carbonization (HTC), gasification, and torrefaction [12]. The conventional carbonization method for producing biochar is pyrolysis, while chars from gasification, torrefaction, and HTC generally do not meet the definition of biochar specified in the guidelines for the European Biochar Certificate (EBC). Owning to its enhanced properties such as rich carbon content, enhanced surface area, high cation/anion exchange capacity, and stable structure [13], biochar and its activated derivatives were reported as very efficient materials to remove various contaminants, including pathogenic organisms [14][15][16][17], inorganics such as heavy metals [18][19], and organic contaminants such as dyes [20][21]. This evidence is however derived only from batch experiments, while a lack of information on the design and optimization of biochar-based systems for the depollution of drinking water and the treatment of wastewater is still largely existing. The ability of biochar to remove organic and inorganic pollutants from wastewater is directly linked to its adsorption capacity, which depends on their physico-chemical characteristics such as elemental composition, surface area, distribution of pore size, surface functional groups, and cation/anion exchange capacity, these physico-chemical properties vary with the nature of feedstock and the preparation methods and conditions [22][23][24][25]. For some recalcitrant molecules, which are present at low concentrations, the properties of biochar should be modulated to allow for a better removal efficiency. The common methods used for biochar modification are regrouped into two classes: chemical modification methods, which mainly include acid modification, alkalinity modification, and oxidizing agent modification; and physical modification methods generally performed by gas purging.

Although biochar showed widespread application prospect in the wastewater remediation, the potential negative impact of biochar application should be also analyzed. Depending on the nature of feedstock and the conversion technique adopted for its production, biochar may contain various heavy metals and other contaminants that could be released during its application in aqueous solutions [26][27]. Therefore, more studies are needed to investigate the stability of biochar and its correlation with the experimental conditions used during biochar production. In this review, the recent studies on the preparation, modification and use of biochar from pyrolysis and chars from other thermal conversion processes for the removal of organic and inorganic wastewater pollutants are summarized. The main mechanisms involved during the adsorption process, in addition to the recent advancement in the application of biochar as filtration media, support for catalysts, and its role during anaerobic digestion of wastewater, will be also discussed.

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