Agricultural waste biomass resource utilization and its application in environmental remediation

Ziyan Dang *

College of Ecology and Environment, Xinjiang University, Urumqi, China

* Corresponding Author Email: maoming@ldy.edu.rs

Abstract. With the increasing demand for energy, human beings need to find new renewable energy sources to promote human survival and development. The rational application of agricultural waste biomass is of great significance to reducing resource waste and improving environmental problems. This paper discusses the resource utilization of agricultural waste biomass and its application in environmental remediation. Agricultural waste biomass, such as crop straw and livestock manure, can be converted into efficient energy or biochar after resource treatment. This biochar has an excellent performance in soil remediation and wastewater treatment because of its high adsorption capacity. The preparation methods of biochar are diverse, including pyrolysis, hydrothermal carbonization, etc., and its properties can be further enhanced through physical and chemical modification. However, there are still some problems, such as low biomass utilization efficiency and unclear long-term impact on the environment. In the future, efficient biochar preparation and modification technology should be further developed to realize its wide application in environmental remediation.

Keywords: biomass, biochar, preparation, application.

1. Introduction

With the continuous growth of global energy demand, the gradual depletion of fossil fuel resources, and the increasingly serious environmental pollution problem, human beings urgently need to find new renewable energy sources to meet the needs of sustainable development. As a widely distributed and easily accessible energy source, biomass has a broad development prospect. However, at present, most of the biomass resources are only disposed through simple treatment methods, such as burial and incineration, which not only does not realize the effective utilization of biomass, but also may lead to the aggravation of resource waste and environmental problems.

Agricultural waste biomass, as an important source of biomass energy, has significant utilization value. With the development of social economy, the by-products of economic activities, such as agricultural waste biomass, are increasingly paid to [1]. The preparation process of biochar is relatively simple, and the production cost is low, and it also has a strong environmental remediation ability. Different kinds of biochar showed good results in the treatment of heavy metal contaminated soil and wastewater [2]. Therefore, the use of waste biomass for environmental remediation not only meets the trend of sustainable development, but also can effectively reduce environmental pollution.

2. Reuse of agricultural waste biomass

Agricultural waste biomass includes crop straw, rice husk, fruit tree pruning, livestock manure, etc. The traditional agricultural waste biomass treatment method is relatively simple, but the energy efficiency is low. Based on this, the agricultural waste biomass resource utilization technology is put forward. On the one hand, through the rational allocation and efficient utilization of resources, this technology realizes the waste of agricultural biomass into treasure, avoids the waste of resources, and reduces pollution emissions. On the other hand, agricultural waste biomass resources can reduce the resource input and ensure the stable output, so as to reduce the cost and improve the utilization rate of resources. Agricultural organic waste is an important part of agricultural waste, containing rich in organic matter, nutrient elements and other resources. The main utilization method of agricultural organic waste is feed and fertilizer. The waste biomass which is not easily used as feed is crushed and directly returned to the field to improve the soil organic matter content and physical and chemical properties, or the agricultural organic wastes such as crop straw, tail vegetables, livestock and poultry manure are treated through static compost and then returned to the field. Crop straw resources are rich, which can be used as animal feed to save diet and promote farmers' income. Moreover, straw treatment through silage, microstorage, ammonification and other technologies can effectively improve straw tissue structure and palatability, improve animal feed intake, and make straw a high-quality feed easy to digest by livestock and good taste. According to the statistics, the annual crop straw production in China is about 1 billion t, the utilization rate is 71%, the annual production of livestock manure is about 4 billion t, and the utilization rate is 61% [3].

3. Energy conversion of agricultural waste

Biomass has the characteristics of cleanliness, renewable, low utilization difficulty and friendly environment, and is known as the "fourth largest" energy after coal, oil and natural gas. At the same time, biomass resources are also one of the most important human renewable energy.

In recent years, the source of waste biomass energy is mainly incineration for power generation, but this method will generate a large number of greenhouse gases. With the progress of science and technology, the use of thermochemical methods to convert waste biomass into biofuels (such as combustible gases, bio-oils, etc.) under heating conditions has become the mainstream way of waste biomass energy generation. Traditional conversion methods can be divided into three categories: gasification, hydrothermal liquefaction and catalytic hydrolysis, among which gasification conversion is the most common. Gasification is a thermochemical process, which is a key technology for the conversion of agricultural waste to clean gas, which can convert carbon-containing materials into combustible gases such as hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2) and methane (CH_4). Hydrothermal liquefaction transforms the biomass in the form of low-grade solid fuels into high-grade liquid fuels or value-added organic chemicals through chemical conversion. Catalytic hydrogenation is another way of efficient utilization of biomass resources, which has been widely used in heavy oil purification and petroleum fraction processing in modern refineries. The reaction temperature of biomass catalytic hydrogenation conversion is much lower than that of pyrolysis and gasification. The cracking of some covalent bonds in biomass and its derivatives and the introduction of (active) hydrogen is an important way to prepare many value-added chemicals and liquid fuels [4].

4. Biomass carbonization

Biochar is a kind of black organic carbon-rich substance with large specific surface area formed after dehydration, decarboxylation, decomposition and reduction under the conditions of limited temperature and oxygen. Biomass carbonization finally forms a stable carbon skeleton through the decomposition of macromolecules, the polymerization of small molecules and gas volatilization. The agricultural waste biomass is prepared into biochar, and further modified to improve its adsorption performance, which can not only realize resource utilization, but also serve as an adsorbent to control environmental pollution, so as to achieve the purpose of waste treatment.

4.1. Biochar preparation

The preparation of biochar refers to the preparation of biochar by superthermal decomposition at a certain temperature and controlled oxygen content. Common methods include pyrolysis method, hydrothermal carbonization method, and gasification method. Pyrolysis is a method to obtain biochar by cracking of biomass materials at high temperature under the condition of no oxygen, which is mainly divided into fast pyrolysis and slow pyrolysis. The liquefied products obtained by fast pyrolysis have high yield, slow pyrolysis pyrolysis residence time is long, and the quality fraction of biochar is high. In the process of pyrolysis of lignin, fat, cellulose under the condition of no oxygen through high temperature formation of carbon-rich biochar, hydrothermal carbonization method is the medium of water, biomass raw materials into airtight high pressure reactor, under a certain temperature and pressure, the biomass into material process of carbon and gas. Hydrothermal carbonization is a simple and low-cost biochar preparation technology, which is widely used in biochar preparation. Now there is a new type of hydrothermal carbonization process, called hydrothermal cocarbonization, this hydrothermal carbonization method of different raw materials mixed to make biochar, can effectively improve the content of organic matter and inorganic nutrients in biochar [5]. Gasification method is a thermochemical method to convert biomass into combustible gas. In addition to obtaining the available gas gas, it can also realize the recovery of high value-added materials of biochar and bio-oil.

4.2. Biochar modification methods

The adsorption and degradation capacity of biochar prepared directly from biomass is generally poor. Therefore, the adsorption capacity of biochar on specific pollutants can be enhanced by modification [6]. Commonly used modification methods are divided into physical modification and chemical modification.

4.2.1. Physical modification methods

Physical modification is to modify the carbon surface of biomass by physical methods, such as high temperature calcination or ultrasonic, and introduce inert gas, which can increase the carbon specific surface area and pore volume to achieve the purpose of enhancing the adsorption capacity. Gas activation is a method of physical modification by increasing the porosity and specific surface area of unmodified biochar, and the introduction of oxygen-containing functional groups (such as groups and hydroxyl groups) to improve the activeof biochar [7]. Gas-modified biochar will be affected by the activation temperature, the quality of the gas and biochar, and the activation time. This method has low cost, but it has some disadvantages, such as temperature is difficult to regulate, insufficient activation and so on. Ultrasonic treatment can increase the reaction rate of carboxylation and hydrogenation of biochar, but also can increase the surface area of biochar. However, long ultrasonic treatment will make the biochar structure destroy [8], so this method has certain limitations.

4.2.2. Chemical modification methods

Chemical modification refers to the use of chemical methods to modify or biochar, and improve the adsorption properties of biochar by changing the physical and chemical properties of the biochar surface and increasing the number and types of functional groups, so as to achieve the purpose of removing pollutants or changing the state of pollutants, and finally reducing its harm. Chemical modification methods usually include acid-base modification method, organic modification method, etc. Through acid modification treatment, impurities in the surface and pores of biochar can be effectively removed, and acidic functional groups can be introduced to facilitate the adsorption of pollutants. Base modification can provide more oxygen-containing functional groups on the surface of the biochar, which leads to the enhanced adsorption capacity of the modified metazoan carbon. Acid-base modification method increases the adsorption capacity of biochar, but it is easy to produce waste acid and waste alkali solution in the modification process, which has the risk of secondary pollution. Organic modification method is the biochar with a lot of functional group of organic matter, by increasing the number of adsorption sites to enhance the elimination ability [9]. Tan et al. [10] and Zheng et al. [11] preparation of organic modified biochar are confirmed that organic modification is a good kind of chemical modification of biochar method, in water and soil remediation prospects, but the organic modification cost is high, and some organic toxicity, volatile, need to be careful pollution.

5. Application of waste biomass in environmental remediation

5.1. Soil remediation

With the development of human production activities, the pollutants produced by industry, agriculture, urbanization and other activities accumulate in the soil and exist for a long time, and the soil pollution is increasingly serious. According to the public data of the National Soil Pollution Survey Bulletin released by China in 2014, the total level of soil in China was 16.1%, and the main pollutants were inorganic pollutants, accounting for 82.8% of all the exceeding levels, among which cadmium, mercury, arsenic, copper, lead, chromium, zinc and nickel all exceeded the standard [12]. Heavy metal pollution will not only reduce soil fertility and crop yield, but also harm human health and damage the ecological environment through biological enrichment.

In recent years, biochar has been used for soil pollution remediation. Its high porosity and large specific surface area make it have a strong adsorption capacity and can reduce the biotoxicity of heavy metals in the soil. Biochar is alkaline, heavy metals in soil are stable with the increase of pH, and biochar preparation from wide sources, and the preparation method is simple, which has great potential in soil pollution remediation. Jiang et al. [13] found that the addition of rice straw biochar increased soil pH, Soil produces hydroxide precipitation. Liang et al. [14] used manganese dioxide (MnO_x) for the modification of pig manure biochar, it was found that the modified biochar could not only passivate the lead ions by electrostatic adsorption. It can also be fixed by forming a stable complex with heavy metal ions. Zhang et al. [15] found that P-modified biochar had the effect of slow-release P, it can make the heavy metal elements in the soil from the weak acid extraction state to the oxidizing state and the residue state transition. The soil contaminated by Pb and Cd can be passivated, is conducive to improving the soil quality.

5.2. Waste water treatment

Pollutants generated by industry and human activities pose a direct threat to the natural environment. At the present stage, the water ecological environment pollution is serious, serious water poisoning, eutrophication and other problems are common, and the source of water pollution is industrial wastewater. The expected pollutants such as phenolic compounds are a class of highly toxic and poor degradability. They are widely found in printing and dyeing, petrochemical and papermaking and other related industrial production, and are easy to pollute surface water and groundwater [16]. Heavy metal pollutants exist widely and occur in the industrial production process, and the water polluted by heavy metals is extremely toxic, which will be enriched in the human body through the food chain, posing a serious threat to human health and the balance of the whole ecological circle. For example, mercury wastewater can cause damage to the kidney and nervous system, lead wastewater can affect the growth and development of infants and young children, cadmium wastewater causes muscle atrophy and bone loss, and arsenic wastewater can cause serious diseases such as skin cancer and lung cancer.

At present, biochar can adsorb organic pollutants and heavy metals in the environment. As an effective adsorbent, biochar has a good adsorption effect on organic pollutants in water. The straw biochar material has a good adsorption effect on methylene blueand Congo red (anionic dye), with the adsorption capacity of 527.6 mg/g and 531.4 mg/g, respectively [17]. The core-shell magnetic mesoporous carbon prepared by can efficiently adsorb EDTA-Cr (III) [18].

6. Summary

The resource utilization of agricultural waste biomass has significant potential in environmental protection and sustainable development, especially in the field of soil remediation and water purification. As an important product of agricultural waste biomass, biochar has shown good results in the removal of pollutants (such as heavy metals, pesticide residues and organic pollutants) due to its high specific surface area, rich pore structure and excellent adsorption capacity. Biochar prepared by pyrolysis and hydrothermal carbonization can significantly improve its physicochemical properties, thus improving its adsorption and catalytic properties. Meanwhile, the efficiency of biomass chtreatment can be further enhanced by physical and chemical modification, such as dof metal ions or introduction of functional groups. The commercial application of biochar still faces some challenges. First of all, the preparation process of biochar is complex and high energy consumption, which needs to develop more economical and environmentally friendly production technology. Second, the stability and durability of biochar in practical applications have not been fully verified, especially the behavior and potential secondary pollution under prolonged environmental exposure need further research. In addition, different sources of agricultural waste biomass show significant differences in the preparation of biochar, and how to optimize and standardize the production process of biochar is still an urgent problem to be solved.

In general, the resource utilization of agricultural waste biomass and environmental remediation of biochar have broad prospects, but its large-scale application still needs in-depth research in preparation technology, modification methods and environmental safety. In the future, interdisciplinary research collaboration and technological innovation will help to improve the performance of biochar and promote its application in environmental governance, thus contributing to the Sustainable Development Goals.

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