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A Review About Preparation and Properties of Biochar and Application Fields in the Environment

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H I G H L I G H T S

- Review the different sources for preparing biochar.
- Explanation of methods of preparation under different pyrolysis conditions.
- Suitable for use as a soil treatment, and successful as an active permeable barrier to keep groundwater from pollutants.
- The use of biochar for processing complies with the principles of sustainable development because it adopts the use of waste and recycling for its manufacture as an effective excellent in the treatment process and thus is environmentally safe and cost-effective.

A R T I C L E   I N F O

A B S T R A C T

Biomass' pyrolysis process is responsible for producing the biochar charcoal, this process does not incorporate the oxygen, and it is utilized as a soil enhancer for each one of the carbon sequestration, and soil health prospects. Biochar can be defined as a stabilized solid which is enriched with carbon and could remain in the soil for extended period of time. Biochar has been studied as a way of carbon sequestration, and it might be a way used for handling climate change and global warming. It happens due to the processes that are associated with pyrogenic carbon capturing and storages. This review is focused on an overview of biochar preparation and application in the environment, previous studies and Applications. Biochar is prepared from various organic materials such as miscanthus, switch grass, corn stover, and sugarcane bagasse. The method of preparation varies with different temperatures and the discharge of nitrogen gas used for a period of one hour not to mention thermal decomposition at different temperatures of heat (500, 600, 700 and 800oC). The success of its use as a adsorbent material, and in treating the soil from heavy metals, its suitability for agriculture, and the treatment of the liquid leachate from solid waste down into the groundwater, in addition to the treatment of groundwater when the topography of the region differs.

1. Introduction

The term "biochar" is an English neologism from the late 20th century. Pre-Colombian Amazonians manufactured biochar via the process of smoldering organicbyproducts. This means the coverage ofburning biomasses with soil in trenches [1] or pits [2]. It is unknown if they are used intentionally the biochar for enhancing soil outcome. European settlers named it terra-preta-de-Indio [2]. Following experiments and observations, a team of researchers working in French Guiana assumed the fact that the Amazonian earthworms Pontoscolexcorethrurus were the majorcontributor of fine-powdering and incorporating charcoal waste in the soil [3].

2. Production

Biochar is a charcoal-like product rich in carbon, in a regulated process named pyrolysis. The transformation of the organic matters of the agriculture and forest wastes by burning them produces this kind of charcoal. Although very similar to familiar charcoal material, biochar is processed by means of a particular method for reducing pollution and storing carbon safely. While pyrolysis of organic materials like woodychips, leaves, or dead plants, they are burned in the containing units with small amount of oxygen. At a relatively low temperature (<700 ° C) [4].

When burning matters, they would release a restricted amount or no smoke. Organic material is transformed into biochar, which is a stabilizedversion of carbon which cannot escape easily into the air When the pyrolysis process is in progress. During

pyrolysis, the heat or energy emitted could be collected and utilized as one of renewable energy sources. Biochar is far more effective. and safer in comparison with other types of charcoal when turning carbon to stable form. As a material which is environmentally friendly and low-cost.From the literature, adsorbents were prepared from environmentally friendly materials, such as [5] prepared pillared clay as an adsorbent from Iraqi clays, [6] prepared the adsorbent from tea leaves, while, [7] prepared adsorbent from a waste of tea. Figure (1) shows pyrolysis as a combustion stage [4].
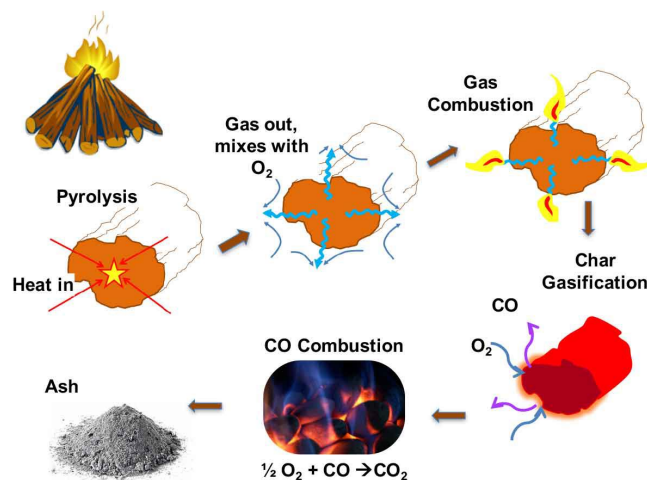

Figure 1: Pyrolysis as a phase of combustion [4]

3. Pyrolysis Phases

3.1 Drying and Conditioning

The majority of biomass has five main parts, in proportions depending on the source: hemicellulose, lignin, cellulose, water and minerals (ash).Seasoned wood on the cellulose / ligninstructure produces 12-19 % water adsorbed.

The water content of newly cut wood or agricultural wastesmay be ranging from 40-60 %wb(wet basisthat is expressed as a percent of the wet weighted of the biomasses). As the biomass is heated above 100° C, much of the water is lost. The biomass begins to break down higher than 150° C,then it starts to break down and soften at a temperature of approximately 150°C (referred to as conditioning). As with limited quantities ofvolatile organic compoundsamd CO_2 , chemically bounding water (from the composition of the biomass molecules) is emitted [4].

3.2 Torrefaction

When the biomassesare heated to the degree ranging from of 200-280 ° C, the chemical bonding within the components of the biomasseswould be starting to set in break.This process involves an endothermic heat supply for increasing the dry biomass degree and breaks the molecular bonds.During this process, methanol, acetic acid, and other oxygenated Volatile-Organic-Compounds are released side-by-side with CO, and CO_2 releases from cellulose and hemicellulose breakdown. Torrefied biomassesis considered far more brittle than freshly produced biomasses, which is the thing that make the grinding such that used for the for boiler fuels, much easier and less energy demanding. It is highly resisting to water uptake, biological degradations, and enhancing storage. The liquid condensate of the vapor with low temperatures pyrolysis was named historically "wood-vinegar" or "smoke-water." It is also named as pyro ligneous acid, and as a flavoring agent utilized as "liquid smoke." It can be used as a seed germinating optimizer, fungicide, a plants growth helper, it also aids in stimulating composite and to increase the efficacy of biocharcoal, relaying on its concentrations and production temperatures [8].

3.3 Exothermic Pyrolysis

Thermal decompositions of the biomasses become highly intense of a temperatures 250 to 300°C, according to the compositions of the feedstock, resulting in a combustible mixture ofCH$_4$, CO_2, H_2, CO and tarsandhydrocarbons. Pyrolysis is considered exothermic as energy is released by the breakdown of the broad biomass polymers. Some oxygen is found in bio-mass structure and is released, with the char and gases, enters into energy releasing oxidation reactions. The energy-released generates the heat required in the biomass for breaking more chemically formed bonds. This process is rendered to be self-sufficient in theory, as well as could proceed 400°C temperature with its own, leaving a residue similar to oxygen depleted, and carbon-enriched charcoal. Practically, heat generated from the pyrolysis area is lost, thus, exterior heat input is required during pyrolysis for increasing and then sustaining the temperatures. Prior to the final stage of the exothermic pyrolysis, the full yield is obtained, but the stable carbon content is relatively low. A wood biochar typically has an ash content of about 1.5-5 %, volatiles are about 25 _35 % by weighting, and the balancing is fixed carbon at 60-70 % [9].

3.4 Endothermic Pyrolysis

The biochar remains at the end of exothermic pyrolysis still containing large quantities of volatile matters. Moreheatis required by decomposing and driving off more of the volatiles for increasing the surface area, fixed carbon contents, and

porosity. A temperature of 550 - 600°C giving about 80-85 % of wood biochar's standard fixed carbon content and about12 % volatile content. At this temperature, wood biochar yields around 25 _ 30 % of the oven dry feedstock weight.

3.5 Activation and Gasification

Adding small quantities of steam and air would be increasing the surface temperature of the biochar to 700-800°C,Once the temperature is more 600°C a couple of two processes will begin:

1. **Activation.** The biochar's surface can be activated by air, steam and heat and release more volatiles. By adding acidic functional groups, this could be increasing the surface region, and cation exchange of biochar's back and forth decrease in yield.
2. **Gasification.** The process is referred to as gasification is much more air and/or steam is applied.This will create a somehow clean gas that could be utilized to producepower. The biochar yielding is poor (usuallylessthan 20%) and the ashes content high[10].

4. Pre-Processing to Enhance Biochar Properties

The pace at which the pyrolysis of the feedstock, and the lastcharacteristics of the biochar could be changed by biomass preprocessing, techniques that can include:

1. Pre-treating phosphoric acid biomasses to boost functional sets, decrease pH, and create a slow release phosphatesfertilizer.
2. To soften the biomasses, i.e. break down lignocellulose compounds, pre-treating biomasses with alkali such as the potassium hydroxide.
3. Pre-treat the biomasses to create a magnetic biochar with Fe salts, for example removing heavy water and metals.
4. To slow the pyrolysis' rate, boosting N captures, and increasing the concentrations of nutrient-rich nanoparticle.
5. The surface, combine clay, salts (e.g. ferrous sulphate) or other minerals such as rock phosphate with biomass.
6. Low-densitybiomassespelletiseor briquette to assist addressing and increasing biochar outcome.

Figure (2) shows the pyrolysis of a single particle and Figure (3) shows the visualizations of the fivepyrolysis' steps [11]
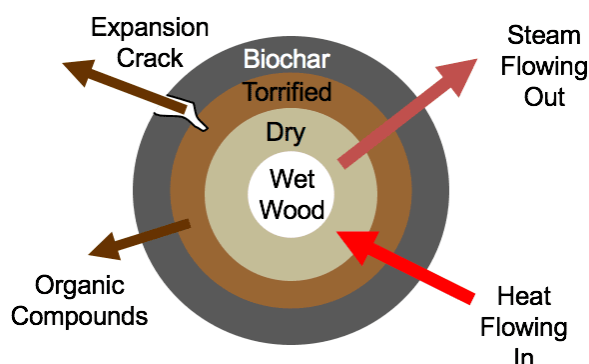

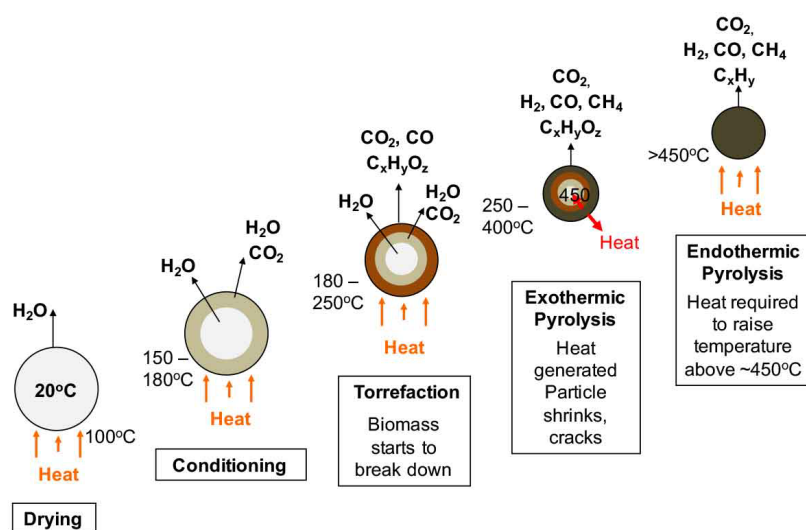**Figure 2:** Pyrolysis of an individual particle[8]

Figure 3: Visualization of the fivesteps of pyrolysis [11]

5. Interaction Between Pyrolysis Time and Temperature

Biochar could be produced in couple of seconds or over several days at different temperatures, according tothe size and form of feedstocks, that illustrated in Figure (4) [12].

There are risks to environmental as well as personal health and protection inherent in biochar processing.
Ensure protection of the operators of equipment and the general public
Minimizing atmospheric contaminant emissions Produce biochars suitable for a variety of particular applications [12].

6. Material used for preparing biochar

Flash torrefactionandcarbonization are other techniquesused for biomass transformation,

pyrolysis, hydrothermal carbonizations, and microwave carbonization are also options in addition to pyrolysis [13]. The flash-fire is ignited at a high pressures (1MPa-2MPa) on biomass packed bed during flash carbonization process to turn biomass to gas and solid phase products [13]. Around 40 % of biomass is reported to be convertedat 1 MPa to solid phase products (biochar)[14]. Other pyrolysis techniques, such asplasma and laser crackmethods, have also been invented in addition to microwaves.

There is no sample use of laser pyrolysis technology and fast heating and cooling couldbeconducted, that effectively prevent secondary reactions from occurring [15]. In preparing coke and syngas, plasma pyrolysis technology is primarily applied. It can substantially increase syngas and minimize bio-oil yields compared to conventional cracking technology [16,17]. However, because of its high-cost, and energy consumption, the modern pyrolysis technology is difficult to popularize. These characteristics were shown in Table (1) [17].
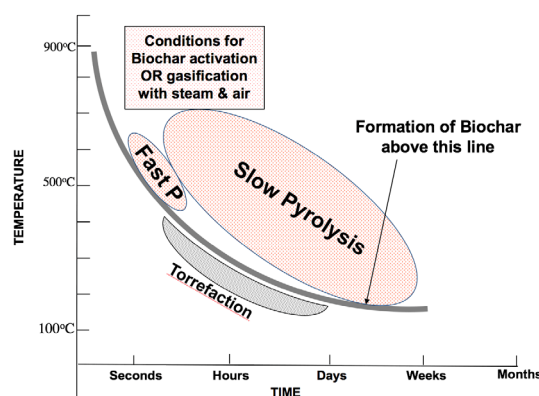

Figure 4: Relationship between temperature and time [12]

Table 1: Physico-chemical traits of biochar made by varioustechniques and process settings [17]

Raw Material	Atmosphere	Temperature (°C)	Heating Rate (°C/min)	Residence Time (h)	Yield (%)	pH	Ash Content (%)	Surface Area (m²·g⁻¹)	Total Pore Volume (cm³·g⁻¹)	Pore Diameter (nm)
Herb residue	N₂	400	10	3	37.9	10.2	28.3	49.2	0.042	3.39
		600			31.2	10.1	31.1	51.3	0.051	3.99
		800			29.1	10.6	37.1	70.3	0.068	3.87
Sesame straw	oxygen-limited	400	5	2	35.6		30.77	37.2	0.0542	
		500			28.2		28.54	46.9	0.0716	
		600			22.9		21.98	289.2	0.1433	
Corn straw	N₂	600		3		10.0	5.02	61.0	0.036	23.7
Pine cone	N₂	500		1		4.66	2.13	6.6	0.016	
Rice-husk		450–500				7.0	42.2	34.4	0.028	
Hickory wood	N₂	450	10	2	28.5	7.9	6.47	12.9		
		600			22.7	8.4	4.18	401.0		
Bagasse	N₂	450	10	2	28.0	7.5	13.66	13.6		
		600			26.5	7.5	15.36	388.3		
Bamboo	N₂	450	10	2	26.3	8.5	8.83	10.2		
		600			24.0	9.2	11.86	375.5		
Poplar chips	N₂	550	5	2	23.18		7.56	212.58	0.356	6.70
Burcucumber plants	oxygen-limited	700	7	2	27.52	12.23	43.72	2.31	0.008	6.780
Pine wood	N₂	600	10	1			4.02	209.6	0.003	
Orange peel	oxygen-limited	400	5	6	11.3		6.93	28.1	0.0409	2.9
		700	5	6	5.93		14.9	501	0.390	1.6
Marine macroalgae	N₂	450	5	2				1.05	0.007	30.41
Municipal solid waste	N₂	400	0.5			8.0	6.1	20.7	0.027	
		500	0.5			8.5	9.2	29.1	0.039	
		600	0.5			9.0	6.2	29.8	0.038	
Rice straw	oxygen-limited	700	2				58.97	369.26	0.23	
Swine manure	oxygen-limited	700	2				60.73	227.56	0.14	
Auricularia auricula dreg		400	2				0.55	77.64	0.0612	4.837
Thalia dealbata	N₂	500	4			10.09	22.0	7.1		
Corn straw	N₂	500	1.5				41.0	32.85	0.0148	5.01

7. Procedure for Preparation of Biochar

Preparing biochar from namely miscanthus, switch grass, sugarcane bagasse, and corn Stover. Firstly grinding and drying under vacuum at 60°C all night long before pyrolysis and converted into. For avoiding any non-homogeneous behaviors

throughout the pyrolysis, use a muffle furnace with three crucibles of same biomass at the same time. the required temperature is reached (with 20°C/min heat ramps) subject to continues nitrogen gas for a period 2 h, then, it is cooled at room temperature subject to continual nitrogen gas. The process was iterated at a variety of the pyrolysis temperature degrees (500°, 600°, 700°,

and 800°C). Secondly the biochars had undergone two-step on chemical activation: temperature and frequency are also low, and ultrasound activation followed by tetraethylenepentamime(TEPA) functionalization each item is indicated by a specific symbol, where namely (R) Raw,(US) Ultrasound Activated, (SG)Switch grass, (MS)Miscanthus, (SB)Sugarcane bagasse and (CS)Corn Stover,. Table (2) shows surface region analyses of raw and sono chemical activated biochar specimens that have been synthesized at various temperatures of pyrolysis [18].

Increasing the proportions of chemical elements due to an increase in the degree of pyrolysiswhere it increased %C and % ashcontent with a shrinkage of %O,%H, and %N these changes become temperaturesranging from 500 - 700°C.In addition, surface region and pores sizes were improved as well atincreasingheatformore than 700°C. The entirety of these contributors played an additive role in the increment of adsorption ability. Surface region is remarkably influenced by thepyrolysis temperature and biochars feedstock [18].

Table 2: Surface regions analyses of raw and sono chemical activated biochars specimens made at various pyrolysis

Samples		Micro-porosity		Micro-mesoporosity	
	pyrolysis temperatures(^{o}C)	*Surface area (m^2/g)*	*Pore volume cc/g)*	*Surface area (m^2/g)*	*Pore volume cc/g)*
R-MS	500	119	0.06	168	0.08
R-SG	500	115	0.06	162	0.08
R-CS	500	96	0.05	149	0.08
R-SB	500	83	0.05	138	0.08
US-MS	500	323	0.15	388	0.2
US-SG	500	215	0.11	250	0.13
US-CS	500	215	0.11	279	0.14
US-SB	500	192	0.11	250	0.13
R-MS	600	303	0.14	345	0.18
R-SG	600	290	0.14	325	0.15
R-CS	600	284	0.14	293	0.14
R-SB	600	221	0.11	273	0.14
US-MS	600	520	0.21	581	0.21
US-SG	600	486	0.17	544	0.21
US-CS	600	399	0.2	454	0.2
US-SB	600	332	0.15	382	0.2
R-MS	700	324	0.15	368	0.18
R-SG	700	325	0.15	344	0.18
R-CS	700	298	0.14	308	0.14
R-SB	700	236	0.12	289	0.14
US-MS	700	532	0.12	588	0.21
US-SG	700	520	0.21	570	0.21
US-CS	700	423	0.2	473	0.21
US-SB	700	352	0.18	400	0.2
R-MS	800	316	0.14	390	0.2
R-SG	800	311	0.14	351	0.18
R-CS	800	288	0.14	357	0.18
R-SB	800	240	0.12	290	0.14
US-MS	800	526	0.21	576	0.21
US-SG	800	503	0.21	550	0.21
US-CS	800	407	0.2	452	0.2
US-SB	800	358	0.18	403	0.2

8. Removing Mechanism of Main Pollutants by Biochars

Biochar's soil contamination remediation mechanisms include ion exchange,physicaladsorption,complexation, electrostaticsinteraction,andprecipitation[19].

8.1 Ion Exchange

Ion exchanges is are the mechanism on the surfaces of acidic oxygen containing functional group.
Biochar like the carbonyl groups, hydroxyl groups, and carboxyl groups, can interact with ions of the heavy metal or the cationic organic pollutants by ionizing H^+ or surface base ions likeK$^+$, Mg^{2+}, Na$^+$, Ca^{2+}, and so on[20].

8.2 Physical Adsorption

Physical adsorptions imply that BC utilizes its surface properties, namely porosity.
Big specific-surface regions such that contaminants like heavy metals organic compounds can be adsorbed or dispersed through the microspores on their surface.Theheavy metal ions'diameter is larger than the normal biochar pore-diameter. In general, the smaller the heavy metal diameter, the more the pores reach the biochar pores, thus increasing the ability of adsorption [21,22].

8.3 Electrostatic Interaction

The electro-static interaction signifies the electrostatic adsorption of biocharand heavy metal's ions between the surface loads.If the pH values of a solution is higher than the biochar (pHpzc) charging point, negative charged on the biochar surfaces was became ,aswell as the positive charged on heavy metal that cause electro-static adsorption. The heavy metal ions with positive charge on the biochar surface combine with the functional groups that contain oxygen like hydroxyl, carboxyl, and carbonyl [23,24].

8.4 Precipitation

Biochar mineral components likeSO_4, SiO_3,OH, SO_3 CO_3, PO_4, and Cl combined with heavy metal's ions for the formation of the water insoluble matters like metal phosphates, metal oxides, and metal carbonates that eases the immobilization and adsorption of heavy materials. The adsorption of Zn, Cu, and Cd by fertilizers biochars were majorly because of thePO_4 and CO_3- precipitation, whereas the complexations of the electron's surface via -OH sets or delocalized π has been minimized [25].

8.5 Complexation

Complexation means the interaction on the surface of biochars and heavy materials between oxygen containing functional sets to be forming complex that would be fixed [26]. The adsorptionsof tetracycline by biochar were majorly mediated by π-π interaction and metal bridges, with the surface complexation as one of the key factors and cationic exchange force. It is often not a single mechanism in the adsorption process, however a hybridization of many mechanisms of adsorption [27].

9. Biochar Characteristics

9.1 Chemical Characterization

The original bio-mass feedstock and its biochar can go through a variety of tests to determine the essential physico-chemical characteristics of each raw and pyrolyzed material have been shown in Fig. (5) [28].

It has always been shown that chemical traits of single feedstock and thus of BC generated from feedstock differing remarkably both temporarily and spatially [28]. Production of BC is also evaluated by changes that may be occurring in elemental concentration of H, S, C, , O, and N and related values [29].

Solid combustible residue which stays following carbonization of a particle sample and ejection of volatile material is known as fixed carbon [30, 31]. It is therefore utilized as estimation of the number of the carbonaceous substances to be formed by a solid sample. In particular, as is usually defined in Van Krevelen diagrams, O/C and H/C ratios are utilized in order to evaluate the maturation and aromaticity degree [32]. On their latest work [33], where BC-based catalysts were used in canola oil transesterification, it was found that elemental analyses have shown a reduction in the ratios of O/C and H/C with an increase in pyrolysis temperature. It has been found that elemental O/C, O/H, and C/H ratios provide reliable measures of the degree of pyrolysis as well as the amount of oxidative modification of BC in soil and solution systems, and are rather simple to calculate [34].

With a rise in carbon burn-off, despite pyrolytic temperature, the areas of BET (Brunauer, Emmett, and Teller) maximized [34]. This means that the carbon burn-off has the most important impact on the surface area's growth. In general, with pyrolytic temperature and residence time, the surface area, average pore size, and pore volume maximized [35]. The BET surfacesregion of BC ($1057 m^2$/g) that has been marginally greater than the value of AC ($970 m^2$/g), was determined. The microporessize of BC (0.24mL/g) has also been less than that of active carbon (0.32mL/g), reliably greater than the latter (3.3 nm) with a mean pore's diameter of the former (5.2nm) [36]. The magnetics BC for theorganic sorption compounds and phosphate worked extensively to establish that the surfacesregions (interior and exteriorsurfacesregions) of BCs were less than other BCs, despite of the fact that themean usage of the former pore radius was higher than the other one. This may be attributed to large amount of iron oxide present in the magnetic BCs, which have less surface regions and ample intermediate pores [37].
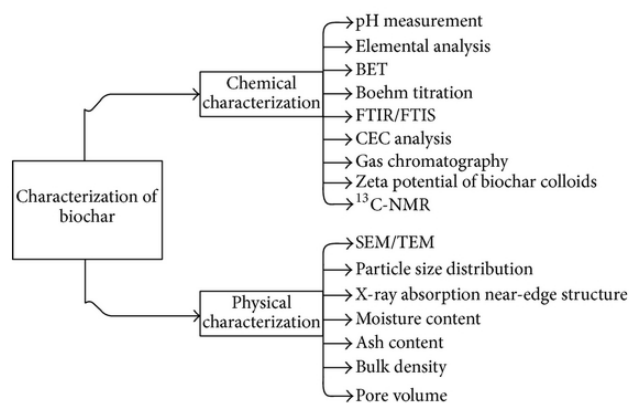

Figure 5: Overview of suggested biochars measurement methods [28]

Operational determinations of the essential and acidic functional groups and on BC may be carried out by Boehm titration[38]. Where BC is balanced in existence of sequentially strong bases (C, HC, OH- and ethoxides) or strong acids (HCl, H_2SO_4, and HNO_3), accompanied by a tight acidic or base extract titration for estimating the reacted fractions. Variations in the number of the bases or acids required are utilized (acidic equilibration) for estimating their relative quantities of the lactonic, phenolic, and carboxylic functional sets (base balance) or fundamental functionality [39]. BC characterization utilized as soil alteration and ethoxides' balance is excludedtypically as it tests functional sets dissociated merely atextremely higher pH, whereas pollutant immobilizations occur at fairly low pH [37]. For hydrophobic BC, Boehm titration works well, but in the case where a large number of bio-oil types or mineral surfaces are present, a significant deficiency occurs[40]. There are 4 regions of transition usually observed under non-hydrothermal conditions in the carbonizations of biomass's feedstock for BC preparations [41]. They are including dehydration, nucleation of graphene,pyrolysis, and eventually carbonization.

These alterationscould be noticed,asBC is subject to Fourier transform infra-red spectroscopy (FTIS/FT-IR). The chemical functional sets presented on the BCC can also be identified by FTIS/FTIR again [42]. As enumerated by Lee *etal*., their recent work [43] had shown that samples characteristics of the bonds used in the preparation of gasification BC (700°C) and quick pyrolysis BC at 450 °C They were identicalto the cellulose ones.

It is evident that there is substantial decreasingof characteristics correlated with O-H ($3600cm^{-1}$-$3100cm^{-1}$), C = C and C = O stretching ($1740cm^{-1}$-$1600cm^{-1}$) and aromatic C = C and C-H deformation modes of the alkenes ($1500cm^{-1}$-$1100cm^{-1}$) between base-line corrected FT-IR spectra of the sample as well as the C–O–C symmetric stretching ($1097cm^{-1}$) properties of the hemicelluloses and cellulose. In combined sorption of Pb^{+2} and its mechanism case study that has been performed by [42]. By the FT-IR spectra analyses of the sludge-derived BC, BC has been found to include an abundant carboxyl and hydroxyl groups (SDBC) amount. Again, after being substituted by the lead at a range of $1400cm^{-1}$ -$1500cm^{-1}$, the complexed carboxyl (-COOMe) band does not show any simple change effect, likely as a result of the corresponding replacement of the cations. The important band change at $3404cm^{-1}$ -$3406cm^{-1}$ (pH = 2), $3429cm^{-1}$ (pH = 4), $3420cm^{-1}$ (pH = 3), and $3422cm^{-1}$ (pH = 5) assisted the proposed complexation between the functional groups Pb^{2+} and hydroxyl as well as carboxyl [44]. Furthermore, the band was moved to $1034cm^{-1}$ (pH = 4) and $1035 cm^{-1}$ (pH = 5) at $1032 cm^{-1}$; they have concluded again that it was a sign of Pb^{2+} coordination with the groups of the carboxylate [44].

Cationic exchange capacity (CEC) as extensivelycalled agronomical sector represented the measurement of the surfaces charging in BC or soil, increasing with the aging of the BC ages [28] and was attributed to an increment in some oxygenated functional sets on surfaces of BC [37]. The highly distinct change in any absolute CEC value was noticed for BC as an outcome of time where it maximized by 278 - 518 $mmole\,kg^{-1}$, most likely due to the fact that the oxidation process created carboxylic and hydroxyl acidic functional sets [45].

Biomasses feedstock is a main factor ruling the status of this physico-chemical characteristics; The most notable process parameter is pyrolytic temperature; carbon content of BC is not directly associated with the BC yielding, maximized from 53 - 83%, and from 300° – 800^oC in one study, whereas theyieldingof BC incrementedby 67 - 26% [46].

9.2 Physical Characterization

The scanofelectron microscopy (SEM) is a microscopic method used to assess the macroporosity of images and physical morphology of solids [47]. BC's macroporoustoplology (pores of about 1µm diameter) formed from cellulose plant material depends on the feedstock's intrinsic architecture, and the water holding and adsorption capability of contaminants in soil and solution systems is potentially significant [47]. Figure 6 shows the BCCS (cotton (Gossypiumher baceum) straw) and BCPS (potato (Solanumtuberosum) straw) SEM micrographs obtained in our previous research [48]. Due to the fact that the existence of tubular structures originally originating from plant cells, the BCs formed at distinct pyrolytic temperatures had a distinctive honey-comb-like appearance. BCs had a high BET surface area as a consequence of these well-developed pores. The importance of pyrolytic temperature leads to the possibility that BC may be suitable for controlling the release of fertilizer nutrients produced at low pyrolytic temperature[49].While high temperatures in environmental remediation would lead to a material similar to activated carbon [50].
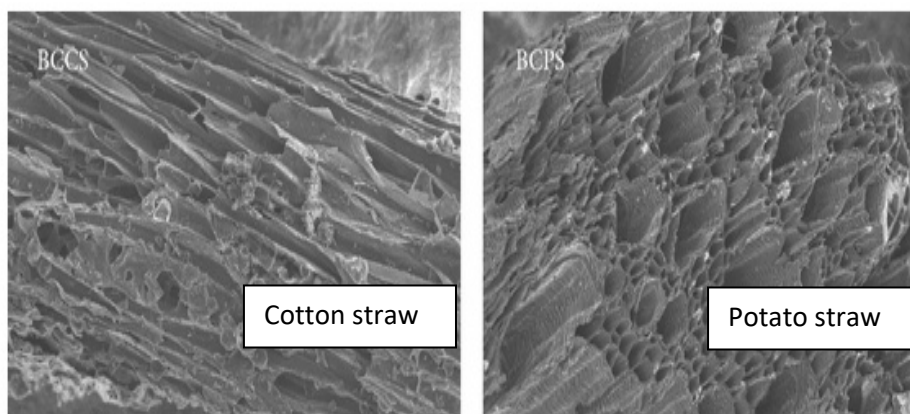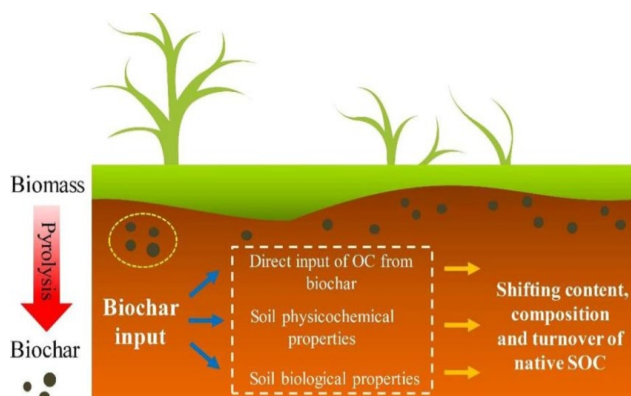

Figure 6: Photomicrograph from SEM [48]

Figure 7: Biochar effect on soil and organic material

It can also be detected that BC low-temperature surfaces may be hydrophobic, whichcan decrease their ability to retain soil water as well as adsorb pollutants. The nature, quality, traits, and potential usage of BC may affect the shape, form, preliminary preparations steps and size of biomass's feedstock and kind of pyrolysis products. Initially, its size would influence the ratio of exposure to the BC's total surface area. In addition, while BC's low pyrolytic temperature is more powerful than products of higher temperatures, it is fragile and once integrated into the soil, pore is abrade into finer fraction[48].

Offered a vivid interpretation when describing the relation between the heavy metal's absorption mechanism and SEM [42]. In SEM photography, bright zones were observed on the porous surface of Pb-loaded BC at pH = 5. Itsenergy dispersive X-ray analysis(EDX)schedule reflects the red-surface, and also confirmed the presence of phosphorusas well as silicon, which could occur in the kind of precipitates of $5PbO \cdot P_2O_5 \cdot SiO_2$ (lead phosphate silicate) that has also been recognized bycalled(XRD)spectraTheysummarized that the precipitates can be a necessaryway of modeling the Pb^{2+} removal mechanism from the soil system, and that they could be connected to the solutions system again [51].

9.3 Proximate analysis

The approximate analysis was developed by the American Society for Testing and Materials Analysis Method (ASTM D-1762-84) for wood charcoal analysis. This method has been used to assess the quality of biochar. A proximate analysis provides characteristic information concerning the material, which includes moisture, volatile matter, ash, and carbon content. The problem of this method the material exposure to oxygen and not well controlled on the moisture content and volatiles during the process.

Mitchell et al. [52] thermo-gravimetric analysis TGA was used for approximation analysis of BC. The moisture content has been calculated as a percentage of the sample mass lost between the temperature of the room and 100^oC, VM as a percentage of mass lost between $150^oC – 450^oC$, Ash as a percentage of the residual mass after combustion is 750 ° C. During the TGA process, the samples have been heated under N_2. Atmosphere to a temperature of 750^oC, the air has been introduced to the system and maintained for 5 min. This method is used for a small sample size which reduces the accuracy of the analysis.

Enders et al [53] modified the procedure. The crucibles have been heated to a temperature of 750^oC, cooled to ensure the absence of moisture before the analysis, the moisture content in an atmosphere rich in argon which was determined as a lost mass at a temperature of 105° C for a period of 18 hrs. Determination of volatiles in an argon-free atmosphere after heating the oven to a temperature of 950 °C. The percentage of ash content was determined as a mass residual at 750 °C after 6 hours in the air [54]. Increasing the temperature of thermal deformation, the volatile and biodegrades production time reduced because of the destruction of cellulose cracks [55]. Also increasing temperature during thermal dissolution increases the amount of volatile compounds within the molecule gradually [56]. Moreover, the increased ash content of BC makes it proper for absorbing phosphates and metal ions [57, 58]. But, ash increases will weaken the ability to adhere to biological coal towards organic pollutants by removing active sites [59].

9.4 Elemental analysis of biochars

In comparison to most organic matter and many widely used criteria, some biochars have extremely high carbon contents (>80 wt %). As a result, only a small amount of sample material needs to be weighed out for carbon content analysis.

This means that the measuring balance must be capable of correctly and precisely weighing in the low milligram range (1–10 mg) (generally 1 g or better).

1) It also means that the biochar sample must be homogeneous enough for a representative sample to be analyzed. Most biochars contain a portion of highly concentrated aromatic carbon that is difficult to combust, which can result in poor peak form, chromatographic component separation, and carbon content underestimation.

2) Although the content of total organic carbon is typically the parameter of interest, many biochars contain calcium carbonate (CaCO3) [53]. If total carbon is the parameter of interest, inorganic carbon must be extracted before analysis or the analysis should be corrected for the presence of inorganic carbon in the sample. The IBI guidelines for biochar product testing demand that total organic carbon, not total carbon, be recorded (IBI 2014).

Since some biochars have very low N content, large samples must be used for analysis if accurate results at low abundance are needed. As a result, there may be difficulties ensuring quantitative combustion and complete degassing of atmospheric N from samples before study, as well as separating a small N peak from a much larger CO_2 peak [60].

9.5 Biochar stability soil

The use of biochar on a large scale in soil has a significant impact on the amount of organic carbon (OC) in the soil.

The impact of biochar on composition and content of OC, on the other hand, is yet to be determined. In sandy soil supplemented with BC formed from manure at low temperature, both limited biochar stability and biochar-induced substantial positive priming effect upon OC mineralization have been typically found. Biochar's stable OC was made up of aromatic OC as well as OC components stabilized by soil minerals.

Biochar primarily promoted the production of macro-aggregates, which has been more pronounced in clayey soil supplemented with manure-based low-temperature-biochar[61]. The relation between biochar, organic material, and soil is illustrated in Figure (7).

10. Some Literature Review

A mixture of husk and cottonseed was used to produce biochar, where the thermal decomposition process was carried out at different temperatures,where temperatures are 200, 350, 500, 650 and 800 °C for 4 hours, in a box furnace with retort under the flow of nitrogen gas, and then kept in retort for the purpose of cooling overnight under the flow of nitrogen gas. Where the surface area of each sample is BET SA CH350°C 4.7 m2/ g, CH500°C 0 m2/ g, CH650°C 34 m2/ g, CH800°C 322 m2/ g [62].

The remnants of the corn cob were used to manufacture biochar. The sample was dried at room temperature and then ground.To carry out the carbonization process, an inverted pressure reactor bar was used, where the reactor has been heated to the required temperature for 1.5 hours at a stirring rate of 150ppm, and was cooled at room temperature, and the hydrochar has been obtained by filtration using a G3 filter, and dried for 24 hours at a temperature of 105 °C [63].

Biochar was produced from corn straw, pyrolysis was done in a muffle furnace at 600°C temperature for 3 hours under nitrogen gas flow, and treated with KMnO4 Where different weight ratios were adopted 1:40 (2.5%), 1:10(10%) and 3:5 (60%),It was dried at 80°C , Where was the surface area BC 61.0 (m2/g) , 2.5%MBC 23.8 (m2/g) , 10%MBC 3.18 (m2/g) , 60%MBC 2.28 (m2/g) [64].

Corn stalks were used to produce biochar, where they were cut and dried at air temperature, and the pyrolysis process was carried out in a muffle oven for 2 hours at 400°C, then it was treated with hydrochloric acid [65].

Sugar cane bagasse and orange peels were used to produce biochar. The materials were collected, washed thoroughly with tap water, dried at room temperature, then dried in the oven and then burned in an outer barrel with a tight lid. The carbonization was carried out in a well-lid inner barrel, as the BET Surface area to theSugar cane bagasse92.30 m^2/g, Total porous volume, 0.04531 m^3/t, Average particle size, 65.0075 nm.TheBET Surface area to theorange peels0.21 m^2/g , total porous volume, 0.00016 m^3/t ,average particle size 28773.72 nm [66].

Using pine fruit peels to prepare biochar, they have been washed and dried for 24 hrs at a temperature of 100°C and were ground, then a thermal decomposition process was conducted for an hour at temperatures of 350, 450 and 550 °C, in a tubular furnace the oxygen was limited. Where was the surface area of each, the BET surface area BC350 0.82(m^2/g), BC450 1.29(m^2/g), BC550 228.11(m^2/g) [67].

Table 3:   Surface area as temperature [69]

Sample	BET (m^2/g)
H220	3.2
H240	5.3
H260	3.5
H280	2.1
P350	1.8
P500	3.3
P650	21.7
P800	122.6

Table 4:   Surface area as temperature [70]

Samples	BET m^2/g	Pore volume cm^3/g
CS	6	0.0125
200-Air	12	0.020
200-N_2	13	0.014
250- Air	12	0.024
250- N_2	6.5	0.012
300- Air	9	0.019
300- N_2	7	0.015
500- N_2	6.5	0.016

Pine wood was used to manufacture biochar, where it was dried in a 105 °C oven, then the sample was placed in a hastelloy autoclave parr reactor. At 400 ^{o}C for half an hour, then it was cooled, washed and dried in the oven at 105 °C[68].

Rice husk was used to manufacture biochar, where it was dried for more than 24 hours at a temperature of 65°C, the carbonization process was carried out in the autoclave reactor at temperatures of 220, 240, 260, and 280 °C. For an hour under self-pressure with stirring by a magnetic stirrer, the hydrochar are dried for 24 hours at a temperature of 65°C. The pyrolysis process was performed in a tubular reactor at temperatures of 350, 500, 650, and 800°C then it is cooled at room temperature. Table(3)shows the surface area for each temperature [69].

Corn Stover was used to manufacture biochar, where it was dried at a temperature of 105 °C, the sample was placed in a tube oven in nitrogen gas or air for half an hour at temperatures of 200, 250,and 300 °C. Table(4)shows the surface area for each temperature [70].

The switch herb was used to manufacture biochar, where it was washed and dried at 60 °C. Thermal decomposition was performed in a muffle oven for one hour at temperatures of 600°C and 900°C when oxygenation is limited with the flow of nitrogen gas, it is then cooled. Where was the surface area of each, BET SA SB600 (m²/g) – 255.8, BET SA SB900 641.6 [71].

Chicken manure was used to prepare biochar, where it has been dried in the oven for 12 hours at 100°C it was ground well, then the pyrolysis process has been carried out in a tube furnace under a flow of nitrogen gas for two hours at a temperature of 200°C to 600°C and then cooled at room temperature. Where the surface area of each BET surface area 100°C (under air – oven) 21.30(m^2/ g), 200°C (under N$_2$ gas – furnace) 35.10(m^2/ g), 300 ^{o}C (under N$_2$ gas – furnace) 41.50(m^2/ g), 400°C (under N$_2$ gas – furnace) 66.70(m^2/ g), 500°C (under N$_2$ gas – furnace) 68.80(m^2/ g), 600°C (under N$_2$ gas – furnace) 54.20(m^2/ g) [72].

Cassava straw was used to prepare biochar, where it was burned well in the oven in the absence of oxygen for half an hour, then the thermal decomposition process began for 1.5 hours at a temperature of 200 ° C where different temperatures were used for thermal decomposition, where the surface area of cassava straw has been 2.46 m^2 / g, and the pore diameter has been 3.37nm [73].

The remnants of the corn cob were used to manufacture biochar, where they were collected, dried at room temperature, and then finely ground. The carbonization process was performed inParr stirred pressured reactor. At a temperature of 250 °C for two hours, then wash well with ethanol and water until a neutral pH is achieved. Then the activation phase begins, where the material is treated with phosphoric acid for a period of 24 hours at room temperature, and then it is inserted in a tube oven with continuous nitrogen gas flow for two hours at a temperature of 500 °C followed by cooling inside the gas, and then it is washed well until a neutral pH is achieved. Dry it in an oven for 8 hours 105 °C,was BET surface Area680 (m^2/g), Pore volume 0.65cm^3/g and biochar was also manufactured using zinc chloride instead of phosphoric acid with the same steps, where was BET surface Area790 (m^2/g), Pore volume 0.74cm^3/g [74].

11. Applications of Biochar in Agriculture: Enhancing Soil and Compost Properties

Globally, soil depletion is a major concern in agriculture.Researchers proposed applying biochar to deteriorated soils to fix this burgeoning problem in order to improve its consistency.Some of the ways biochar can aid in the improvement of soil quality include:

1. -Increasing soil structure
2. -Increased retention and aggregation of water
3. -Reducing acidity
4. -Decreasing the emission of nitrous oxide
5. -Enhancing Porosity
6. -Nitrogen leaching control
7. -Enhancement of electrical conductivity
8. -Enhancing microbial properties

As it decreases greenhouse gas emissions and avoids the depletion of nutrients in the compost, Biochar is also found to be useful for composting. It also encourages microbial development, which accelerates the process of composting in turn. Plus, it helps to minimize the loss of ammonia, bulk density and odor of the compost [75].

11.1 The role of biochar in sequestering carbon and mitigation of the climate change

The production of biochar is a carbon-negative process, meaning that CO_2 in the atmosphere is actually reduced. The unstable carbon in the decay plant material is transformed into a stable form of carbon in the process of producing biochar, which is then deposited in biochar. As biochar is added to soil, for possibly hundreds or thousands of years, it preserves the carbon in a safe location. In fact, if they were left to decompose naturally, the feed stocks used for bio charging would release higher levels of carbon dioxide to the atmosphere. BC technology gradually lowers carbon dioxide in atmosphere through heating the feedstock and converting their carbon content to a stable structure which does not react to oxygen. By enriching the soils and decreasing the necessity for chemical fertilizers, which in turn decreases the emissions of the greenhouse gas, Biochar also contributes to climate change mitigation. The increased fertility of the soil also promotes plant growth that absorbs carbon dioxide. Biochar has many advantages for both the environment and agricultural systems, making it a promising method for regenerative farming [76].

11.2 Biochar improve soil quality

Utilizing a range of applicationspreparationandrates methods, Biochar is used for agricultural soils. Particular soil conditions and thematterutilizedfor producing the biochar would primarily depend on the rate of applications and preparations of the biochar. For inoculating it with nutrient elements   and beneficial types, it is also advised to blend compost or other materialswithbiochar. According to how nutrient-rich or nutrient-depleted the soil is; the advised technique for applying BC can differ. One must at the beginningto consider the soil prior to using biochars in the farm or garden. Refer to the Recommendations for the International-Biochar-Initiative and Wakefield Biochar for more detail about how to apply biochar to various soil types [77].

11.3 Biochar: an environmental solution

Biochar may appear to be a simply structured material, however it can help assist an assortment of general issues all the while. For example, the interaction by which it's fabricated may help sequester a billion tons of carbon yearly and hold it in the dirt for millennia, where it's generally valuable.

During the creation of biochar, perfect and environmentally friendly power is delivered as a side-effect—this can be utilized as an option in contrast to consuming petroleum products, which has exacerbated a worldwide temperature alteration by adding ozone harming substances to the climate.

A portion of the other ecological advantages of biochar incorporate diminished groundwater contamination, filtration of water at a cheaper cost, decreased measures of waste and higher productivity for ranchers. This innovation additionally adds to food security by expanding crop yields and holding water in zones inclined to drought [78]

11.4 Biochar as Permeable Reactive Barrier used in:

1-Remediation of Groundwater Contaminated with heavy metals Ions,

The significance of this study is the sludge produced in enormous quantities from water supply system plant in treatment of aqueous solution (or groundwater) contaminated with lead ions. Both batch and continuous testing showed that this sludge has a high reactivity in the removal of lead ions and can therefore be appropriate for the permeable reactive barrier technique reactive contentBatch tests were performed with initial pH (3-6) operating conditions, contact period (about 120 min), sorbent dose (0.03to 1 g/50 mL) for initial lead concentrations varying from 50 to 500 mg/L at 200 rpm agitation pace.The best values for these parameters are 5, 1 hour, and 0.3 g/50 mL at the initial50 mg/L concentration, respectively, to achieve a maximum97 %elimination [78].

12. Remediation groundwater contaminated with leachate spilled from sanitary landfil-l

Utilization of penetrable-receptive barrier (PRB) innovation of the waterworks sludge's side-effect created from the water supply treatments plants for remediating recreated groundwater dirtied with leachate spilled from the cleaning landfills. To clarify the relationship, leachate polluted with cadmium (Cd(II)), bunch sorption tests were performed (Cd(II)), Nitrogen alkali (NH_3-N) or disintegrated natural matter Chemical oxygen demand (COD) and slime from waterworks. The multi-layered sorbent bed being referred to have a great ability to cure a leachate polluted with Cd(II), NH_3-N, and COD [79].

13. Conclusions

This review provided background information on biochar technology, substrate use from various sources as miscanthus, switch grass, corn Stover, and sugarcane bagasse. Also illustrated, is the prepared method with different pyrolysis temperature. Biochar suitable to use in several way as soil remediation, and successes as permeable active barrier to maintain the groundwater from pollutant as heavy metal, and the leachate from landfall. Biochar is an excellent, environmentally safe, and cost-effective means of managing water and soil pollutants.

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