Journal of Sustainable Civil Engineering and Technology
e-ISSN: 2948-4294 | Volume 3 Issue 2 (September 2024), 178-183
https://joscetech.uitm.edu.my

Application and Research Progress of Biochar in Environment Pollution Control

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Received: 15 May 2024 / Accepted: 05 August 2024 / Published online: 30 September 2024

Abstract

Biochar is a carbon-rich material with a wide range of raw materials, low cost, and environmental friendliness. It has a range of advantages such as high porosity and rich surface functional groups. Recently, the application of biochar to control environmental pollution and to improve soil quality have become increasingly widespread. To systematically summarize the application status, efficiency, shortage and development prospects of biochar in environmental pollution control, this article concludes the viewpoints from resent research of biochar materials in marine oil, soil pollution control and industrial wastewater, and made the prospect of biochar materials application in the environmental pollution control and remediation.

Keywords: Biochar; Environmental pollution; Marine oil pollution; Soil pollution; Heavy metal ions

1. Introduction

Biochar is a refractory solid substance with a highly aromatic structure treated at high temperatures under the condition of oxygen isolation or oxygen restriction (Manyà, 2012). In water treatment processes, the use of biochar's has risen due to their relative abundance, sustainability, and low cost compared with conventional technologies (Tan et al., 2023).Its advantages are as follows: first, with large specific surface, high porosity and various micro-porous structures (large hole: 50nm, medium hole: 2~50nm, small hole: <2nm), it is suitable for filling microplastics with various particle sizes; second, most plastics are difficult to degrade, which is non-polar, highly hydrophobic biochar has strong permeability to non-polar pollutants (Madadi & Bester, 2021); third, the high carbon element content (polyaromatic carbon structure) is easy to adsorb microplastics containing benzene rings, and stable physical and chemical properties and strong adaptability. Biochar is a porous material characterized by low cost, simple preparation, and rich carbon content. Its surface contains a large number of functional groups and its own aromatic structure, which can enhance adsorption performance. The physical and chemical properties of biochar are related to its preparation method. Biochar is a type of porous material rich in carbon and highly aromatic, generated by the pyrolysis of biomass raw materials under anaerobic or anaerobic conditions. Biochar raw materials come from a wide range of sources, mainly including agricultural and forestry waste, animal manure, and sludge. Among them, agricultural and forestry waste such as straw, trees, and grass leaves are the most commonly used raw materials for preparing biochar.

Adsorption is an economical, simple and direct treatment method, a natural organic adsorbent, wide source, easy to obtain, and strong biodegradability (Guo et al., 2024). As one of the natural organic adsorbents, carbon material has attracted more attention in recent years due to its advantages of developed pores and large specific surface area (Leng et al., 2021). As the most representative biochar has the characteristics of strong adaptability, extensive raw materials and simple preparation, and can be used as a fuel with direct combustion capacity after adsorption of oil. Biochar originated from a dark and fertile soil found in the Amazon Basin, "Terra Preta", which means "black soil". The reason why the "Terra Preta" soil maintains high fertility is that it contains many

"charcoal" -like substances, which are later called "biochar" by scientists. Biochar is a carbon-rich solid substance formed by heating in an anoxic environment. The raw material source includes plants, feces, activated sludge, waste materials and others (Wu et al., 2018). The physical and chemical properties of biochar are mainly influenced by the type of raw materials and the preparation conditions. In general, biochar has the advantages of high porosity, large specific surface area, high cation exchange amount, stable structure, easy access to raw materials and low cost (Lehmann & Joseph, 2015). Therefore, biochar has become a research hotspot in recent years. As an ideal adsorbent, biochar is often used to remove all kinds of pollutants in the environment, such as heavy metals, pesticides, antibiotics, oils and so on. Secondly, when biochar is used in soil, it can maintain soil fertility, improve soil physical properties, improve crop yield, and reduce nitrogen emissions (Morales et al., 2015). The discovery of biochar is an important study of environmental pollution control.

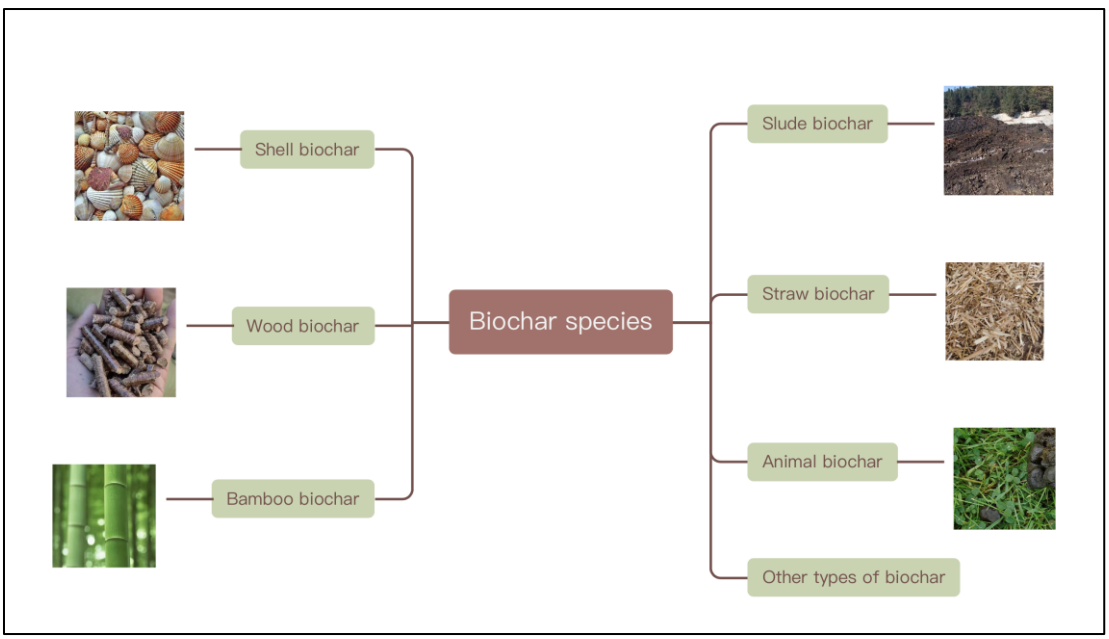

Figure 1. Classification of biochar sources

2. Research Status

This paper mainly focuses on three aspects of research on biochar in the treatment of marine petroleum-based, soil pollution and wastewater pollution.

2.1 The Effect of Biochar on Marine Oil Pollution Control

Oil is an important energy source and industrial raw material for mankind. Leakages of oil nevitably occur during the extraction, transportation, and refining of oil. As an important channel of oil transportation and a gathering place of land-based pollutants, the ocean has a high risk of oil pollution. There have been oil spill accidents such as "Exxon Valdez (Exxon Valdez)" oil spill, "Deepwater Horizon (Deepwater Horizon)" oil spill, "Hebei Spirit (Hebei Spirit)" oil spill, "Sangi wheel (Sanchi)", "Penglai 19-3 oil spill", "11 · 22 Sinopec East Yellow oil pipeline leakage accident", and "Symphony wheel (Symphony)" oil spill, Marine oil pollution is accompanied by the development of human society and economy, In the short and long term., And it has caused great damage to the human living environment. In the long run, the environmental quality has gradually deteriorated. A large amount of leakage in the initial stage of the oil spill will cause the death of plankton, fish and birds, and the decline of Marine aquatic resources (Quigg et al., 2021). However, petroleum hydrocarbons (such as polycyclic aromatic hydrocarbons), which have existed in the Marine environment for a long time, will cause genetic damage at the level of Marine plants-mangroves (Aly & Abouelfadl, 2020), which will change

the hormone levels in Marine organisms and cause death (Khan et al., 2021a). After the occurrence of oil spill pollution, effective treatment techniques or methods can reduce the impact of oil pollution on the Marine environment. At the same time, due to the unique characteristics of biochar, it is widely used in the study of environmental remediation. Marine oil pollution is an inevitable and important environmental pollution problem in the process of human exploitation and utilization of the ocean, and the long-term existence of petroleum hydrocarbons in the Marine environment will have a serious impact on the Marine ecosystem. Due to the versatility and environmental friendliness of biochar, it is gradually developed and used in the remediation research of Marine petroleum hydrocarbon pollution.

The pore structure and surface hydrophobicity of biochar determine its excellent performance in water surface oil spill adsorption. The developed pore structure of biochar increases its pore volume and provides more adsorption sites for petroleum adsorption (Ahmed et al., 2016). Large pores can increase the oil absorption capacity of biochar. The components of biomass leave a larger number of pores after thermal decomposition and volatilization. The appropriate pyrolysis temperature will produce more larger porous structure, and too high temperature will destroy the large porous structure, resulting in more pores and micropores, resulting in the decrease of oil adsorption (Zhao et al., 2013). Biochar has a large specific surface area and rich functional groups and has a high adsorption potential for various organic pollutants (O'Connor et al., 2018). When combining plants and biochar, found that the application of biochar significantly increased the adsorption of PAHs in the sediment and had a significant correlation with the pyrolysis temperature, and reduced the bioavailability of plant tissue PAHs (Jia et al., 2020). In addition, the researchers pointed out that in sediments, biochar can accelerate the reduction of organic substrates through redox reactions, which can serve as a catalyst for biogeochemical and pollutant redox reactions (Oh et al., 2012). Gomez-Eyles & Ghosh, (2018) in evaluating the bioavailability effectiveness of pine biochar as an improvement in reducing the availability of PCB and PCB-contaminated sediment and found that it greatly reduced the pore water concentration of PCB and PCB (> 95%) and bioaccumulation (> 93%) in the sediment (>95%).

2.2 The Effect of Biochar on Oil Pollution

Soil is the main foundation of human life and the existence of life, which occupies a very important position in human production activities and is also the basis of human survival (Khan et al., 2021b). With the intensification of pollution in industrialization and urbanization and the increase of the types and quantity of agricultural chemicals, soil pollution is becoming more and more serious, the pollution degree is also gradually rising, and the area is also increasing year by year. The deterioration of the soil environment is caused by a variety of reasons, such as the discharge of waste gas, wastewater and waste residue in the process of industrial production, the unreasonable use of pesticides and fertilizers in agricultural production and cannot be decomposed by microorganisms and the discharge of all kinds of sewage in the process of urban life (Akhtar et al., 2021). Heavy metal pollution is also one of the causes of soil environmental pollution (Li et al., 2021). Metals with a proportion of more than 4 percent are usually called heavy metals, including Pb, Ni, Hg, Zn, Cd, As, etc (Kiran et al., 2022). Heavy metals are also the main pollutants affecting the quality of agricultural land.

At present, the main uses of biochar in soil treatment are acid soil improvement, fertility-poor soil improvement and contaminated soil remediation (Chang et al., 2019). Biochar can change the physical properties of soil compaction, water retention capacity and soil particle size distribution; can improve the physical and chemical properties such as pH, salt base saturation, ion exchange amount and organic carbon content; and can change the physical and chemical properties of soil microbial community structure and enzyme activity. Yao et al. (2022) found that adding biochar could reduce the emission of NO_2 in soil by 59.1%, and the degree of its influence was closely related to soil. Especially for soils with strong nitrification potential, the addition of biochar may increase type N_2O gas emissions. Many literature studies show that the combination of biochar and compounds is also a way to improve the performance of biochar for soil remediation(Guo et al., 2020). Adding biochar can improve the formation rate of soil organic matter, increase the content of organic matter, enhance soil fertility, and stabilize the organic carbon storage in the soil (Oh et al., 2012). The research on the adsorption mechanism of biochar on heavy metal ions in soil has an important reference value for the application of biochar in soil pollution remediation.

2.3 Research on the Treatment of Wastewater Pollution by Biochar

At present, the older the problem of wastewater discharge, the more serious. In recent years, biochar adsorption of ammonia nitrogen wastewater has been the focus of research at home and abroad, mainly reflected in the research of native biochar adsorption, modified biochar adsorption and composite adsorption materials.

The raw material sources of native biochar are very wide, so it can solve the problem of domestic waste and waste treatment and provide a new idea for the solution of ammonia nitrogen pollutants in wastewater. However, some proto biochar has the disadvantage of poor removal of ammonia nitrogen pollutants in wastewater, so it is necessary to modify the proto biochar to enhance the treatment effect of ammonia nitrogen wastewater (Guo et al., 2012).

Native biological carbon in the treatment of low concentration of ammonia nitrogen wastewater adsorption efficiency can be further improved, the existing research shows that native biomass-modified product have a huge adsorption effect of adsorbent(Omosa, 2014), and is used for the preparation of native biomass material after certain physical modification, acid and base modification, metal ion modification and biological modified (Zhao et al., 2022), the adsorption effect of organic pollutants, by many scholars to the adsorption of ammonia nitrogen wastewater. Physical modification refers to the use of physical methods to modify the biochar treatment, to achieve the purpose of improving the adsorption effect, the common methods for mechanical shock, thermal radiation, high-frequency electric field, etc. Most researchers use carbonization, activation, roasting, acid sedimentation and other processes to physically modify the biochar. Among them, the most used process for preparing biochar adsorbent is carbonization and activation. Acid-base modification is a way of chemical modification, and acid-base modification is to change the physical and chemical properties of biochar through chemical reactions. The most common method of acid-base modification is to soak the modification with the corresponding chemical reagents (HNO_3, $HClO_3$, NaOH, KOH). Metal ion modification is by soaking biochar in metal ion solution to achieve biochar metal ion modification, soaking in the surface of the biochar will form a layer of metal oxide, can improve the specific surface area of biochar and provide more active adsorption site (Cheng et al., 2022), to further improve the ability of biocarbon adsorption of ammonia nitrogen. Biological modification refers to the pretreatment of biochar through the digestion of microbial species, to optimize the physical and chemical properties of the target biochar. Zhou Shan et al[Error! Reference source not found.] prepared bamboo charcoal-immobilized microorganisms by fixing nitrifiers, nitrifiers and other microorganisms on the bamboo charcoal carrier. When the initial concentration of ammonia nitrogen is 50 mg/L, the pH value of the solution is 8, and the dissolved oxygen mass concentration of the water sample is 1 mg/L, the removal efficiency of ammonia nitrogen in the solution can reach more than 70%. In addition, the bio-modified biochar has the effect of promoting microbial reproduction, so the biochar modified by the corresponding microbial flora has a good removal efficiency of ammonia nitrogen in wastewater.able and figures should be systematically constructed to facilitate the discussion of results of the study. All tables and figures must be carefully described to answer the research questions. The results of the study need to be compared with the literature. All tables and figures must not be appended in the text of the manuscript.

3. Summary

As a new type of treatment technology for pollution control, biochar and biochar modification technology have achieved good results in environmental contanmination treatment, but different types of biochar materials have differences or deficiencies in production cost, adsorption saturation, cycle life, stability, and other aspects. This paper systematically expounds on the effects of biochar materials including modification method on the marine oil pollution remediation, soil pollution treatment, and wastewater pollution treatment. At present, the research on the application of biochar in the field to ccontrol environmental remediation tend to increase, but the following points should be considered during preparation and application:

(1) Large-scale practical applications of biochar materials in the environment need to be studied, which is crucial for their future research and development.
(2) The influence of biochar preparation process on their adsorption performance and quality is further clarified.

(3) The modification of biochar materials is not enough perfect and requires further validation studies.

Acknowledgements

The authors would like to acknowledge the support of Shaoxing University for providing the facilities and financial support on this research. The authers would like to thank supervisor, Prof.Zijing Zhou, who provided a lot of help for my experimental design and other aspects during the writing of the thesis.

Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

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