Research on the remediation of heavy metal contaminated soil by biochar

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Abstract. This paper systematically reviews the application research of biochar in the remediation of heavy metal contaminated soil. As a porous solid granular material rich in carbon, biochar shows excellent heavy metal adsorption capacity and potential for soil remediation. This paper introduces in detail the preparation methods of biochar, including pyrolysis, hydrothermal carbonization, etc., and its application principle in soil heavy metal remediation, focusing on the analysis of the mechanism by which biochar reduces the mobility and bioavailability of pollutants by adsorbing and fixing heavy metals and improving soil properties. This paper also discusses the classification of biochar from different raw material sources and its diversified applications in agriculture and environmental protection. In general, biochar has broad application prospects in the field of environmental remediation and is one of the important green technologies to solve the problem of heavy metal pollution in soil.

Keywords: soil, heavy metals, adsorption mechanism.

1. Introduction

Heavy metal contaminated soil is a serious environmental problem, posing a serious threat to humans and the earth's ecosystem. With the rapid development of human industry and cities, heavy metal contaminated soil is becoming increasingly serious in many countries [1]. At present, the main methods for remediating heavy metal contaminated soil include engineering measures, physical and chemical remediation, chemical remediation, water regulation, soil replacement or soil replacement, bioremediation technology, microbial remediation and soil animal remediation. The reasons for choosing biochar to remediate heavy metal contaminated soil mainly include its applicability to a variety of scenarios, good soil remediation effect and the effectiveness of heavy metal pollution remediation schemes. Biochar and soil conditioning have become a hot topic in the sustainable development community. With the rapid development of biochar, how to use biomass carbon to remediate heavy metal-contaminated soil has become a new development direction.

At present, the main methods for remediating heavy metal contaminated soil on the market are: engineering measures, soil leaching, physical and chemical remediation and activated carbon adsorption [2].

Engineering measures refer to reducing the heavy metal content of soil by removing contaminated soil or deepening the tillage layer. This method is simple to implement, but it is costly and may damage the original structure of the soil, so it is less used [3]. Soil leaching is to separate the contaminated soil according to its particle size, separate the coarse-grained gravel, sandy soil, etc. from the fine-grained silt and clay components, and use water and other leaching fluids to wash the coarse-grained soil, transferring the pollutants from the surface of the coarse-grained soil to the liquid phase for centralized treatment. The cleaned coarse-grained soil can be used as a resource, and the leaching fluid needs to be collected for harmless treatment. The treated water can be reused in the leaching process, and the treated residue is subjected to back-end deep treatment [4].

Physicochemical remediation refers to the physical or chemical treatment of the soil in situ, and the bioavailability of heavy metals is reduced by adjusting the soil pH value. There are two methods of physical remediation, namely electroremediation and electrothermal remediation. Electroremediation refers to the use of electric current to transport heavy metal ions and inorganic ions in the soil to the electrode by means of electroosmosis and electromigration, and then collect and treat them in a centralized manner. This method of electroremediation is suitable for low-permeability clay and silt soil, which can control the flow direction of pollutants without stirring the soil layer. The remediation time is short, and it is an economically feasible in-situ remediation technology. Electrothermal remediation uses electromagnetic waves generated by high-frequency voltage to heat heavy metal-contaminated soil, desorb pollutants from soil particles, and accelerate the separation of some volatile heavy metals from the soil, thereby achieving the purpose of soil remediation. The obvious disadvantage of physical remediation is that it consumes a lot of electricity. Chemical remediation refers to the fixed conversion, dissolution extraction and extraction separation of heavy metals by adding chemical modifiers to contaminated soil, thereby reducing the heavy metal content in contaminated soil [5].

Biochar adsorption is currently a more efficient heavy metal treatment method. Biochar is a highly aromatic, carbon-rich porous solid granular material generated by thermochemical conversion of carbon-rich biomass under anaerobic or anoxic conditions. Biochar has the characteristics of biochar porosity and large specific surface area, and contains a large amount of alkaline substances including potassium, sodium, magnesium, calcium and other metal ions, which can increase soil pH, improve soil acidification, increase water retention, and increase soil porosity [6].

The biochar adsorption heavy metal treatment method is simple to operate and efficient. This paper reviews the preparation methods of biochar, the types of biochar, and the principle of heavy metal adsorption by biochar [7].

2. Preparation methods of biochar

The production methods of biochar mainly include pyrolysis, hydrothermal carbonization and furnace burning.

Pyrolysis is the most widely used method and the easiest method to implement. Its characteristics are wide sources of raw materials, simple operation, and stronger operability than other methods under certain conditions [8]. The pyrolysis process refers to the chemical reaction process in which biomass is heated and decomposed under high temperature conditions of 200~900℃ to form solids, liquids and gases. In the actual production process of biochar, the pyrolysis method can be divided into slow decomposition and fast decomposition according to the different parameters such as pyrolysis reaction temperature, pressure, temperature speed, time, heating medium, etc. of biomass [9].

As a new technology for efficient thermochemical conversion of biomass, hydrothermal carbonization technology is one of the core key common technologies with the most development potential and prospects for efficient resource utilization of biomass in my country. Hydrothermal carbonization converts wet biomass into high value-added products through the action of subcritical water or supercritical water. This method has many advantages. First, there is no need to pre-treat the raw materials by drying and dehydrating, and the operation is simple and has wide applicability. Secondly, the process is controllable, and it is easy to achieve a relatively uniform carbonization process. The carbon content of the prepared carbon material is higher than 60%. Finally, the problems of long raw material pretreatment time and high cost in the pyrolysis and carbonization of high-water content materials are solved. The hydrothermal carbonization method can be a self-contained system, or it can be used as a pretreatment step in conjunction with other methods. Therefore, the hydrothermal carbonization method has become the preferred way to prepare carbon materials from biomass raw materials and reduce carbon emissions.

At present, there are several types of furnaces that are mainly used in this method: The first is a firewood-saving charcoal burning furnace, which is made of bricks. While burning charcoal, the heat generated can be used for heating or boiling water. It consists of a furnace cover, a carbonization chamber, a combustion chamber, a volcanic wall, a windward wall, a chimney, a furnace door, etc. The second is a removable charcoal burning furnace, whose structure consists of an upper furnace body, a lower furnace body, a flue, a vent, a furnace cover, an ignition rack, and a grate. Its advantages are compact structure, easy operation, convenient movement, high carbonization rate, good carbon quality, low labor intensity and seasonal influence. The third type is a mobile carbonization furnace, with a grate at the bottom, 200mm above the ground; an ignition ventilation rack is erected in the center of the furnace body, and an ignition port is set on the top cover, which can be closed with a lid. Close the ventilation pipe opening, and after half an hour, close the exhaust pipe opening for closed smoldering. The fourth type is an intermittent carbonization furnace, first load the raw materials into the carbonization furnace, then heat the outside of the carbonization furnace for carbonization, and then cool it to produce carbon, one furnace for one burning, one furnace for one charcoal. According to environmental protection requirements and profit-output ratio, combined with the above biochar processing technology, the continuous carbonization furnace can be mass-produced, and this method will also be more popularized and adopted.

3. Classification of biochar

These biochar raw material sources cover different types of agricultural and forestry wastes. According to their sources, biochar is mainly divided into sludge charcoal, wine lees charcoal, wood chip charcoal, medicine residue charcoal, rice husk charcoal, rice straw charcoal, corn straw charcoal and wheat straw charcoal [10].

Sludge charcoal may be made from sludge produced by sewage treatment, while rice husk charcoal is made from rice husks after rice processing. These classifications reflect the diversity and wide application potential of biochar raw materials.

4. The principle of biochar soil restoration

Page Number The principle of biochar to improve heavy metal contaminated soil mainly includes adsorption and fixation of heavy metals, improvement of soil properties, and increase of plant survival rate and yield. Biochar is mainly composed of four elements: C, H, O, and N, among which the C element has the highest content [11]. These elements constitute the aromatic structure and alkyl of biochar. The ash of biochar contains a large amount of mineral element oxides, carbonates, phosphates and other substances, which can significantly improve the basic properties of soil, such as pH, cation exchange capacity (CEC), water and nutrient retention, and can also maintain soil microbial diversity and soil water holding capacity, and improve plant survival rate [12]. In addition, biochar has the characteristics of large specific surface area, high cation exchange capacity, rich functional groups, and high chemical and biological stability. These characteristics enable biochar to effectively reduce the mobility and bioavailability of heavy metals in soil [13]. In addition, biochar effectively fixes heavy metals in soil through a variety of mechanisms, including cation-π interaction, ion exchange, complexation reaction, coprecipitation reaction, redox reaction and electrostatic adsorption [14]. These mechanisms work together to enable biochar to fix heavy metals in soil, reduce their bioavailability in soil and their concentration in the edible part of crops, thereby reducing the toxic effects of food heavy metals on the human body [15].

5. Summary

As a porous solid granular material rich in carbon, biochar has shown excellent application potential in the remediation of heavy metal contaminated soil. Its unique porous structure and highly aromatic carbon composition give it excellent adsorption capacity, which can effectively fix and adsorb heavy metal ions in the soil, thereby reducing the bioavailability and mobility of these harmful substances and reducing secondary pollution to plants and the environment. The preparation processes of biochar include pyrolysis, hydrothermal carbonization and gasification, all of which use the thermochemical conversion process of biomass under anaerobic or anoxic conditions to convert agricultural and forestry waste into biochar with high adsorption function. According to different raw materials, biochar can be divided into sludge charcoal, wine lees charcoal, sawdust charcoal, medicine residue charcoal, rice husk charcoal, rice straw charcoal, corn straw charcoal and wheat straw charcoal. This diversity not only expands the application range of biochar, but also provides a variety of options for soil remediation in different regions. In addition, the application of biochar is not limited to the field of soil heavy metal pollution remediation. In agriculture, it can also promote plant growth and increase crop yields by improving soil structure, improving water retention capacity, and enhancing soil microbial activity. The use of biochar is of great significance to achieving sustainable agricultural development and protecting the ecological environment. In general, biochar, as a soil remediation material with simple preparation, readily available raw materials and powerful functions, has shown broad application prospects. With the continuous development and improvement of related technologies, biochar will play an increasingly important role in the field of environmental remediation and is expected to become one of the key green technologies to solve the problem of heavy metal pollution in soil.

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