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# PREPARATION AND APPLICATION OF BIOCHAR

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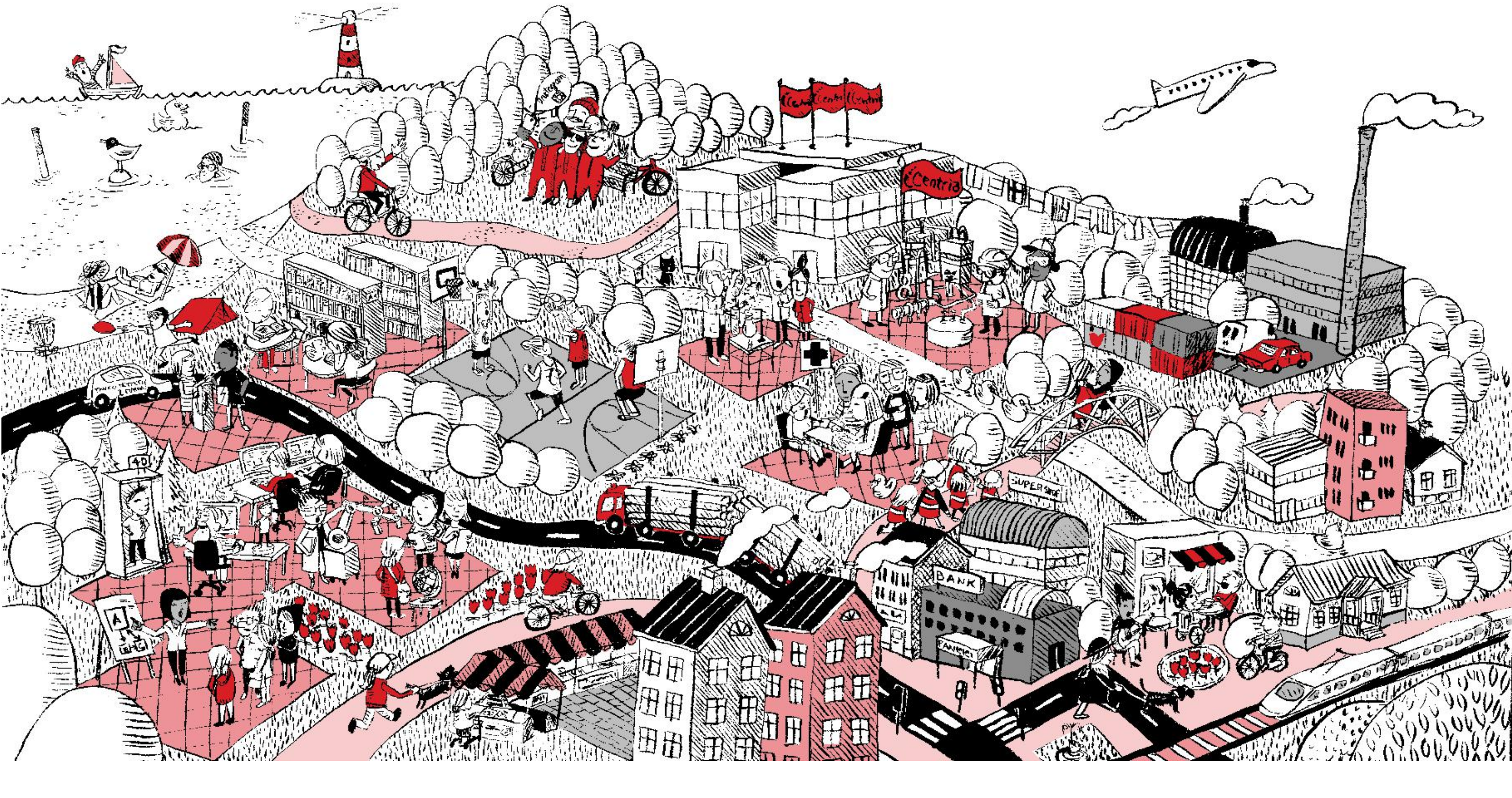

**ABSTRACT**

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Biochar is a material with high carbon content formed by the pyrolysis of biomass at low temperature under anoxic or anaerobic conditions. It is the product of resource utilization of agricultural waste. The application of biochar to soil can improve the physical and chemical properties of soil and promote plant growth. It has the characteristics of porosity and high stability. It can reduce the bioavailability of organic pollutants and heavy metals in the environment. It could also slow climate change. At present, biochar is a very hot research topic. What the study want to explore is the differences of biochar obtained under different preparation conditions. Therefore,this study selected different types of biomass as raw materials and prepared biochar under different conditions. In this way, their different physicochemical properties were obtained.

This study explores the preparation process of biochar and the influencing factors on the product. It focuses on the role that biochar can play in the future life. First of all, biochar is an excellent soil conditioner. Historically, there have been many examples of soil improvement using biochar, but research has only recently begun. The effect of biochar on soil improvement depends on the nature of the soil. Second, biochar can play an important role in environmental protection because of its own adsorbability and other properties. It can be used as a carrier for pollutant transport. The adsorption capacity of biochar is also related to the properties of the adsorbed material. The adsorption capacity of biochar on organic matter and heavy metals is relatively better. The emission of carbon dioxide aggravates the greenhouse effect. The use of biological carbon sequestration can curb the greenhouse effect. Urban waste, agricultural waste and livestock waste are all difficult to deal with. This waste is treated and utilized through pyrolysis. Many complex problems can be accomplished using the production characteristics and characteristics of biochar. The biochar project has a very broad development prospect.

**Key words**
Biochar, physicochemical properties, stability, heavy metals, yield.

## CONCEPT DEFINITIONS

### Biochar

Charcoal used as a soil conditioner to aid plant growth and for agricultural purposes as well as for carbon capture and storage, as opposed to conventional charcoal used as a fuel.

### Heavy metals

The original meaning of heavy metals refers to metals with a specific gravity of more than 5 (generally metals with a density of more than 4. 5 grams per cubic centimeter), including gold, silver, copper, iron, lead, cadmium. Heavy metals accumulate in the human body to a certain extent, which will cause chronic poisoning.

In fact, there is still no strict unified definition of what heavy metals are. In terms of environmental pollution, heavy metals mainly refer to heavy elements with significant biological toxicity, such as mercury (mercury), cadmium, lead, chromium and metal-like arsenic.

### Yield

In a chemical reaction (especially in a reversible reaction), the ratio of the actual to the theoretical yield of a product.

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## 1 INTRODUCTION

Biochar is a type of charcoal used as a soil conditioner to help plants grow, for agricultural purposes and for carbon capture and storage, as opposed to conventional charcoal, which is commonly used as a fuel. Like common charcoal, biochar is the product of pyrolysis of biomass energy raw materials, and its main component is carbon molecules. Scientists became interested in biochar because of research on the black soil of the Amazon. In Japan,the use of biochar in agriculture has a long history. (Hockaday,Grannas,Kim&Hatcher 2007,3440-3443.)

In recent years because of carbon dioxide, nitrous oxide and methane and other greenhouse gases contributing to climate change, scientists began to attach importance to the use of biochar, which will help to borrow by biological carbon sequestration, capture and remove greenhouse gases in the atmosphere, turning it into a very stable form, and stored in the soil for thousands of years. In addition, the use of biochar can increase agricultural productivity by 20 percent, purify water, and help reduce the use of chemical fertilizers. (Brodowski,Amelung,Haumaier&Zech 2007,223–230.)

## 2 PHYSICAL AND CHEMICAL PROPERTIES OF BIOCHAR

Biochar, which has been appearing increasingly in scientific journals in recent years, was identified at the first International Biochar Conference in Australia in 2007. The International Biochar Initiative defines biochar. (Glaser,Lehmann&Zech 2002,213–225.) Biochar is a fine grained charcoal that is rich in organic carbon and difficult to degrade. It is produced by the pyrolysis of plants or waste raw materials at high temperature. It belongs to a type of black carbon in a broad sense. As a soil conditioner, biochar forms a carbon negative soil carbon aggregate and stores atmospheric carbon dioxide in highly resistant soil carbon pools. When biochar is applied to soil, its nutrient persistence is enhanced, which not only reduces the need for fertilizer for crops, but also has a certain impact on climate and the environment. (Tripathi,Stegen,Kim,Dong,Adams&Lee 2018,1072; Shakoor,Riaz, Niazi , Ali,Rizwan,Arif &Arif 2019,386–397.)

For biochar research, the earliest living in the amazon basin from the 19th century it was found that a special kind of special "black soil" contains rich organic matter. The black soil is to restore the productivity of the soil,plantation is early human form of a special kind of fertile soil, rich in biological carbon and other organic material. It plays an important role in restoring soil productivity and improve soil. For thousands of years, the carbon-rich black soil produced by the indigenous inhabitants of the Amazon has dozens of times the carbon content of the surrounding soil, and is far higher than that of other regions. The rich carbon in the soil has maintained its fertility for thousands of years, and the soil is extremely productive. The discovery of Amazonian black soil has brought the study of biochar into a new stage. (Hammes,Torn,Lapenas&Schmidt 2008,1342–1350.)

Biochar now as a product of comprehensive utilization of agricultural wastes, is made up of biomass pyrolysis in the case of a partial or complete lack of oxygen to produce a kind of high carbon content, carbon content of 60% or more) of highly aromatic substances, due to its special physical and chemical properties and its global biogeochemical cycle, environmental system and the important role of climate change, in recent years has become one of the most attractive research direction. (Suda&Makino 2016,70–75.)
The elemental composition of biochar mainly includes carbon, nitrogen, hydrogen, oxygen, and it also contains rich soil nutrients. It is divided into elements such as phosphorus, calcium, magnesium, potassium and trace elements such as manganese, zinc and copper. Generally, the carbon content is as

high as 60% or more. Biochar is generally composed of stable aromatic structure and contains a large number of aliphatic and oxidized carbon structure substances. (Brodowski,John, Flessa&Amelung 2006,540–543.)

The carbon forms of biochar are related to the preparation conditions, the formation process, the characteristics of carbon in plant cell structure, and the geological conditions of the growing place. Biochar produced with different raw materials, temperature and time has physical and chemical properties such as specific surface area, pore volume, pore size, structure, pH, ash content, water retention, apparent density. There is a big difference. Generally speaking, the biochar prepared by different biomass types or carbonization conditions shows different properties. After the biochar is prepared, the good pore structure of the original material is basically retained, with large specific surface area and porosity. Experiments were carried out using high-temperature charred coconut shells and bamboo. 1h later, it was found that the specific surface area of carbonized coconut shell carbon was 410m$^2$/g, while the specific surface area of bamboo charcoal was as high as 370m$^2$/g. Meanwhile, the adsorption capacity of bamboo charcoal fired at high temperature (1000°C) is 10 times that of traditional charcoal, and the specific surface area of biochar prepared from sludge can reach 32. 24 m$^2$/g, which is 5 times that of the original sludge. (Brodowski et al. 2007,223–230.)

Biochar not only have more space, specific surface area is large. At the same time, a large number of phenolic hydroxyl and carboxyl and carbonyl and its amount of surface negative charge and the characteristics of high charge density, can adsorption fixed water, the inorganic ions in soil or sediment and polar or non-polar organic compounds. This for the application of biochar in terms of adsorption. (Glaser B 2007,188–195.)

## 3 THE DIFFERENCE BETWEEN BIOCHAR AND ACTIVATED CARBON

Both activated carbon and biochar are pyrolytic materials containing carbon, important products of environmental technology, and have been studied in depth for a variety of purposes. Strict distinctions between these materials are not always possible and there is a lack of generally accepted terminology. However, research on the two materials is increasingly overlapping: adsorption and remediation are the domain of activated carbon, which can now also be addressed through biochar research. Therefore, research and knowledge of the differences between activated carbon and biochar are necessary for the design of new types of research on pyrolytic carbonaceous materials.
(Janik, Skjemstad,Sheperd&Spouncer 2007,72–80.)

Activated carbon and biochar are pyrolytic carbonaceous materials. They are produced by the thermochemical conversion of carbonaceous materials. (Griscom,Adams&Ellis 2017.) Activated carbon is produced from any carbon source (fossil, waste or renewable) and is designed to be used as an adsorbent to remove contaminants from gases and liquids. Therefore, it is defined as a contaminant absorbent material, and its production material has a general sustainable supply and less treatment methods after the use of activated carbon. (Major,Lehmann, Rondon&Goodale 2010a,1367–1378.) Biochar is produced from sustainably sourced biomass for non-oxidizing applications in agriculture and is also discussed as a raw material for industrial production processes. If biochar is used as fuel, when it is burned and the carbon is converted to $CO_2$, it is actually classified as charcoal. Both materials have their own distinct histories, widely separate scientific communities and separate literary bodies. Unfortunately, generally accepted terms and definitions are lacking. (Haumaier L,2010.)

However, as the applications of activated carbon and biochar increasingly overlap, an understanding of the other areas may be useful in each case. As an example, both activated carbon and biochar are now used for soil remediation, which has been the previous application of only activated carbon. (Chan,Van Zwieten,Meszaros,Downie&Joseph 2007,630–633.) When activated carbon is not removed after application and if this activated carbon is produced as a renewable feedstock and complies with further specifications, it can be considered biochar. In addition, there is a growing need for specialized adsorbents in environmental technologies including wastewater treatment and soil remediation, leading to a lot of research in possible alternatives to conventional activated carbon based biochar materials. Therefore, the purpose of this work is to provide an overview of the definitions, uses, and production of activated carbon and biochar and related pyrolytic carbonaceous materials, in order to highlight their similarities and differences. (Fidel,Laird,Thompson&Lawrinenko 2017,365–370.)

### 3. 1 Activated carbon

Activated carbon was originally defined as any form of carbon that can be adsorbed. Historically, it began with the use of charcoal as an adsorbent, dating back to the Roman and Chinese empires, and possibly even further. The Romans realized that charcoal could purify water. However, although charcoal has a long history of being used for purification, it has taken more than 3,000 years to optimize it to remove specific pollutants. In 1863, Schmidt observed that charcoal removed oxygen from the air for up to a month. However, not all charcoals have the same capacity, and animal bone-based charcoals have higher productivity than wood based charcoals. This is the starting point of a rapidly growing field of research into the differences and properties of charcoal that lead to different adsorption properties. (Griscom et al. 2017.)

As early as the 19th century it was noted that charcoal also contains various adsorbed organic compounds. The first activation reduces the amount of chemicals absorbed after production. Thermal activation is considered to be the only technique to remove the adsorbed organic compounds from the surface of charcoal. Charcoal skeletons still exist and new surface areas are created. Chemical groups become active and can be used for adsorption. (Leifeld,Fenner&Müller 2007,424–435.) With this, the science of charcoal activation and activated carbon began. Several complex factors preclude the determination of the adsorption mechanism. The first factor is that charcoal can be altered even under environmental conditions. After storage under laboratory conditions, the adsorption capacity of $N_2$ changed threefold. The second factor is that even the inorganic precipitated salts on the charcoal contribute to the adsorption process. (Muralidhara 1982,44–58.)

In addition to adsorption, activated carbon can also be used as a catalyst, for example, in the anaerobic reduction of azo dyes, and support the formation of free radicals to oxidize dyes or pollutants in the oxidation treatment of industrial wastewater. It is also used in microbial fuel cells. Today, several markets are increasing the global demand for activated carbon. These include drinking water regulation, energy storage and environmental technologies driven by new regulations, such as clean-up requirements for mercury emissions from power plants. (Hamer,Marschner,Brodowski&Amelung 2004,823–829.)

### 3. 2 Introduction to the modification of activated carbon

In addition to the porous morphology, the surface chemical characteristics determine the adsorption characteristics of activated carbon. Modification refers to the optimization of surface chemisorption of specific sorbate salts. The types of oxidation, vulcanization, nitriding and coordination functionalization are defined. (Verheijenz,Mankasingh&Penizek 2017,141–150.)

Oxidative modification of activated carbon materials is not the same as activation, as oxidation is made by hydrogen peroxide or nitric acid at low temperatures and the main purpose is to generate oxidative functional groups, rather than to increase the surface area. (Masiello 2004,202–214.) In fact, $HNO_3$ in particular is known to reduce specific surface area and pore volume due to the destruction of porous structures. Oxidation and ozonation of activated carbon can also be considered as physical/thermal activation. Sulfurization may also have destructive effects on porosity through the use of $SO_2$ or $H_2S$, for example, significantly increasing the ability to adsorb mercury. Activated carbon nitrification or nitrogen modification is mainly by using ammonia in the gaseous or dissolved state, to increase the polarity and alkalinity, to optimize adsorption, but also the catalytic performance of activated carbon. For example, in the case of biochar, the use of nitrification and subsequent remediation improves the adsorption of copper. Functionalization using ligands is primarily intended to optimize metal adsorption on activated carbon, although it appears to be readily adapted to optimize nutrient carrier behavior for example biochar for soil improvement. For this purpose, activated carbon is treated with a complex organic liquid. (Zhang,Sheng,Wolf&Feng 2004,868–871.)

The strict distinction between activated carbon and biochar depends largely on the end use of these materials. Activated carbon and charcoal have been studied much earlier than biochar and provide a great source of useful information for biochar. For a comparative study of activated carbon and biochar, the two materials can be produced from the same feedstock using different impregnation ratios and burnout rates, respectively, and a comparative series from non-activated activated carbon/biochar production. Such a study would allow for an overall economic assessment, since there would be tradeoffs such as pollutant absorption capacity and yield. (Nguyen& Lehmann 2009,845–850.)

# 4 BIOCHAR BASED FERTILIZER

Charcoal-based fertilizer is a kind of biochar as the matrix, according to different regional land characteristics, different crop growth characteristics and scientific fertilization principle, adding organic matter or/and inorganic compounds prepared by Eco-friendly fertilizer. (Lehmann 2007,140–144.)

## 4. 1 Basic theory of biochar based fertilizer

The basic theory of charcoal-based fertilizer is the charcoal-organic theory of soil fertilizer, that is, to increase the content of charcoal-based organic matter in the soil,rapidly transform the soil structure, balance salt and water. And create a soil environment conducive to the healthy growth of plants through rapid ripening, so as to increase soil fertility and promote crop growth. (Loganathan,Feng,Sheng&Clement 2009,965–973.)

## 4. 2 Basic types of biochar based fertilizers

Charcoal-based fertilizers are divided into three basic types: charcoal-based organic fertilizers,charcoal-based inorganic fertilizer,carbon based organic and inorganic compound fertilizer. (Cui,Wang,Lou,Chen,Yu,Shi,Xu&Khan 2009,609–615.) Charcoal-based organic fertilizer refers to the ecological fertilizer formed by the reasonable combination of biomass charcoal powder and organic fertilizer. Charcoal-based inorganic fertilizer refers to the ecological fertilizer formed by the reasonable combination of biomass charcoal powder and inorganic fertilizer. Charcoal-based organic-inorganic compound fertilizer refers to the ecological fertilizer formed by the reasonable combination of biomass charcoal powder and organic-inorganic compound fertilizer. (Blackwell,Riethmuller&Collins 2009,205–223.)

# 5 PREPARATION METHOD OF BIOCHAR

Biochar is the materialization product of organic matter. There are many kinds of raw materials for the preparation of biochar. Theoretically, all organic materials can be used as raw materials for the preparation of biochar. (Brewer,Schmidt-Rohr,Satrio&Brown 2009,384–395.) Currently, most of the research and application of biochar is based on agricultural waste such as rice stalks, wheat stalks, and corn stalks. Cotton stalk, walnut shell and grass, forestry waste such as pine, palm waste, livestock waste such as pigs, cattle, sewage sludge and as raw materials. These solid wastes produced in the process of industrial and agricultural production, if not effectively disposed of, will not only cause a waste of resources, but also cause environmental pollution and even harm to human health. (Hernandez-Soriano,Kerré,Goos,Hardy,Duffey&Smolders 2016,374–380.) On the contrary, thermolysis of these organic solid residues with less water content into biochar can not only reduce pollution, but also make comprehensive use of resources, which is of great significance. According to the different heating rate and retention time at the highest temperature, biomass pyrolysis can be divided into slow pyrolysis, fast pyrolysis, pyrolytic gasification and flash carbonization. (Liang,Lehmann,Sohi,Thies,O'Neill,Trujillo,Gaunt,Solomon,Grossman,Neves&Luizão 2010,207–213.)

## 5. 1 Slow pyrolysis of biochar

Slow pyrolysis method is the preparation of biochar from biomass in a relatively low heating and drying rate, after a long pyrolysis time (several hours to several days). Charcoal has been prepared by traditional carbonization methods for hundreds of years. Due to the slow pyrolysis condition of equipment and the preparation of biochar request is not high, many research directly using ordinary muffle furnace can be achieved by controlling the temperature, for example, under nitrogen protection of the environment, with muffle furnace with heating rate of 5 ℃ / min respectively (150 ℃, 250 ℃, 350 ℃, 500 ℃ and 700 ℃) and keep the 6 h get straw biochar, yield of 93. 9% 64. 6%, 44%, 38. 7% and 37. 0%. (Wang D et al,2017b. ) Pyrolytic temperature was maintained at 353℃ for 2. 75 h and 380℃ for 2. 5h, respectively, to prepare the biochar from yellow birch and maple sugar trees. (Ronsse, Van Hecke, Dickinson, Prins 2013,108-116.)

However, Keiluweit et al. (2010) prepared pine sawdust and tall fesequa by slow pyrolysis at different temperatures (100-700℃). Brewer et al. (2009) put the corn stalks into a sealed tank, then put them into a muffle furnace, raised the temperature to 500℃ at a rate of 15℃/min, and prepared the cornstalk biochar by slow pyrolysis for 30 min. The bio-yield of the corn stalk biochar was 33. 2%. The yield of switchgrass was 41. 0% after slow carbonization for 2h at the same heating rate to 500℃. Under normal conditions, the production of biochar by slow pyrolysis is carried out under the conditions of relatively low reaction temperature and long reaction time, and the yield of biochar can be compared. Because the required equipment is simple, easy to operate and control, and other advantages, this way more widely used. (Ronsse et al. 2013,108-116.)

**5. 2 Rapid pyrolysis of biochar**

Fast pyrolysis of biomass in anaerobic environment rapidly heated to high temperature, and the biomass pyrolytic conversion of large molecules, generated a small molecule volatile gas product. And product such as tar condensable volatile is rapid cooling as may be the flow of fluid, called biological oil or tar. In fast pyrolysis system, anaerobic environment dry biomass heating rate very fast (up to 1000 ℃ / s), and the product usually need to be in quenching ways to reduce the production of bio-oil, unlike the slow pyrolysis and fast pyrolysis usually get a higher biological oil production rate and low production rate of biochar. (Cheng&Lehmann 2009,1021–1027.)

In addition, the obtained biological subdensity is relatively quotient and acidic (pH 2. 8-3. 8),with higher water content (15%-30%) and lower calorific value. For example, Brewer et al. (2009) prepared different types of biomass by rapid pyrolysis, and the yield was about 15-20% of that of biomass raw materials. Rapid pyrolysis is usually carried out in a fluidized bed reactor. In order to investigate the effects of secondary temperature on the physical and chemical properties and structure of the biomass prepared the bio-products by rapid carbonization (2S) of Pinus brassicalis in a fluidized bed reactor (in an oxygen-free environment) at 300℃, 400℃ and 500℃,respectively. (Busscher, Novak,Evans,Watts, Niandou&Ahmedna 2010,11-14.)

When the pyrolysis temperature rose from 300℃ to 500℃, the yield of biofilm decreased from 60. 7 4 ℃ to 14. 4%. Similar study through pyrolysis at different temperatures (400-500 ℃), the fast pyrolysis of solid waste in Canada (including agricultural waste such as straw, straw and flax, forest residues such as straw sawdust and poultry waste.) in the preparation of different kinds of biochar. Study the pyrolysis temperature on the physical and chemical properties of biochar, and the effects of straw. The results showed that the carbon content of biochar was much higher than that of raw materials, up to 70-80%. And with the increase of pyrolysis temperature, the pH value of biochar decreased gradually. (Antal&Grønli 2003,1620-1640.)

**5. 3 Gasification of biochar**

The gasification and pyrolysis process first converts biomass into gas by controlling the oxidant content at a higher temperature (above 700℃). Effects of different biomass feedstocks and production temperatures on the physical and chemical characteristics of biofilms. The process of mixing (including CO,$H_2$,$CO_2$,$CH_4$ and other gaseous products as well as a small amount of carbohydrates). The yield of biocarbonization from gasification and pyrolysis is usually 5-10% of the biomass feedstock. The oxidant used in the gasification process can be oxygen, air, or a mixture of the two gases. (Agblevor,Beiss,Kim,Tarrant,Mante 2010,299-306.)

Air gasification to produce synthetic gas calorific value is lower 4-7 MJ/Nm$^3$, and the mixture of gasification to produce synthetic gas calorific value high 10-14 MJ/Nm. The scientists in a capacity of 3 kg/h of bubbling fluidized bed reactor using air/nitrogen as a fluidization gas, respectively, in the average temperature is 760 ℃ and 730 ℃ gasification pyrolysis preparation switchgrass and cornstalks biochar, the yield is 10% of the biomass. Due to the high temperature of gasification and pyrolysis, similar to that of rapid pyrolysis, the yield of biochar prepared by this method is significantly lower than that of slow pyrolysis, and the main crystallization obtained is gas. (Brewer, Schmidt-Rohr,Satrio&Brown 2009,384-395.)

**5. 4 Hydrothermal carbonization of biochar**

Hydrothermal carbonization is under certain temperature and pressure, biomass with saturated water as reaction medium. Under the action of catalyst, hydrolysis, dewatering, press, aromatization and condensation reaction of inflammation of biological process, the method according to the real transition temperature and different can be divided into low temperature hydrothermal ashing method (below 300 ℃) and high temperature hydrothermal method (300-800 ℃). The main products of the hydrothermal reaction at this stage are gaseous products, such as methane and hydrogen, because the conditions required for the reaction of thermalization of warm water are much higher than those for the stability of most organic materials. (Mia,Dijkstra&Singh 2017,1-48.)

At present, most hydrothermal methods are carried out at a temperature of 180-250°C and a pressure of 2-10 MPa. Studies on hydrothermal carbonization of biomass have been carried out at home and abroad, using agricultural solid wastes such as silage corn as raw materials. Wheat stalks, corn stalks, wood chips, poultry stool,straw. (Hilscher,Heister,Siewert,Knicker 2009,334-342.) and forest wastes such as willow branches, pine chips and fir branches. Compared with the pyrolysis method, the reaction conditions of hydrothermal carbonization method are usually mild, and the carbonization rate is relatively low, so the aromatic structure in the biological substance is less and the stability of biochar is also relatively poor. (Haumaier 2010;Tripathi,Stegen,Kim,Dong,Adams,Lee 2018,1072.)

However, the process of preparing biochar by hydrothermal process is relatively simple, the yield of biochar obtained is relatively high, and the functional groups are abundant. In addition, this method is carried out in an aquatic environment, which is less affected by the moisture content of biomass raw materials. It is more suitable for commercial-moisture content biomass compaction, and has great application potential for full utilization of resources, reduction of resource waste and mitigation of environmental pollution. Of course, there are many ways to prepare biochar, and the properties of biochar obtained by different pyrolysis methods are different. (Lorenz,Lal 2014,653-670.)

## 6 RESEARCH STATUS OF BIOCHAR

Biochar as a product of agricultural waste resource utilization, biomass such as wood, crop waste, plant or animal waste in anoxic and anaerobic conditions, such as low temperature pyrolysis to form a higher carbon content of a kind of material, applying the soil can not only increase the storage of the carbon in the soil, reduce the release of $CO_2$, but also can be used as a soil conditioner, improve soil physical, chemical and biological properties, improve soil fertility and productivity. At the same time, biochar can also promote plant growth, slow decomposition, reduce the bioavailability of heavy metals and organic pollutants, and is widely used in the fields of agriculture and environmental protection. (Lehmann 2007,140-144;Leifeld et al. 2007,424-435.)

Biochar technology has gradually become a research hotspot in agriculture and ecological environment at home and abroad. International Biochar Initiative(IBI) has promoted the rapid and healthy development of the global Biochar industry. (Hammes&Abiven 2013,158-176.) In 2009, the UK's Lausanne experimental station launched a long-term Biochar localization pilot program at Woburm Farm. The Brazilian Agricultural Research Corporation, Embrapa, has launched a biochar project that aims to create more "rich, high-carbon black soil". The establishment of China's first Biochar Network Center in 2010 has played a positive role in promoting the development of biochar research and application. (Major et al. 2010a.)

Researchers at home and abroad have done a lot of research on the properties of biochar and its effects on soil improvement, crop growth and ecological environment improvement. There have been many ideas about the effects of biochar on soil improvement and crop yields, as well as on carbon sequestration and emission reduction to improve the ecological environment. (Hileman 2007,32-35.) However, there is still a lack of systematic research, especially in-depth research on the mechanism of biochar. Therefore, it is urgent to broaden the research field of biochar, explore its mechanism, and conduct systematic and in-depth research. At present, the production and application of biochar has not attracted enough attention, and there is still a lack of a perfect industrial chain. Therefore, biochar has not been widely applied and is still in the stage of experimental research. Some studies have shown that biochar can increase the degree of soil alkalization, but its application has certain limitations. Therefore, appropriate biochar should be screened and prepared according to different soil types. Biochar industry should be based on the recycling of waste resources to avoid environmental pollution. Using biochar returning technology to reduce carbon dioxide emissions can fundamentally solve the problem of resource waste and achieve sustainable development of agriculture. (Blackwell P et al. 2009.)

# 7 APPLIED RESARCH ON BIOCHAR

As an important product of biomass thermochemical conversion, biochar has received much attention because of its wide application prospect. Biochar is a kind of high quality soil conditioner, and can also be used as pollutant adsorption material and carbon dioxide sequestration agent. Biochar has been widely used in soil improvement, water purification, heavy metal adsorption, carbon sequestration and emission reduction. It also has the potential to address problems such as soil degradation, environmental pollution and climate change. (Chen,Zhou&Zhu 2008,5137-5143.)

## 7. 1 Agricultural applications

Soil degradation may be caused by human activities such as mining and industrial activities and agricultural production processes. Biochar applied to soil can effectively improve soil structure, increase soil fertility and promote plant growth, so it is an excellent soil conditioner. (Lehmann J 2007;Major J et al. 2010a.) People's attention to biochar also stems from the discovery and research of Terra Preta in the Amazon region. (Loganathan,Feng,Sheng,Clement 2009,965-973.)

Biochar has high organic carbon content and pore structure, which can be applied to soil as a soil regulator to improve soil physical, chemical and biological characteristics. For example, the application of biochar to soil can significantly improve soil pH, change soil texture, and enhance cation exchange capacity, electrical conductivity and water holding capacity. According to research reports, the water holding capacity of soil after biochar is applied can be increased by about 18%, which may be related to the hydrophobicity and surface area of biochar. (Verheijen et al. 2017.) After biochar restoration, soil capacity, pore structure and water conductivity is significantly increased. (Janik,Skjemstad,Sheperd,Spouncer 2007,72-80;Abiven,Schmidt&Lehmann 2014,325-327.) In addition, due to the unique surface characteristics of biochar, it can strongly adsorb different kinds and forms of nutrient elements (N, K, P) in soil aqueous solution, thus reducing the loss of nutrient elements. (Major et al. 2010a;Liang et al. 2010.) For example, the study of  Laird et al(2010a) found that after adding different pig manure biochar to agricultural soil, the total amount of N, P, Mg and Si nutrient elements in the leachate decreased significantly with the increase of the addition amount of biochar. After adding 20 g/kg biochar, the leachate amount of N and P decreased by 11% and 69%, respectively. Biochar itself also contains nutrients that can be released when applied to the soil to increase soil fertility. (Nguyen et al. 2008,845-850.)

On the other hand, biochar can be mixed with other organic or inorganic fertilizers and applied to soil, which plays an important role in increasing crop yields, reducing irrigation needs and enhancing fertility efficiency. In addition, the application of biochar to soil can also reduce the loss of soil inherent nutrient elements. However, the research on the use of biochar as soil remediation agent to improve crop yield is still under study, and no unified conclusion has been reached so far. (Ronsse F et al. 2013.)

The effect of biochar on crop yield can be either stimulative (e. g. , 60% increase) or inhibiting (e. g. , 30% decrease), depending on the type and nature of the soil. (Bruun,Jensen,Jensen 2008,838-844.) Some types of biochar may increase crop yields by as much as 100%, while others may reduce crop yields by this amount. Second, the influence of different types of soil. The positive effect on crop growth is usually found in highly degraded and nutrient-deficient soils. At present, there are no reports that applying biochar to fertile soil can significantly improve crop growth. It can be seen that the effects of biochar applied to soil on crop yield have great differences. Such large differences are likely due to the wide range of biochar application rates and differences in crop and soil properties. Different types of biochar may also have different response effects. Therefore, the effect of biochar application on crop yield needs further study. Currently, large amounts of biochar are applied to agricultural systems in order to increase soil organic carbon content, which has an important impact on soil microbial activity. (Hammes&Abiven 2013,158-176.)

Lehmann J et al,(2007) reported that biochar and soil microorganisms can have direct and indirect interaction effects. Although biochar does not provide a suitable habitat for soil microorganisms directly, (Qiu&Guo 2010,380-385.) but the activity of soil microorganisms is indirectly affected by soil porosity, pH, ion exchange capacity and adsorption characteristics. For example, soil microorganisms can directly utilize the active components in biochar as their energy source. However, Ameloot et al. (2014) showed that the activity of soil microorganisms would decrease during 1-4 years of field biochar remediation experiments, which was not consistent with the results of short-term experiments in other laboratories. This difference means that more research is needed to further explore the effects of biochar on soil microorganisms. (Clough,Bertram,Ray,Condron, O’Callaghan,Sherlock&Wells 2010,850-853.)

### 7. 2 Remediation of environmental pollution

Due to their porous nature, biochar can also adsorb inorganic, organic, and viral microbial contaminants, significantly reducing their activity and toxicity. On the contrary, soluble or colloidal biochar particles can also serve as carriers for these pollutants to accelerate their migration in the environment. (Wang,Fonte,Parikh,Six&Scow 2017b,111-118.) Biochar can not only improve the chemical and biological properties of soils, but also alleviate environmental problems such as the migration of heavy metals (Cu,Zn) and organic pollution (such as pesticides) from soils. The adsorption behavior of biochar on different pollutants (such as heavy metals, organic pollutants and other pollutants) is different, which is related to the characteristics of pollutants. (Qiu et al. 2010.) The adsorption mechanism of pollutants is also related to various properties of biochar, including surface functional groups, specific surface area, pore structure and mineral composition. The effect of biochar on the migration, transformation and bioavailability of organic pollutants in the environment has always been one of the hot topics of researchers. (Chen et al. 2008;Cetin,Moghtaderi,Gupta, Wall 2004,2141-2150.) The adsorption capacity of biochar for organic pollutants in soil is not only controlled by the carbonized and non-carbonized components of biochar, surface area and comprehensive characteristics. (Qiu et al. 2010.) but also affected by the hydrophilic groups on the surface of biochar. (Janik,Skjemstad,Sheperd,Spouncer 2007,72-80.) The mechanism of biochar adsorption of organic pollutants is also very complex, including electrostatic reaction, hydrophobicity, hydrogen bonding and hole filling. Usually, the adsorption of pollutants by biochar is the result of a variety of different reactions. For example, Beesley et al. (2011) discussed in detail the interaction mechanism between biochar and organic pollutants. The adsorption rate of lignin biochar on aromatic compounds such as polycyclic aromatic hydrocarbons is relatively fast, and its adsorption mechanism includes electron interaction and pore-filling mechanism, (Chen et al. 2008.) multi-molecular layer adsorption, surface covering, compression condensation in capillary pores, and adsorption into complex polymer matrix. (Almendros G et al, 2003. )

In summary, the adsorption of organic pollutants by biochar is mainly focused on persistent organic pollutants such as polycyclic aromatic hydrocarbons. For example, Chen B et al. (2008) compared the adsorption properties of orange peel biochar prepared at different temperatures for violet and 1-phenol. Cheng C-H (2009), such as rice straw as raw material, the preparation of different under different temperature conditions of straw biochar. Then they study the biochar nitrobenzene in water, of

nitrotoluene, polycyclic aromatic hydrocarbons (purple) and organic matter, such as adsorption performance and influencing factors. And discusses the biochar may exist for these organic pollutants adsorption mechanism and structure-activity relationship. (Almendros,Knicker,González-Vila 2003,1560-1567.)
In addition to studies on the adsorption of PAHs, the adsorption of new persistent organic pollutants, polybrominated diphenyl ethers (PBDEs), has also been reported. Jia and Gan (2014) compared and studied the locking behavior of different biochar on PBDEs in soil. In addition, although there are many reports on the adsorption behavior of biochar to heavy metals in environmental pollutants, researchers have not reached a consensus on the adsorption mechanism of biochar to heavy metals. It is generally believed that biochar itself has high specific surface area and high surface energy, which means that its surface has a high complexing ability of heavy metals, so it can achieve the purpose of removing heavy metals from water or soil by combining with metal ions (Blackwell et al. 2009,205-223). These adsorption processes can be attributed to the complexation of heavy metals with surface functional groups of biochar, the exchange of biochar with metal ions ($Ca^{+2}$ and $Mg^{+2}$), or physical adsorption. (Lorenz&Lal 2014,653-670.) In addition, oxygen-containing functional groups on the surface of biochar can also stabilize heavy metals such as $Pb^{+2}$ and $Cu^{+2}$ . (Ronsse F et al. 2013.)The surface area and pore structure of biochar are also important factors affecting the adsorption behavior of heavy metals, but the influence on the adsorption behavior of heavy metals is less than that of surface oxygen-containing functional groups. (Fidel,Laird,Thompson,Lawrinenko 2017,365-370.) The adsorption mechanism is also greatly affected by soil types and cations in biochar. Some other components of ash, such as carbonate, phosphate or sulfate. (Garcia-Perez 2008.) also play a role in the stabilization of heavy metals through precipitation.

Alkaline properties of biochar are considered to be a factor that reduces the availability of heavy metals in biochar remediation soils. High pH biochar applied to soil can lead to heavy metal deposition. In addition, biochar can also reduce the migration ability of heavy metals and change their redox state. For example, Cr (VI) changes to a less mobile Cr (II) form when biochar is applied. (Bornemann L et al. , 2008. ) Therefore, the adsorption mechanism of biochar on heavy metals also involves many reaction effects, including electrostatic attraction, ion exchange, physical adsorption, surface complexation or sedimentation. However, the relative contribution of biochar to the stabilization mechanism of heavy metals still unclear, they attempted to use biochar to remediation mine soil contaminated by a variety of pollution, and found that the bioavailability of Cd, Pb and Zn and the migration of Cd, Cr and Pb were significantly reduced after biochar was applied to the soil. (Bornemann,Welp,Brodowski,Rodionov&Amelung 2008,1539-1544.)

Hammes K et al. (2013) analyzed the effects of 10 kinds of biochar (5 raw materials, 2 temperatures) on soil heavy metals. The results show that high or low ash or P content has little effect on the migration of heavy metals. Conversely, biochar prepared at 700°C is more effective, which may be caused by transformations in its raw material, including the removal of heterocyclic atom N and leachable aliphatic functional groups.

**7. 3 Mitigating climate change**

It is well known that since industrialization, man-made $CO_2$ emission is an important factor leading to global warming. For the immediate benefit of humans and the natural environment, immediate and effective measures are needed to reduce and control GHG concentrations to mitigate climate change. Currently, scientists generally believe there are two ways to reduce the concentration of greenhouse gases in the atmosphere. (Major et al. 2010a.)

One way is to reduce greenhouse gas emissions to the atmosphere, (to mitigate climate change. ) and the other is to remove greenhouse gases from the atmosphere (carbon dioxide removal or carbon storage). (Glaser 2007,188-195.) Specific measures to reduce greenhouse gas emissions include increasing fuel combustion efficiency (fossil fuels), replacing fossil fuels with renewable energy sources, and capturing and storing greenhouse gases emitted by industry or power plants in the deep sea or in geological formations - also known as carbon capture and storage. (Venegas,Rigol,Vidal 2015,192-198.) In turn, measures to remove greenhouse gases from the atmosphere include afforestation, ocean iron fertilization, or enhanced weathering. As a solid substance with high carbon content and strong stability, biochar can exist in the environment (soil) for a long time, and it has a broad application prospect in carbon dioxide removal methods. (Glaser 2007.)

Biochar can not only store carbon in soil, but also improve soil quality. The mitigation effect of biochar on climate change mainly comes from the inert characteristics of biochar itself, (Cheng et al. 2009;Nguyen et al. 2009.) which reduces the return of fixed carbon produced by photosynthesis to the atmosphere. Biochar can also improve soil fertility, promote plant growth, and thus consume more carbon dioxide, while the energy generated in the preparation of biochar can also be used as a supplement to reduce the use of fossil fuels. In addition, applying biochar to the soil significantly reduces $NO_x$ emissions (reducing the amount of nitrogen fertilizer used). Since $NO_x$ is about 320 times more potent than carbon dioxide, biochar plays an important role in mitigating greenhouse gas emissions. However, the mechanisms and quantitative methods involved still need to be further studied. It has been calculated that the potential contribution of biochar to climate change mitigation on a global scale is 12% of the currently believed total $CO_2$-C emissions, while the total net offset of biochar over the past century was 130 Pg$CO_2$-Ce. (Lehmann 2007,140-144.)

These results are feasible at current levels of fuel availability, biodiversity conservation, ecosystem stability and food security. Their study also shows that if the maximum conversion of all sustainably obtained biomass to bioenergy, rather than to biochar, the net offset would be about 10 per cent of current anthropo-induced CORCE emissions. The potential of biochar and biochar to mitigate climate change mainly depends on factors such as soil remediation fertility and carbon density and the type of biomass. (Major et al. 2010a.)

### 7. 4 Waste disposal

With the growth of population and the improvement of urbanization, the waste discharge from industrial and agricultural production process is increasing. As the country with the largest output of agricultural waste in the world, China produces 700 million tons of crop straw every year, of which 230 million tons are straw and 220 million tons are corn stalks. In addition there are a large number of livestock and poultry excrement and forestry waste and municipal garbage. (Chen et al. 2008.)

If not effectively and reasonably disposed, a large number of agricultural, municipal and forestry wastes are directly incinerated or placed for natural degradation. Thus releasing a large amount of carbon dioxide and methane back to the atmospheric environment, causing serious pollution to the environment and ecology. (Agblevor et al. 2010,299-306.) In addition, the pollutants produced by livestock waste seriously pollute local groundwater and surface water, which not only cause huge waste of resources, but also lead to serious environmental problems and pose a serious threat to human health. If these large amounts of waste can not be properly managed and disposed of, it will not only cause a huge waste of resources, but also cause environmental pollution and threaten human health. Therefore, strengthening the management and resource utilization of these industrial and agricultural wastes has gradually become an effective way to solve the problems of resources and environment. (Ronsse et al. 2013.)

Studies have shown that straw, wood, city garbage, livestock and poultry manure and other organic material sources, low price. If these waste pyrolysis way into biochar can not only reduce the solid volume and quality, also can avoid the problems of environmental pollution due to burning, and get the biochar products can also be as the by-product of the biomass energy. Utilization of biochar many benefits in agriculture, ecological environment and energy. The conversion of waste biomass to biochar should not conflict with other uses such as food processing or returning to land. Therefore, the conversion of waste to biochar by pyrolysis has great potential and is economically feasible in waste disposal. (Liang et al. 2010.)

### 7. 5 Research on the application of biochar in new energy field

China's rapid economic development has been based on a high energy consumption, high emissions, high pollution of the energy structure, is not sustainable development mode. The increasing energy crisis has become a bottleneck restricting economic and social development. With the exhaustion of fossil fuels, it is urgent to actively develop and utilize new alternative energy sources, optimize the energy industrial structure and establish a new system with multiple energy sources coexisting. (Sohi et al. 2012,1032-1035.)

Biomass energy is the only renewable carbon source on earth, which has special advantages in environmental protection and resource utilization. It is considered to be an important source of energy and chemical fuel in the future and has great development potential. The research and development objects of biomass energy generally refer to agricultural and forestry wastes such as rice husk, sawdust, peanut shell, straw as well as some energy plants, aquatic plants, some industrial and domestic wastes. Biomass has the remarkable characteristics of large reserves, wide distribution, easy access, renewable and low cost. (Cui et al. 2009,609-615.)

Biomass energy conversion technology can efficiently produce all kinds of clean energy, replacing coal, oil and natural gas, which is an important way to save energy in the energy field. Biomass energy utilization technologies mainly include direct combustion, liquefaction, gasification and solidification. Each of these technologies has its own advantages, but in practice, there are many problems such as high production cost, limited application and low utilization efficiency. (Almendros et al. 2003. )

Biochar is difficult to popularize it in a large area. With the improvement of low cost carbon production technology, biochar will probably gradually become the main form of efficient utilization of biomass energy. However, because the agroforestry biomass available for carbon production is distributed in the vast rural areas, the amount is large and scattered, and the collection, storage, transportation and processing all have insurmountable difficulties. The biochar industry remains at a standstill. (Sun et al. 2014.)

Shenyang agricultural university "biochar in liaoning engineering technology research center" after studying, invented the new technology of coking furnace "particles" production. It completely solve the "bottleneck" problem in the preparation of biochar, the agriculture and forestry biomass waste collection storage and transportation, different concentration carbonization and deep processing, agriculture, forestry and waste biomass in the origin in situ carbonizing. (Tripathi et al. 2018.) The deep processing of carbon collection in different places or in situ completely solves the contradiction between the concentrated carbonization and the difficulty of the dispersion, collection, storage and transportation of agricultural and forestry biomass, and makes the large-scale carbonization and utilization of agricultural and forestry waste biomass possible. (Weber 1993,32-36.)

The technology does not require expensive production equipment and high manufacturing costs, and almost no additional energy is needed in the production process. Carbonization of waste biomass in agriculture and forestry will be realizedThe biochar produced by this technology has good combustion performance, high calorific value, clean and pollution-free characteristics. (Hilscher et al. 2009,334-342.) The carbon biomass coal produced by plastic post-generation has high heap density and strength, easy to store and transport, clean and environmental protection, high combustion efficiency. It can replace gas, coal and other non-renewable energy, widely used as a new energy for rural scattered heating and heating. And it can be used for urban central heating, power generation. In actual use, carbonized biomass coal is easy to ignite smokeless, tasteless, pollution-free, less residue, light weight, high calorific value, combustion and use performance are better than similar fuels. It can replace wood, raw coal, liquefied gas and other common fuels of the new renewable energy, market development potential is huge. (Glaser B et al. 2002.)

It can be predicted that with the exhaustion of fossil energy resources, the price of fossil fuel will rise sharply. The renewable and low cost advantage of biomass energy will become prominent. Combined with China's national conditions, it will be an inevitable choice to vigorously develop and apply carbonized biomass coal, which is made from agricultural and forestry waste biomass. (Cetin, Moghtaderi,Gupta&Wall 2004,2141-2150)

## 8 CONCLUSION

As the product of agricultural waste recycling, biochar from different sources has different contents of C, N and H, and its carbon content is relatively high, and the carbon content gradually increases with the increase of preparation temperature. Regardless of maize straw charcoal or peanut shell charcoal is alkaline, and along with the enhanced temperature alkaline, maize straw alkaline stronger than the peanut shell carbon, for the corn straw charcoal modified acid soil provides good foundation, (Brewer et al. 2009.) also provide a reference for subsequent development and application of carbon basal basis: maize straw and peanut shell carbonization rate varies with temperature rise and fall.

Biochar has a long history of practical value in agriculture. The use of biochar has been found in the Amazon. It is a good soil conditioner. It was found that biochar has high organic carbon content and pore structure, and application of biochar in soil can significantly increase soil pH value, change soil texture, and improve cation exchange capacity, electrical conductivity and water holding capacity. (Brodowski et al. 2006.)

Soil microorganisms can directly use the active ingredients in biochar as energy sources. Only recently have they begun to study these aspects. The effect of biochar on soil improvement depends on the nature of the soil. Biochar can play an important role in environmental protection because of its own adsorbability and other properties. Due to its porosity, biochar can also adsorb inorganic, organic, and viral microbial contaminants, significantly reducing its activity and toxicity. It can be used as a carrier for pollutant transport. (Shakoor et al. 2019.) The adsorption capacity of biochar on organic matter and heavy metals is relatively better.

Biochar has great promise in dealing with the greenhouse effect. Biochar has the advantages of high carbon content and strong stability, which is of great help to biological carbon sequestration.
With the growth of population and the improvement of urbanization, the waste discharge in the process of industrial and agricultural production is large. (Mia,Dijkstra,Singh 2017,1-48.) A large amount of agricultural, urban and forestry wastes need to be properly treated. If they are directly incinerated, a large amount of carbon dioxide and methane will be released back to the atmosphere, causing serious pollution to the environment and ecology. In addition, pollutants from livestock and poultry waste have seriously polluted local groundwater and surface water, causing serious environmental problems and posing a serious threat to human health. Research showed that straw, wood, municipal waste,

animal manure and other organic material source, low price, if these waste pyrolysis way into biochar can not only reduce the solid volume and quality, also can avoid the environment pollution problem caused by the burning, and obtain the biochar products also can be used as a by-product of biomass. (Bird,Moyo,Veenendaal,Lloyd,Frost 1999,925-930.)

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