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Advances in preparation and applications of Biochar and its composites

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Abstract: With specific surface area, high adsorption capacity, low cost, and strong stability, Biochar has been widely applie D to improve soil quality, increase soil carbon sequestration, remediate polluted environment, and reduce soil emissions of greenhouse gases. Recently, efforts have been made to enhance the adsorption capacity of biochar by preparing biochar-based composites with New properties and new structure via combining biochar with the other materials physico-chemically. This review summarized the preparation, characterization, and applications of Biochar and biochar-based. The adsorption behavior and remediation mechanisms of biochar and its composites in soil and water environment were ssed in details. Key points and directions on Biochar Composites were proposed.

Keywords: biochar; composite material; organic pollutants Pollutants

biochar (biochar - refers to raw material in anaerobic or anoxic conditions , at a certain temperature (<700 " pyrolysis generation High carbon content of , solid biofuel with a larger specific surface area , also is called biomass carbon [1]. Common biochar includes charcoal , rice husk charcoal , straw Xuan Charcoal and bamboo charcoal etc [2]. They are mainly composed of aromatic hydrocarbons and elemental carbon or have a "graphite structure of carbon composition , except C element , The also includes H ,O , N ,S and a small number of trace elements ' Although the nature of Biochar is prepared by the bar items have greater impact , but overall , Biochar has a large surface area , Bulk Weight small , Stable high , Strong adsorption capability [4] , is widely used in ecological repair , Agriculture and environmental protection [5]. add biochar to soil ,not only Increase soil fertility , increase crop yields , can also effectively adsorb soil Heavy metals in soil or sediments (like Pb Hydrate ,Cd Hydrate ,Hg 2 + and organic pollutant(like pesticides , PAHs gas at the same time , Biochar has a high Chemical stability , hard to degrade by biodegradation , can play a fixed atmosphere Carbon ,, Increase emissions , Mitigating the effects of climate change . biochar from wide Universal , is a greener , more cost effective material , is thus advantageous for its application in environmental remediation [7] .

The ability of biochar to adsorb contaminants depends on their physical , Chemical quality , the properties of the Biochar prepared under different raw materials and pyrolysis conditions are very big difference . Jeffery etc [8] compare different pyrolysis temperature (with~) X) Physical and chemical properties of the prepared biochar ,found with cracking temperature increased , biochar yields lower , ash content increase , than the surface

Product Increase , PH elevation , surface charge reduction ; during high temperature pyrolysis , Wave The removal of organic matter makes biochar C content elevated,H,O Low content , Bio-carbon surface ion Functional Group Reduction . The reduction of the ion functional group to some extent reduces the knot of biochar and metal ionsclose with ability _. In addition , Bio-carbon to environment with solid-liquid separation Difficult disadvantage . research

shows ,_ The adsorption of contaminants on composite materials effect better than single material [one.] so , There are

currently some scholars close Use a combination of biochar and other materials , take physical ,Chemical Side method to combine biochar with other materials to have new performance , new knot construct material , Its overall performance is superior to the original composition of the material , to me*et al*l kinds of Different requirements .

In this paper, the preparation methods of Biochar and its composites are summarized and the in the application of environmental pollution remediation . for different types of biochar composite material , summarizes the basic methods of preparation and the action machine for contaminants reason , The provides references for the study and application of bio-carbon composites .

1. Preparation and characterization of biochar and its composites

1.1 Preparation of Biochar and its composites

1.1.1 biochar

in the traditional agriculture phase , crop waste is generally burnt burn The fields in a way that is handled , People usually use the soil to cover the The biomass method of ignition to achieve smokeless combustion in anoxic conditions Burn , after burning biochar left in the soil , can improve the soil and increase the the soil fertility . with the development of technology , current Biochar preparation more than kiln for , Increased efficiency , but basic principles and traditional agricultural hands The section is the same .

the commonly used method of preparing Biochar is Pyrolysis method , is the oxygen limit warming carbonization . According to different reaction conditions, the pyrolysis method can be divided to two kinds : _ is quick pyrolysis , reaction temperature generally , with on , the preparation of biofuels usually takes this approach ; Other _the normal rules cracking Act , temperature generally in % below , biochar mainly used this method . research shows , category of biomass raw materials The nature ofbiochar (space structure and characters) has an impact . in the same cracking condition , bio-carbon with different biomass sources not only stable qualitatively different ,adsorption capability for contaminants , the physical and chemical properties of the soil affect also different [1m51 . ameloot etc reports different sources of biomass effects on bio-carbon Properties , higher lignin content in raw materials , system prepared bio-charcoal material aromatic c content and c: N The higher the ratio , at the same time the salinity of biochar is lower . In addition to raw material species class , pyrolysis temperature is also a biological carbon preparation process one A very criticalfactor , It not only affects the yield of biochar , also controls health surface structure and adsorption properties of carbon . Chun wait reports different temperature (300 ~700 " the difference between the bio-charcoal prepared by , found with

temperature Increase (300~600), bio-carbon specific surface area increase (116~ 438 m2[g1 , and when the pyrolysis temperature rises to the ? Zhang , biochar ratio table area reduced (363 m 2 * G -), description Biological Charcoal Table face one Some fine pore structures are destroyed , The visible temperature is the decision Biocharimportant factor for surface structure . Chen Baoliang etc [a] research Zhang and ? Bio-carbon and organic pollutants from the cleavage of the. (naphthalene , Phenol ,methyl naphthol , between two nitrobenzene interaction mechanisms , discovery Next System Carbon for organic matter adsorption by distribution and surface adsorptionInteraction ,% adsorption of organics on organic compounds by surface adsorption is dominant . Study on the preparation of bio-carbon by using pine needles the also found , in The Biochar prepared under the is highly polar and fat sex , increase with temperature (100~700, aromatic Play of Biochar Increase , But polarity drops quickly ,Biochar gradually from the Soft Carbon transitions to Hard Carbon and rapid increase in surface area (0.65 m2 * G 1 added to 490.8 m2 . G 1 [?] 0 Lu Network study different pyrolysis temperature , different security Effect of time on biochar stability , finds with cracking temperature elevation and retention extensions , biochar Methyl (–CH) and sub - methyl (-CH) fade away , aromatic ring structure increased , biochar Aromatic degree enhanced ,H / C Drop , visible cracking temperature and cracking time will beaffects Biochar properties .

The application of biochar in the field of environmental protection has been studied at home and abroad general

concerns , However, due to its high temperature cracking process loss Department Split-ion functional Group , Insufficient solid-liquid separation after adsorption , has learned people begin to study compound biochar with other materials , improving biochar physical and chemical properties , to enhance its adsorption capacity . bio-carbon composites the Preparation of is usually added to biomass raw materials (magnetic material , Nanomaterials , inorganic salts, etc.), and then prepared by pyrolysis to composite (process diagram 1 shows . The following are some common types of health carbon composites .

Biomass raw material raw materials and bio-Charcoal -

Other materials Q Solution Blending Q composites

diagram 1 Biological Carbon Composite preparation process

Figure 1 Procedure for preparing biochar-based composites

1 2 biochar - Magnetic composites

uses the adsorption properties of Biochar itself , with other material composite to new material , to give biochar new performance . to magnetization the adsorbent is a new water treatment technology , After adsorption, you can to recycle the absorbent material through an external magnetic field , the non-magnetic suction is overcome

problems with the separation of solid and liquid by attachment , to provide a for the application of Biochar has a new advantage . According to current research , Most scholars choose to pass prepared bio-carbon water suspensions with Fe3+/ Fe2+ solution blending , use Fe3 +/ Fe2 + to magnetized biochar , Simpler preparation process ,easy to operate . to than magnetized char properties (specific surface area , aperture , surface element composition , magnetic intensity, etc., and the ability to adsorb contaminants can be explained by biochar - Advantages of magnetic composites . other , from applied angle See , biochar cheap , source wide , with other magnetic adsorption agent (such as magnetic nano ferric oxide , 0 iron and so on compared to have a larger application space [21-25] .

Mohan , and so on [a] first place the rubber tree and the rubber bark in the 400, 450 The rapid pyrolysis of carbon into Biochar , will be made of biochar suspension liquid vs Fe3+ /Fe2+ Solution Mix , to add NaOH adjustment response system's PH to ten, after aging , clean , dry make magnetic oak biochar (MOWBC and magnetic oak skinbiochar (mobbc , details fine flow diagram 2 shows . identify two composite materials with a "" increase by the token , is 1.40%~80.6% (MOWBC , 0.21%~ 51.3% (mobbc ,describes the preparation method that is used to effectively make the health Carbon magnetization . reduction of material in the process of metal oxide and biochar material organic content , increases the porosity of the composites (MOWBC 0.01~0.69 cm3 . G-1; MOBBC 5.4xten Nine 0.48 cm3 . G -), however

The specific surface area of two composite materials is reversed . , MOW - BC the specific surface area of the is from the 2.04 m2 . G - 1 added to 6.1 m2 . G 1 , and mobbc on specific surface from 25.4 m2. G - 1 drops to 8.8 m2. G 1 . This largely depends on the NaOH removal of surface tar from Biochar , because they react to produce soluble salts ,and mobbc " , " Large number of Ca with NaOH Solution Forms insoluble Salts , So comparison table changes in area with different trends ; another , Fe 3+ introduction of leads to biological convert from single particle to mixed particle , overall density of composites more difficult to establish . This indicates a change in the specific surface area of the composite. different [-*-]. will be made of composite materials for processing in water Pb"" , Cd2+ , finds saturated adsorption of magnetic Biochar (QMOWBC : PbHydrate 30.2 mg *g -1 , Cd2+7.4 mg *g- 1 ; QMOBBC ; Pb Hydrate 10.13 mg* g-1, Cd 2 + 2.87 mg • G -) significantly larger than not magnetized bio-carbon (QOWBC : Pb 2 + 2.62 mg • G 1 , Cd 2 + 0.37 mg • G 1 ; qmob - BC : Pb Hydrate 13.10 mg . G 1 , Cd Hydrate 5.40 mg . G -) net . Devi etc [+] , 0 price ferromagnetic biochar (ZVI-MBC , First make paper sludge to be cracked into bio-charcoal under %, , and then biochar with 16-alkanes Base three methyl bromide (ctmb mixed , in after drying , and then Add to feso4' 7H2 NaBH4 Mixed solution , Stir fully min Filter , To make the mixture dry by ZVI - MBC Blends material ; compound after ZVI - MBC specific surface area of (BC M 2- - g-1,

ZVI-MBC 101.23 m2 - G ") and Aperture (BC 3.17 nm , ZVI - MBC 4.78 nm) all increased . through Fourier

infrared spectroscopy (FTIR Compare surface functional group changes before and after composites , find complex composite material ZVI- MBC The number of functional groups on the surface of the increases Tenki , Alcohol , etc ;Composite material ZVI - MBC for actual wastewater five chloro (PCP removal , finds its pair of PCP The removal rate of is significantly High (BC : ~80% ZVI - MBC : 100%).

To summarize , after the bio-carbon magnetization, the specific surface area and aperture increase Large , Surface functional group increased , These are all adsorbed contaminants. main mechanism , Therefore, the removal capability of magnetic composites for pollutants significantly increased , and easy solid-liquid separation after adsorption , Only with an external magnetic field can be .

1.1.3 biochar - Nano-composites

The preparation of new composite materials using biochar and nanomaterials , to display to Improve the performance of Biochar, including enhancing soil fertility ,Carbon Storage and sewage treatment . currently studying more Biochar - nanocomposites main graphene , carbon nanotubes , nanometer oxide , In addition to the Nano 0-iron (the latter gives composite magnetism , in magnetic composites explained). bio-Charcoal - Preparation of nanocomposites by dipping method , Direct raw raw material directly to suspension of nano material Close , Stir evenly after drying , then at high temperature lower limit oxygen anaerobic / cracking . system Composite not only larger than surface area , surface charge more , acidic officer number of groups increased , with better thermal stability , To apply .

Inyang , and so on Carbon nanotubes prepared by dipping method / biochar (Carbon nanotube - Biochai), separate raw raw material mountain Walnut fragments and bagasse are immersed in carbon nanotube suspensions , Full Stir 1 H after drying in oven , then add mixture to tube furnace oxygen Cracking 1 H , Carbon nanotubes -Hickory biochar composite (HC - CNT) and carbon nanotubes - sugarcane residue bio-carbon composite material (BC - CNT). with raw Hickory biochar (HC and bagasse biochar (BC compared to, added carbon nanotubes increased thermal stability of biochar , surface area women 0:289 with 2 ^1, [^- CNT:352 m2. G 1 ; BC : 9 m2 . G 1 , BC -CNT : 390 m2 . G -),- hole Gap Volume (HC0.001 ML . G 1 , HC - CNT : 0.138 ML . G - 1 ; BC : 0.000 ML . G 1 , BC - CNT : 0.220 ML . G -)/ surface charge (Zeta potential HC : -28.8 MV , HC - CNT : -41.4 MV ; BC : -32.7 mvbc - CNT : -44.6 MV , optimization of these traits makes a compound The material's ability to remove methylene blue significantly improves women's 0:9%, only 0- CNT : 47% BC : 25%, BC - CNT : All %) . Zhang etc [+] using The same method as prepared graphene cladding Biochar (Graphene - coated Biochai composite , Apply made composite to remove methylene blue in water , Its saturated adsorption of methylene blue amounts to through 174 MGF1, far greater than biochar saturation adsorption of methylene blue amount 8 mg. G-1 . Zhang etc [a] After to prepare biochar / Turner m alumina composite for removal of methylene blue in water , its saturation adsorption amount by 8 mg' g-1 increase to mg'-1 , Add the nano-alumina The plus significantly enhances the removal of biochar from methylene blue .

To summarize , nanomaterials not only have large specific surface area but can have To adsorb All types of contaminants , and its surface chemical groups (carboxyl , - hydroxyl , High affinity adsorption sites provided by , can increase nano Material's ability to combine contaminants . but nanometer material solubility poor , and easy to reunite in the environment , These disadvantages restrict nanomaterials extension [a], so that it has a very low cost source with a wide range of creatures Carbon composite ,Improve composite performance , has actual environmental implications . 1.1.4 biochar - inorganic composites

A chemically modified method of combining inorganic materials with Biochar , in the Bio-carbon surface to add groups that can interact with contaminants , To increase the adsorption effect . scholars have focused their research on the manganese oxides and Biochar composite , The is mainly due to manganese oxides on the land The environment is rich in reserves (30% above , for the promotion of composites should Is provided with convenience [%- Notoginseng].

Song , and so on [9] in The corn straw is cracked down by the 3 H made to live Char , biochar with kmn 0 4 Solution Mixed Ultrasound 2 H , through @ Zhang dry , placed in a muffle furnace 0.5 to roast h, last made Mnox- bio-carbon composites (MBC. vs. Raw biochar (BC) , its ash content from 5.02% up to 23.4%, aperture increase (BC: 23.7 nm; MBC : 92.2 nn) , MBC * * * ( ) The o/c from 0.04 elevation to 0.53, X Ray photoelectron

spectroscopy (XPS) analysis show , this Some increased oxygen mainly to mn-oand Mn-oh The form exists , This is Composite to Cu, The maximum adsorption of increased significantly (80:19.6 melon Lu - g-1; MBC : 160.3 mg. G -) for the primary reason. Zhang etc [A] the will beet dregs (sbts ,, sugarcane residue (SB , cotton porch (CWS, Pine (PWS, peanut shell (PSS These five biomass raw materials and MgCl2 - 6H2OSolution Blending , in under the oxygen cracking 1 H , made MgO - Bio-carbon composites , Scanning electron microscope (SEM show MgO particles evenly distributed on biochar surface , Enhanced biochar surface product . in accordance with the above mentioned five biological raw materials order , Synthetic Composite surface area is 253.7, 338.0, 270.7, 432.6, respectively. 346.5 m ^g1. will be made with MgO- biochar for wastewater Removal phosphorous , The saturated adsorption capacity of P and N is achieved respectively 835, mg. . G-1 . agrafioti etc [+] the will CaO solution , FeO powder , fecl 3-6 H 2 0 Solution with rice husk (RH, Organic Solid Waste (SW raw material blending , Preparation of composite biochar material only - 0 3 and , One only - FeO , RH - Fe3 + , SW - FeO , SW - Fe 3+ , to make the prepared compound apply to AS. (V)Removal , find composite material to , for Remove rate (50%~95%) is higher than raw biochar without compositing (25%~55%). Zhang etc [Panax] Place Cotton in the [] under oxygen- cracking solution 1 h Preparation of Biochar , and then associate it with the MGCL 2-6 H 2 0 and AlCl 3- 6H2O Solution Blending , in under the drying to make MG-Al Hydrotalcite bio-organisms carbon composites (Biochai /mgal-ldh , Composite materials to the most large adsorption increased 5~50 Times . visible , biochar and inorganic materials complex close after ,_ Aspects of the bio-carbon surface have been added to the base of the pollutant effect Group , on the other hand , Bio-carbon provides attachment points for inorganic groups , Benefits increases the ability to function with contaminants .

U . 5 modified Biochar

uses the KOH,H2O2, 0 3,H2SO4 / HN 0 3 etc modified Creatures Charcoal [-], to increase the surface area of biochar , add biochar table Surface functional groups (such as carboxyl , Increase the carbon retention of contaminants Force . Regmi etc [[] in the The is prepared by the hydrothermal reaction of the Alamo Willow Bio-Charcoal , and use the KOH Modified Biochar increases its surface Product increase adsorption capability , and will be modified Biochar (htbc and not * modified Biochar (htb to adsorb heavy metals in water Cd * , research Investigate the modified biochar (htbc surface area is 5.01 m 2 - G 1 , is not modified Biochar (htb surface area 2.4 Times ; HTBC to Cd 2+ adsorption capability (mg ' G -) higher than modified biochar htb (to mg. G -) Qklasson etc [i Study phosphate Immersion modified MT Peach Shell biochar to heavy metals Cd 2 + adsorption capability of , The result indicates that when the Cd2+ The initial concentration of the is the mmol "" ' L 1 and mmol ' L 1 , by modified biochar to CdThe adsorption amount for the is 0.97 mmol -g-1 and 1.3 mmol * G 1 . and research shows , Advanced raw material biodegradation of bio-carbon from pyrolysis after anaerobic digestion The removal effect of the object is better . inyang etc [all] Compare raw sugarcane " cinder biochar" (BC - with anaerobic-digested bagasse made frombiochar (DBC to water Pb"*" Remove Effect , found DBC on Pb2 + maximum adsorption for (653.9 MMO bu kg -) is BC (31.3 mmol*kg -) times . visible advance to biomass raw materials Anaerobic treatment , can increase the ability of biochar to remove contaminants .

The Bio-carbon composites listed above in are removed from the contaminants in the has advantages , the literature shows that more and more scholars have started in recent years studying Bio-carbon composites [21-43] , However, the focus of these studies will be "" "On the characterization of composites and the removal of contaminants in water bodies , on the basis of existing results , Apply composite material to the soil repair tool has a wide space , soil Microbes , dissolved organic matter and compositeThe role of the material is worth delving into. (For example, graphene Toxic to microorganisms , So biochar - nano composites Whether the impact on indigenous microorganisms will result in a repair effect drop low . other , Current research scope of bio-carbon composites limit , mostly focused on inorganic materials , Carbon Nanomaterials , nanometer oxide things , about biochar and other kinds of materials of composite , such as organic high Molecular material , The other types of nano-materials such as nano-sulphides and the complex Research on the application of composite materials rarely reported . Organic polymer material with good nice biocompatibility , is more environmentally friendly when combined with Biochar . Visible broaden the selection

of bio-carbon composites , In turn, it is necessary to apply to the field of environmental protection .

1.2 characterization of Biochar and its composites

Physical of Biochar , chemical and mechanical properties with preparation conditions , changes in biomass raw materials and load materials , to Biochar material for characterization , Understanding features , Benefits The mechanism of Biochar The research and application of the . Research currently in progress , common creaturescharacterization of carbon and its composites mainly includes element composition (C , H , O , N , specific surface area , Zeta Potential , X X-ray diffraction (XRD , Fu Fourier infrared spectroscopy (FTIR , Raman Spectra tr,) TG Analysis (TGA,X x-ray photoelectron spectroscopy (XPS) , scan electron microscope (SEM, transmission electron microscope (TEM etc .)

The element makes up , surface area and Zeta potential is often used as Biochar the basic physical and chemical properties of the and its composites are listed , easy to analyze material Performance changes . by analyzing the elements of Biochar and its composites % of , to infer the loss of various substances in the pyrolysis processcondition , with H / C and O / C the represents the hydrophilicity and aroma of the material, respectively - _ as pyrolysis temperature increases ,H/C and o/c Drop , The indicates a drop in the hydrophilicity of the material , Aromatic Enhancement [a] . bio-Charcoal and other materials (such as inorganic material) composite , The content of This element in the composite , , can also be used to verify that the composite method used is valid to compound two materials [%] . usually large specific surface area for material to Dirty dye adsorption , use Biochar with other materials (as nano-composite , The Composite's because of its larger specific surface area specific surface area greater than raw biochar (9~390 m2 *g-) [a], however biological The specific surface area of a carbon composite is sometimes lower than the original biochar , Yu Zhihong etc [one] The finds a compound of biochar with manganese oxides Material specific surface area (3.18 m 2 - G -) far below biochar (60.97 m 2- g -). This is because manganese oxides will be biochar most of the middle hole and the micro hole fill , This can be from SEM View (Chart 3 a). from SEM The diagram can see , More evenly attached to biology surface of Carbon, so Biochar retains its original form. , because of a medium hole and a micro-hole filled with manganese oxides , reduce specific surface area of composites . Although the introduction of the manganese oxides reduces the specific surface area of the composites , however complex composite material pair A(lll) maximum adsorption increase (biochar : 11.41 mg - G 1 ; Charcoal - Manganese composites : 20.08 mg -g -), This is because manganese oxide The property increases the adsorption sites of the composite surface . Song wait [9] Research the investigate also get the same conclusion , through XPS (diagram 3b) knowable biologycharcoal - manganese oxide composites form more mn- O Key (63.9%) and mn-oh (26.3%) key , Visible though the composite creature

the specific surface area of the carbon decreases (61.0~2.28 m2-g -, but), average aperture To increase the (23.7 ~ 92.2 nm,), Enhanced Manganese oxide load , make complex The content of oxygen-containing functional groups in the composite materials increased , for heavy metal adsorption provided , advantageous conditions .

XRD is commonly used for material phase analysis , The material being measured dot-matrix spacing and diffraction intensity of the and diffraction data for standard object phasecomparison , to determine the presence of objects in the material . Wang wait [+] using Eucalyptus leaves with FeC ^ ^ 6h2 0 Preparing Eucalyptus leaf magnetic biochar (melrc, andthrough XRD , FTIR and SEM for composite materials MELRC to make table sign . from XRD figure (diagram 4i() The obviously observes the Fe 3 0 4 characteristic peaks of ⑽is in turn 30.1°, 35.4°, 43.0°, 53.9°, 57.0°, 62.6.), said Ming magnetite is composite material MELRC The main crystalline structure in . ftir Spectrum (diagram 4H to characterize magnetization processes and surfaces of materials Group change [all] , in the 587 cm - 1 The is observed at Fe - O Flex Vibration , The indicates that the surface of the material forms an iron oxide compound [a] . through scanning electron microscope (SEM observe Fe3 0 4 scattered over a specific part of the surface of biochar , Instead of covering the entire surface , so MELRC The retains a larger ratio than the surface area [ ]. Mix composite melrc with deionized water in R • min -1 under oscillation 600 min,sem observe

MELRC surface does not change significantly , Description Fe - OH and C - OH knot Close very tightly , facilitate solid-liquid separation and recycling after adsorption . Sunetc [50] for straw in different temperatures, bio-charcoal and fruit trees . Char characterization , respectively with NMR ,X Ray photoelectron spectrometer (XPS"") scanning electron microscope (SEM, surface area method (BET study particle size , temperature pyrolysis rate and pyrolysis time to biology Chemical composition of charcoal , Effect of fragrance and pore structure , The results indicate Slow cracking process , increasing the pyrolysis temperature or prolonging the cracking time carbon content in biochar ,The oxygen content and surface hydrophilicity decrease . inyang etc [,] to Biochar / carbon nanotube composites (HC -CNT, BC -CNT and bio-charcoal (HC,B 0 The Raman intensity of , Thermal stability features such as are analyzed , Raman spectra include sp3 Miscellaneous lure leads to defect peaks D Peak (~1350 cm-) and representing graphite structure G Peak (1500~1600 cm -), Two peak integration strength ratio Id / Ig and An inverse relationship between the average size of a microcrystalline or a defect-free area on a network plane , The ratio can be used to evaluate the degree of graphitization of a material [a]. and bio-charcoal more than , bio-Charcoal / Carbon nanotube composite Raman intensity Id / Ig Increase , indicates an increase in the surface defect of biochar after adding carbon nanotubes , functionality Regiment (–OH ,- C= O ,- C （8） H ,- F Add , is precisely due to the surface of the official breeding G Addition of the regiment , makes Biochar / Carbon nanotube composites to methylene blue
Enhancement of the adsorption capability of (HC: 9%, hc-cnt: 47%; BC : 25%, bc-cnt : 64%)

2. Application of Biochar and its composites in environmental remediation

Biochar has a larger surface area and porosity , Soluble Low , High carboxylic acid esterification and aromatic structure , is a natural adsorption material . Bio-carbon composites have larger specific surface areas , more Surface Active functional group number and type , increased complexing capacity with contaminants strong , " " Therefore, the application of bio-carbon and its composites in environmental remediation cited for general attention . current , Biochar and its composites should be broadlyto adsorb inorganic contaminants in the environment (Heavy Metal , fluorine and organic pollutant (as dyes , Petroleum Hydrocarbons , Pesticide , antibiotics, etc. [i] .

2.1 application of in the remediation of inorganic contaminated environment 2 1 removal of heavy metal ions

Heavy metals accumulate in organisms and the environment and are severely enriched by assemblies Threat Biology Health and Ecology . Biochar has a large surface area , The advantages of high adsorption performance and low cost , so as the adsorbent is applied the Heavy metals in the environment (^+^ Strict ^^+^^^ ? ^ person^+^^ , and so on fix [to]. The adsorption mechanism of biochar on heavy metals mainly has electrostatic suction attached to , ion Exchange action , Adsorption of mineral components on the surface , Yang ion - n effect , The role and sedimentation of surface functional groups [i] .

because the surface of biochar is generally negatively charged and has a high positive ion exchange (CEC , anode ion pollutant contact to the birth char , Electrostatic Absorption plays a leading role . The the strong electrostatic absorption degree depends on the variable surface charge produced by the negative group on the surface of Biochar , subject to PH The effect of the is greater gas in the soil applying biochar , to increase the cation exchange effect of soil , to enhance soil absorption of heavy metals Attach Ability [a]Q Wang etc [+] in ,,, prepared hematite composite Biochar Material (HPB), HPB to as 5+ The maximum adsorption for the reaches the 429 mg*kg-1 , is rawbiochar (PB maximum adsorption (265 mg - kg-) nearly twice times , Composite against as 5 + During the adsorption process , Static adsorption and surface groups play a leading role .

temperature (300, 500, M, anaerobic slow cracking prepared buffalo miscellaneous grass biochar , apply to Cd" and Pb* The removal of , Discovery * down for bio-carbon specific surface area is much larger than Zhang and The raw prepared under carbon (m BET 279.8 m2 . G-1 ; Tbet 1.35 m2 . G-1 T : BET 4.83 m2 . G -) , , T : biochar to Cdonand Pb2+ adsorption 咼 , reach 11.63,333 mg-g-1, because t Biochar has a higher ion exchange capability and complexing

effect .

Biomass raw materials contain a variety of mineral components , such as Si , Ca , Mg , Fe , Mn , and so on , Bio-carbon cracking process , These components are in ashForm Enrichment in Biochar [More]. in the process of interacting with contaminants , live the adsorption capacity and affinity of mineral components in carbon to heavy metals

To a higher than organic carbon component . Chen Zheoming etc 6] Contrasting biochar RC 350, RC ? with acidification to surface mineral Biochar RC All -da , RC ? -da toPb2 + adsorption capability of , with an untreated creature Carbon compared to [RC : (65±6.9 mg. G -1 ; RC : (76.3±3.6 mg.) G-1], after acidification of biochar to heavy metals Pb 2+ absorption significantly reduced low [RC350 -da: (29.6±1.0 MG.G-1 ,RC -da : (38.2± 1.4) ' -1]. Organic functional groups on Biochar and

no significant reduction , and inorganic Minerals (such as SiO) reduce , so inorganic minerals The object component plays a key role in the adsorption of heavy metals . and in the adsorption process for organic objects , biomass raw materials after pyrolysis adsorption performance increased is mainly due to the change of organic carbon components during pyrolysis , and not mineral components [?].

cation - N effect (Cn) size depends on biochar surface fragrance , N 軛 More aromatic structures , The stronger the electronic power [+] . Lee Force etc [63] on on T and m T The corn straw was prepared. charcoal BC all and BC, Apply it to heavy metals CdAdd to adsorption , through two-site Langmuir equation calculation discovery , on adsorption Cd* the ion exchange adsorption capacity of the process is 5.4, 0.6 mg -g1- , Yang ion - n Action adsorption capacity 33.8, 52.3 mg ' G 1 , Meter to calculate The adsorption capacity of the cationic-N for total adsorption capacity 86%~98%, describes this procedure cationic - n sorption dominates . Cd* the formula for adsorption of the on the surface of biochar can be expressed as : Cn+2H2O ^Cn-H3O ++OH " Cn-H3 O++ Cd2+^Cn -Cd2+ +H3O +

or cn+cd2+- CN-CD2+

(N Electronic and Cd2 + The track of has a coordination effect)

Biochar has rich carboxyl and phenolic hydroxyl groups on its surface including Oxygen Groups , Heavy Metals can and these functional groups occur metal - ligand The has a complex effect [A/^. bio-charcoal is compounded with other materials on the surface form complexes and oxygen groups , in conjunction with heavy metals swing main role . Yu Zhihong etc [$] research Biochar - Manganese oxide complex composite material to soil Cu2+ adsorption effect of , found composite obvious increased red soil to Cu2+ adsorption capability of , and not compound biochar greater than , adsorption increased 509% Composite enhances red soil to Cu 2 + suck The ability to attach a mechanism by altering red soil surface functional Group Composition , Increase Red soil surface -oh, mg-o,si-o number of functional groups . Wang etc [a] studied mncl 2-4H 2 O Composite Pine bio-Charcoal (MPB, water Sodium manganese Mineral composite Pine Bio (BPB to Water Pb 2 + and As 5 + Adsorption effect Fruit , discovery MPB (to 4.91, 0.59 g.kg -) + BPB (respectively to 47.05, 0.91 g. kg -) to Pb2 + and as 5 + The is much more absorbent than composite biochar (BC , to 2.35, 0.20 g-kg -), compound the enhancement of the adsorption capacity of heavy metals by the material is mainly dependent on surface oxidation Complex effects of heavy metals . xue wait [[] contrastH2O2 modifier before after peanut shell biochar to heavy metals Pb Hydrate Removal effect , Results Table modified biochar to Pb maximum adsorption for reaches 22.82 mg-1-,, is not modified Biochar Times . This is because the H2O2 modifier after , bio-carbon surface oxygen functional groups (in particular carboxyl) significantly increases plus, enhances material's ability to complex heavy metals . Song etc [9 will give birth to char with Mnox composite Preparation Mnox- bio-carbon composites (MBC to remove in water) Cu 2 +, finds composite to Cu 2 + for adsorption capability significantly increased (MBC : 160.3 mg. G-1; BC : 19.6 mg . GL , the Leading role is Mnox with the surface of Biochar compounds and oxygenated groups .

The sedimentation of biological carbon and its composites to metal ions main to be reflected in two ways : one aspect , Biochar added to solution can improve Solution pH value , to Promote heavy metals (Cu| , Zn Hydrate , Cd Hydrate , Pb Hydrate , and so on) form hydroxide precipitation [all]. on the other hand ,Xu etc [a] through Study on

cow dung charcoal to heavy metals Cu, Zn 2 + , Cd Hydrate Adsorption discovery precipitation for contribution to heavy metal removal reach 75% above . This is because the biochar for raw materials used in animal manure usually contains / more soluble phosphate and /or carbonate , can be combined with heavy metals from the to formphosphate , and carbonate precipitation .

2.1.2 fluorine ion removal

Biochar and its composites are often used to adsorb fluoride in water dye , adsorption effects affected by ambient conditions , such as PH , temperature etc . Mohan wait[] Comparative Study of magnetic Biochar (mcsbc and non-Magnetic Biochar The effect of (csbc on fluorine in groundwater . first to be prepared corn straw bio charcoal withFea/feh Solution mixed with Magnetic biochar (MCSBC , after magnetized biochar surface form oxygen Iron Increase MCSBC " specific surface area ." by studying different temperatures &5, 35, and effect of on the adsorption effect , found with the adsorption temperature elevation , adsorption of fluoride to decrease (csbc:Q 2°5=6.42 mg • G 1 , =5.17 mg • G 1 , (0 [5=4.99 mg • G 1 , MCSBC : =

4.11 mg . G 1 , (Q°5=3.45 mg . G 1 , (0 5=3.41 mg . G -), adsorbed The process conforms to the pseudo -First-level dynamics equation . Oh etc [a] studied different temperatures (4°°, 6°°, 7°° "") prepared orange peel charcoal and water treatment contaminated peat Repair Effect of fluoride-containing wastewater . Active sewage peat high ash content (76%~ 90%) , Low Carbon content (6%~8 %) , as the pyrolysis temperature increases , its h/c and o/c scale down . on pH 2.0~3.3 scope , High temperatureprepared orange charcoal (+ Zhang and 700 " can adsorb more fluoride , and The best of active contaminated peat, pH to 5.0, This is because fluorine ions with active contaminated peat surface alumina , iron oxide forms complex complexes , pH lowering lead to fluorine aluminate release , reduce active contaminated peat to fluorineadsorption efficiency . Mohan etc [+] in and 450 The is prepared with a pine charcoal and pine skin charcoal , apply to repair groundwater fluoride pollution . Pine Charcoalon PH to the 2.0 the best adsorption for fluoride , is observed in the experiment biochar expands in water . This is because biochar is rich in oxygen . (8 % ~ One %), increases internal porosity when added to water , fluorine ion capacity easy access to biochar internal pores further enhancing adsorption effect , From to sub-exchange and the precipitation of ash and fluorine ions in Biochar adsorbed main to contribute . Research also finds , Although pine and pine skin biochar surface area (Sbet : 1~3 m2. G -) far below activated carbon (Sbet :~ 1000 m 2*g-), but its adsorption capacity for fluorine is quite even more , probably because of the increased porosity after biochar is added to water . after determination , Loose charcoal and pine peel carbon after drying about 0.37~ 0.38, 0.26~0.57 g. G 1 , so water occupies a in biochar 0.37~ 0.38, 0.26~0.57 ML.G 1 , This moisture increases the bio-carbon inner hole gap , spread to bio carbon hole wall .

2.2 application of to remediation of organic contaminated environment

2.2.1 dye removal

Dye Industrial wastewater is easily identifiable by the naked eye , High Organic content , Alkaline and toxic features , because of its stable nature , hard to do Oxygen Digestion , Conventional water treatment technology is difficult to degrade it . Bio-carbon and its "" The adsorption of dyes on composites is quite extensive. [*] , This kind of research often use methylene blue as model dye . Zhang etc [to] The contrasts the stone Graphene / biochar (gcbc) with Biochar (BC) to) water methylene blue removal effect. research shows gcbc saturation adsorption of methylene blue amount to 174 mg* g-1 , larger than BC saturation absorption of methylene blue attach 8 MG*g-1 . This is because the graphene on the surface of the bio-carbon and the methyl between blue molecules produces powerful n-n " effect , to increase the methylene blue The adsorption capability of the . studies have shown that methylene blue and other aromatic groups have an organic compound that can be formed with graphene or graphiten-electronic effects , because of the this gcbc can also be applied to other organic pollutant removal [$]. with Langmuir Adsorption isotherm is fitted to the adsorption process , discovery creature carbon for methylene blue adsorption process more consistent with Langmuir equation , says adsorption mechanism of adsorbent to pollution after adding graphene by assignment With the main gradually into the surface adsorption of the main . Xu etc in All under prepared rapeseed stalk (CS , Peanut stover (PS ,,soy stalk , (SS) and rice husk (RH biochar , and used to remove methyl violet from water , Four kinds of

Biochar's ability to remove methyl violet from high to low CS >PS>SS> RH , This is determined by the respective cation exchange capabilities . Zhang etc [+] Bio-charcoal is made under -I, / Nano-alumina composites to remove methylene blue in water , Its saturated adsorption capacity by raise to MG*g-1 , The addition of nanometer alumina significantly improves the health of the carbon methylene blue adsorption capacity . This is due to the unique carbon nano structure increases the biological carbon surface reaction dot bit , More efficient adsorption pollution Dye . added at preprocessing Al3+ not only to provide alooh nanoparticles , It also acts as activator, In the pyrolysis process to increase the biological carbon / Functional group function of nanometer alumina , therefore composite to the methylene

The adsorption capability of the base blue is enhanced .

2.2.2 removal of petroleum hydrocarbons and pesticides

Biochar Petroleum hydrocarbons and pesticide contamination of hydrophobic organic compounds in the environment fix is the hotspot of research , However, the current bio-carbon composites in the application of petroleum hydrocarbon and pesticide remediation rarely reported. , Research more than one biological carbon single material application .

different temperature (100, 300, and ? a pine leaf prepared under carbon (named P 100~P, for polycyclic aromatic hydrocarbons (naphthalene , fi ,, sorption mechanism ,Results Display P100 non-stereotyped organic matter content in High , High linear correlation of polycyclic aromatic hydrocarbons isothermal adsorption curve , assignmentplay a leading role , is non competitive adsorption ; increases with cracking temperature , P 300~p [* * * *] [* *] () m contains more aromatic carbon , adsorption of organic matter for nonlinear adsorption , Surface adsorption plays a leading role , is Competitive adsorption . in addition to Assign effects and surface adsorption , There are also some microscopic adsorption mechanisms for. ring biosorption of organic carbon to organics [+] . Hale etc TM Research Biology the adsorption ability of carbon and activated carbon on pyrene to evaluate its remediation of soils Effects , The study found that the aging temperature was to maximize changed the physical and chemical properties of the material (as PH elevation , Bio-carbon cation to the Exchange up to 50%, adsorption experiments show that biochar and activated carbon are suitable Remediation of petroleum hydrocarbons in contaminated soils . research shows , cracking temperature The plays a major role in the adsorption mechanism of Biochar . low cracking temperature , high carbon content of the , assignment plays a dominant role . along with increase cracking temperature , reduced organic content in Biochar ,surface area and porosity increase , Surface sorption plays a leading role [?].

Biological Carbon Treatment of pesticides mainly include organic chlorine , Amino formate , chlorobenzene compounds etc . klasson etc [Bayi] in 650 Zhang to fracture the almond shells 1h Prepared with almond shell Carbon , then Under the steam to activate the min, , Makes the adsorbent have a greater ratio than surface area 344 m2 * G-1 , Its adsorption capacity for two bromide is up to 102 m2 'g- [1] , and successful field experiment .

2.2.3 Antibiotic removal

antibiotics as a new pollutant , has been learned at home and abroad Universal attention , Its main source of agricultural production and domestic sewage , the Adverse effects of antibiotics entering the environment on aquatic ecosystems , guide produce multiple resistant bacteria , Also make aquatic animal life activities by to affect ,drinking water at the same time , food chain and other ways to human health To potential threat [up]. Biological Carbon and its composites adsorption of antibioticsPerformance has broad research prospects . Jing Xiangrong etc [$] prepared methanol change Bio-carbon materials for adsorption of four in waste water (CTS . first apply biochar to 3 mol*L- 1 , NaOH Stir in solution 1 H , divide use distilled water to clean biochar repeatedly until pH neutral , then mix The treated biochar with methanol , occurrence of esterification and , Alcohol carbonylation reaction , Preparation of modified biochar (Meoh-char ,

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for CTs adsorption of , MeOH - Char to CTs Maximum suction With 95.63 mg ' G - 1 , greater than raw Biochar (Ori-Chai-) the most "" Large adsorption 81.00 mg - G - 1 . This is due to methanol modified , MeOH-char surface

carbonyl absorption capability increased , is useful for sucking Primer CTs structure and related groups , so enhance it goRemove Effects . Enhanced adsorption performance of biochar with other materials , Provides an alternative to the treatment of antibiotics in the environment .

is currently , Bio-carbon composites in environmental remediation , in particular Application Study of organic pollutant treatment less , Bio-carbon composites to the adsorption mechanism of organic pollutants is based on the structure of biochar itself On the , by assignment , Surface adsorption and micro adsorption mechanism together for with [-.] when the biochar surface loads other materials , its organic The adsorption mechanism is also affected by load materials .

Overall , biochar Composites in structure (specific surface area , Hole clearance degrees,) and performance superior to biochar itself , Remediation of contaminantseffect better , with broad research and application prospects .

3. Summary and Outlook

Biochar has a relatively large area , wide range , Low price etc Benefits , Broad application prospects in agriculture and environmental protection . to promote The into future research and practical Applications , the should put more research into the : .

(1 to produce more efficient biochar composites . Current biological Carbon Composites research focuses on inorganic materials and carbon nanomaterials material ,about Biochar composite with other kinds of material , such as organic Polymer Material composite , Other types of nano-materials such as nano-sulfide complex research rarely reported , And the application of composite materials more than a number of bureau Limited to the laboratory for pollutant removal effect of the comparison . for biochar modifier , Increase surface functional group function , improve adsorption performance for future research focus on . on this basis , should study composite material for pollution Object Dynamics , thermodynamic process , clarifying the mechanism , is applied to the actual The provides scientific justification for .

(2 Current research on Biochar is concentrated in the water Body Pollution , Rare application of its in soil . In fact , soil ring is more complex than water bodies , The microbes in it , Soluble organic matter The relationship between the and the bio-carbon composites is worth studying further . is greater than as , nanometer material (such as graphene toxicity to microorganisms , high effect biochar - Whether nano-composites are applied to the soil will cause the species and number of native microorganisms decline , affects the soil environment , this Some questions need to be taken seriously in future research .

(3) The removal of contaminants by biochar composites is often affected by a variety of mechanism control , Add magnetic material , nano material or inorganic materialself interacts with biochar , Current research

More from a qualitative perspective on the role of various mechanisms , rarely quantified Study The mechanism of composite material on contaminants . in the Future You can place heavy points in quantitative research aspects , provides a magnification of the advantages mechanism Scientific basis .

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