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1. Bio-Char

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Abstract:

Biochar is a secondary_dark black product obtained after the biomass is treated under pyrolysis process. Heavy metals are those elements with high atomic number, atomic weight and density of more than 5grams per cubic centimetre (g/cm^3) which includes Pb, Cd, Hg, Cr, As, Co, etc. They are the elements that lies in the d, p and f-block series of the periodic table (not all the elements). Biomass used in the biochar preparation are the organic derived biomass which are the product of agricultural waste. Combustion of waste organic biomass and agricultural residues contributes in the produce of a large amount of carbon dioxide which directly contributes to the global worming by the excess emission of the greenhouse gas. Gasification of the said organic biomass would help convert it to Biochar which when applied to soil can store this CO_2 in the soil leading to reduction in the production of Green House gases and improving of soil fertility.

Keywords:

Biochar, Heavy metals, organic matter.

1.1 Introduction:

Biochar is a highly porous, stable, carbon rich substance pyrolysis product of unused organic matter such as wood, saw dust, almond husks, walnut husks, etc., which has high carbon content and less economic value. Pyrolysis is the process of heating the organic material in limited oxygen at high temperature ranging from 400 to 700 degrees. Biochar as a soil amendment is a very good and cheaper alternative than other amendments as it possesses a variety of inherent properties that help improve the quality of the soil which in turn enhances the crop growth. It can also help mitigate the emission of carbon dioxide from the soil through carbon sequestration. The presence of heavy metals in the soil are a high concern to the health of the soil as well as that plants and includes Pb, Cd, Hg, Cu, Ni, Co, etc. Among these some are essential in small concentration and some are non-essential, which act as carcinogens to human and animals causing cancer. So, the heavy metals need to be removed from our food chain to prevent from biomagnification.

But this process cannot be stopped completely because of the use of various chemicals in the agricultural field like insecticides, pesticides, but can be checked by the use of biochar as they have the adsorbing power and can retain them. There are various raw materials that can be used to prepare biochar, these materials include organic matter that have low economic value. They include woods, straw, husks, tree leaves. Firstly, we collect them and dry them. They are then dried to reduce the water content in the biomass. We then dig a pit to a cone shape so that it will be easier to burn the biomass at 400-700 degrees and cut off the oxygen supply once it is black charred. The prepared raw biochar is then crushed and sieved and then mixed and are ready to use as a biochar and can also be with mixed with concentrated fertilizers so that they can be used as a fertilizer.

Biochar, an Organic Remedy to Contaminated Soil with Heavy Metals:

Heavy metals are those metallic elements which density is very high. They are mostly used as a basic component of insecticides, pesticides, etc which are a basic need in the modern agriculture trend. These elements are nonbiodegradable and are carcinogens to human and animals consuming them.

Their concentration increases once they enter in animals body causing biomagnification. There is no any accepted theory to remove the heavy metals from our body once it gets in our food chain. So, only way to escape is to not let it in the food chain.

1.2 Biochar Preparation Process and Value Addition Process:

1.2.1 Raw Materials:

There are various raw materials that can be used to derive biochar for use. They are usually derived from organic matter or biomass which have no or very low economic value and these are changed to high economic value items. Various organic raw materials such as rice husks, almond husks, walnut husks, paddy straw, wood barks are used in the preparation of biochar. The sources from where we can get the raw materials which can be used as the value addition process include Forestry, Agriculture (livestock, farming) and other non-agricultural industries.

A. Pyrolysis:

It is the process of the heating the biomass (raw materials) in the presence of limited amounts of oxygen. The temperature is usually maintained in the range of 400 degrees to a maximum of 700 degrees based on the biomass used. If the heating degrees exceeds the recommended temperature, the yield reduce drastically from 378.2 to 216.7 g kg^{-1} (57.29% decrease) in the case of rice straw, 331.4 g kg^{-1} to 204.1 g kg^{-1} (61.59% decrease) in saw dusts, 450.1 g kg^{-1} to 322.5 g kg^{-1} (71.65% decrease) in sugar cane plants residue, and 277.9 g kg^{-1} to 165.0 g kg^{-1} (59.37% decrease) in the case of tree leaves.

Biochar yield can be calculated using the following equation:

Biochar yield = Weight of pyrolysis materials (g)/ Mass of raw material input (kg)

B. Gasification:

Another method of producing biochar is gasification. Gasification is a thermochemical process which converts carbonaceous materials to fuel gas they are also known as synthesis gas (syngas), at high temperatures without combustion. The process takes place in a gasifier, which is usually at a high temperature/pressure vessel that contains oxygen or air and steam. The feed material is directly contacted with the gasifier's contents, which causes a series of chemical reactions that convert the feed into syngas and ash or slag. Others processes include grinding, sieving etc.

C. Grinding:

In this process the harvested biochar is crushed to small size materials using mechanical energy to make sure that the size is small so as to increase the surface area of the adsorption of potentially toxic elements in the porous point of the biochar.

D. Sieving:

In most of the cases, we use 2mm sieve in the sieving process because the size of the biochar need not to be that large as it reduces the surface area, if it is too small then the specific surface area will be very large, the water retaining capacity will be very strong and cannot be made available.

1.3 Properties of Biochar:

1.3.1 Size:

Commercially available biochar has various purpose based on its size. There are a variety of sizes available and can range from nano to coarse particles. Nano-sized particles are smaller than 100 nm, micro-sized particles range between 100 nm to 1 mm, small particles range between 1 to 3 mm, medium sized range from 3 to 6 mm, large particles range between 6 to 9 mm and coarse particles size are greater than 9 mm.

1.3.2 Porosity:

Porosity refers to the pore size and the pore distribution of the biochar. It is the property of biochar that helps to absorb ions and water molecules. There is various pore sizes based on the raw materials used for the biochar preparation process.

There are three basic pore sizes-

<u>Macropore</u>: In this case the pore size is less then 2mm (in diameter).

<u>Mesopore</u>: Here the pore size is between 2 mm to 50 nm in diameter.

Micropore: Here the pore size is less than 50 nm (in diameter).

1.3.3 pH:

The pH of biochar is generally alkaline, ranging from 7.1 to 10.5. If the temperature during pyrolysis is increased higher, the pH of biochar increases. This is because the ash content increases.

1.3.4 Cation Exchange Capacity:

Cation exchange capacity of biochar varies from 5 to 50 cmol/kg to as high as 69 to 204 cmol/kg. Biochar possesses a variety of oxygen containing functional groups like -COOH, -OH, ketones, quinones, etc. These functional groups enhance the CEC of biochar which, when applied to soil can also improve the soil CEC.

1.3.5 Water Holding Capacity:

Biochar structure has a lot of pores, where water can be held and retained. The large internal porous structure of biochar can help retain a large amount of water. The smaller sized biochar particles can also aid in retaining water through adsorption due to its large specific surface area.

The weight of a wet sample (Wi) can be used to calculate the water holding capacity (WHC) of biochar. To accomplish this, samples could be kept in distilled water in a beaker for a period of one to two days.

The saturated sample was weighed once more after the excess water was filtered through Whatman #2 filter paper (Ws). The following formula is used to determine the water holding capacity:

$$WHC = \{(Ws - Wi) + MC \times Wi\} / \{(1 - MC) \times Wi\}$$

where MC is the sample's original moisture content (decimal), Wi is the biochar's initial weight in grams, and Ws is the biochar's saturated weight in grams. The mass of the biochar in a scaled flask with a known volume of one liter is measured in order to calculate the bulk density (BD) of the biochar. Both the bulk volume and the sample weight are measured and recorded. To compute the bulk density, use

BD =mass of biochar× 100/Bulk volume of biochar.

1.4 Some Chemical Properties Can Be Determined by Using Some of The Techniques:

1.4.1 Electrical Conductivity and pH:

Using a glass electrode, pH and electricity can be measured in a material/water extract at a ratio of 1:5 (v/v).

1.4.2 Organic Carbon (OC):

Organic carbon (OC) can be determined by the dry combustion method at 540 °C for 4 h, which involves heating the biochar sample in an oxygen-free environment until it loses all its volatile matter, then weighing the residue and calculating the organic carbon content by subtracting the inorganic carbon content.

1.4.3 Organic Matter:

Organic matter can be measured by combustion at 550 °C for 8 h.

total nitrogen (TN) can be measured by Kjeldahl digestion (model VAPODEST; range 0.1 mg to 200 g N.

1.4.4 Potassium (K):

Potassium (K) content can be determined by atomic absorption

1.4.5 Phosphorus (P):

Phosphorus (P) content can be determined by the use of the calorimetric method.

The quantities of calcium (Ca), magnesium (Mg), and sodium (Na) can be determined by a fame photometer.

1.5 Nutrient Retention:

In finely powdered biochar, nutrients are retained not only by one characteristic feature, but by a combination which include chemical and physical adsorption, with its complex pore structure and high surface area.

1.5.1 Chemical and Physical Adsorption:

Biochar molecules have both positive and negatively charged sites, in the negative charged site the cations which are essential to plants are adsorbed and stored on its surface and help the plants to absorb nutrients such as potassium (K+), calcium (Ca2+), and magnesium (Mg2+).

1.5.2 Complex Pore Structure:

Biochar's pore's structure creates a large surface area for water to adhere to, which helps to store water (intra particle sites) within the biochar particles. Because of the complex pore structure and large surface area of biochar particles a single gram of biochar can have a surface area as large 1,000 square yards.

1.5.3 Large Surface area:

Biochar's pore structure provides a habitat for microorganisms and fungi, which can further improve soil's nutrient retention and cycling. For example, some fungi form a symbiotic relationship with plant root fibres, which helps plants uptake more nutrients.

1.6 Home to Some Microorganism:

There are various organisms that live inside the soil, macro, micro both flora and fauna. The mass of biochar is very porous because in the preparation process all the fluid mass has been removed by volatilisation and evaporation so the vacuoles are left vacant. This is the site for the home to this micro fauna and the roots of the floras are all able to penetrate in it as it contains organic matter and water from the soil environment.

1.7 Is Biochar Hydrophobic or Hydrophilic?

Let’s check the hydrophobicity of biochar, it mostly depends on the size of the biochar. The results shows that smaller the particles size of the biochar material, the material have higher tendency to have water repellent properties. so accurately particles size greater than 0.25mm have hydrophilic properties and particles size less than 0.25 were seen to have hydrophobic properties

1.8 Effect of Biochar on Soil Physical Properties:

The physical environment of soil is improved to a great extent by the use of biochar. Sandy soils respond more to biochar than the clayey soils. Biochar is a potential soil amendment, but the hydraulic and physical properties of the biochar is not widely known yet. When there are changes in the soil physical environment there is change the numerous services that soils provide.

1.8.1 Bulk Density:

The bulk density of soil is an important property of soil that affects the porosity of soil which in turn regulates the aeration and water movement in soil. It also affects the growth and development of plant roots. Biochar application in the soil generally reduces its bulk density by 3 to 31%. Biochar has a lower bulk density, so when applied to soils with a higher bulk density, the soil's bulk density is expected to decrease. Scientific studies show that sandy soils have more pronounced effects compared to loamy or clayey soils.

1.9 Porosity:

The decrease in bulk density brings about an increase in the porosity of the soil. Biochar application increases porosity by 14 to 64%. The changes in soil porosity are mainly due to the intrapore of biochar and interpore between biochar and soil as well as the particle size distribution. Biochar application in the soil increases the macropore volume but has no significant changes in the meso- and micro- pore volume.

However, this change in the pore volume depends on the size of the biochar particle being applied**.** The porous structure of biochar influences the surface area of biochar itself. Biochar being highly porous exhibits a large surface area. This encourages the growth of microbial communities and enhances their activity in the soil.

1.9.1 Aggregate Stability:

The wet aggregate stability of the soil increased by 3 to 226% on biochar amendment and improved soil consistency, but showed mixed effects on dry soil aggregate stability. The biochar applications improved soil structure by increasing macroaggregates and decreasing microaggregates, resulting in higher saturated water contents and lower residual water contents.

1.9.2 Soil Hydraulic Properties:

The high porosity and surface area properties of biochar improve soil water permeability, increase SWHC, and alter water flow paths. In coarse textured soils, biochar decreases the saturated hydraulic conductivity while in fine textured soils, it increased. This could be caused by the filling or clogging of soil macropores with fine biochar particles.

Biochar having hydrophobic properties can increase the water repellence an reduce the water infiltration as well as the hydraulic conductivity. Biochar increases available water by 4 to 130%. This is due to biochar being highly porous thus retain water not only inside the pores but also between the particles because of the high specific surface area. The low water retention capacity of sandy soil makes adding biochar more beneficial than clay soil.

1.10 Effect of Biochar on Soil Chemical Properties:

pH:

Soil pH is a key indicator of soil properties and impacts fertility and crop growth. Generally, biochar has a higher pH than the soil it is applied. Therefore, as the application rate increases, so does the soil pH. This increase in pH may be due to the presence of oxides, hydroxides and carbonates of alkaline metals like Ca, Mg, etc. When biochar is applied to the soil, these undergo dissolution, making the soil more alkaline. This effect is better observed in coarse-textured soils with low pH.

EC and CEC:

The soluble ash content of biochar improves soil base saturation, leading to a significant increase in EC values. Biochar from various raw materials exhibit higher EC levels between 0.4-3.2 compared to soil. CEC is an important property of soil that enables it to adsorb, retain and exchange cations. Soils with a high CEC can retain plant nutrients and cations on the surface of biochar, humus, and clay, allowing nutrients to be retained rather than leached or absorbed by plants. The presence of negatively charged functional groups like -COOH and -OH in the biochar structure increases the soil CEC.

Biochar has high adsorption capacity and can absorb mineral nutrients due to the presence of the functional groups. This is due to the oxidation of carboxyl groups and the high negative surface charge of phenolic biochar.

Organic Carbon Content:

Biochar use can increase the soil organic carbon to 27%, and also improve soil aggregate to stability.

Mineral Content:

Biochar can increase soil mineral content, and can form cationic bridges with soil minerals to improve aggregate stability.

Nutrients Content:

Biochar can improve potassium uptake in banana plants, and can also stimulate root growth to help plants obtain more nutrients and water

1.11 Biological Impact of Soil:

Biochar used on the soil has a very high advantages on the biological ecosystem of the soil environment. The pores are the site of habitation of the soil microorganism. The pore site is a site of the availability of the adsorbed nutrients, which are the site for the conduction of the nutrients of the plant's roots.

Sources of Heavy Metals in the Soil:

Pesticides, Fertilizers, Manure and biosolids, Waste water, Mining of metals and processes, Industrial waste, Airborne sources and origin

Effects of Pesticides

Adverse effect on soil fertility and productivity as a result of intense use of pesticide causing destruction in the ecosystem of soil microorganism

Persistence of Pesticide on Soil:

There is pesticide that don't persist long in the soil environment, but gets decomposed (biodegraded) soon after it serves its purpose. Persistence of pesticides in the soil for a long time is undesirable. They gets deposited in the soil. Taken up by the

Some Major Key Plays in the Biochar Market

Biochar Product, Inc., Biochar supreme, LLC., Carbon Gold, Ltd., Pacific Biochar Benefit corporation, Swiss Biochar GmbH, American Bio Char Company,

Scenario in the Context of India:

India could produce 40% tons of biochar from the surplus agricultural waste and crop residues. India has vast agricultural land and has diverse crop residues, holds immense potential for biochar adoption

1.12 Other Remedy Process for Checking Soil Contamination:

1.12.1 Phytoremediation:

It is the process of detoxification of the soil contaminants and harmful chemicals by using trees and associated soil microbes. it's a cost-effective environment restoration technology so it's widely accepted

A. Types of Phyto-Remediation

Rhizofiltration:

It's the process of phyto remediation that involves the filtration of toxic elements, ground water, surface water, waste water and excess nutrients using the roots of plants by the process of both adsorption and desorption. It's a cost-effective process for checking the high-volume contaminated water with less expenses for long time period and without inorganic waste output. Tts comparably inexpensive with more potential to exploit than the existing technologies

Phytoextraction:

It's the process of extraction of the contaminants from the soil by the roots and store the extracted contaminants in the plants upper part of the plants body (above the ground) by absorbing the contaminants, store them in the body and precipitate them.

Phyto Transformation:

It's the process of absorbing the organic contaminants from the soil by the roots into the plants and break the absorbed compound by the metabolic process or the action of the enzymes.

Phytodegradation:

It's the process of the degradation of the contaminants in the soil directly by the release of the root exudates

1.12.2 Bioremediation or Biodegradation:

It is the process of removal or decomposition of the toxic and unwanted chemicals from the soil by using microorganism

1.13 Conclusion:

In the above chapter, Biochar can address several agricultural challenges in the country, including soil degradation, low crop productivity, and crop residue management. Biochar is also one of the most accepted remedies out of a lot of remedy available to check environmental soil pollution such as phytoremediation, bioremediation, etc are just vast topics to come under soil pollution checking. It’s always better to go for the organic remediation than to go for fast inorganic procedure. There needs time for the regeneration process to save our resources and sustainable use of the available resources, so that this could our valuable gift to our future generation.

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