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CARBON DIOXIDE CAPTURE USING BIOCHAR – A CLIMATE CHANGE PERSPECTIVE

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ABSTRACT

The global temperature and arctic sea ice are continuing their long trends of change which are ultimately steered by increasing concentrations of heat-trapping carbon dioxide and other greenhouse gases in the atmosphere. As a greenhouse gas, carbon dioxide (CO_2) is one of the major contributors to global warming and is significantly produced from anthropogenic sources. Though various CO_2 capture technologies have been proposed, a stable carbon-rich solid by-product produced from pyrolysis of biomass which is called as biochar, has gained considerable interest due to its proven role and application as an adsorbent. This paper provides an overview of recent advances in biochar utilization as an adsorbent for capturing carbon dioxide (CO_2). Discussion on biochar production methods, properties and advanced characterization techniques are also produced. Biochar is a treasured resource however, its effective utilization require further investigation of its structure and properties, and methods to modify this.

Keywords: Biochar, Greenhouse Gas, Pyrolysis, Adsorbent, Carbon Capture

I. INTRODUCTION

Current trend in atmospheric CO_2 concentrationlevels calls for sensational diminishment in anthropogenic CO_2 emanations with a specific end goal to keep away from runaway situation of conceivably calamitous temperature and ocean level ascent. The yearly mean CO_2 development rate was fundamentally higher for the period from 2011 to 2015 (2.90 ± 0.1 Ppm/yr), contrasted and the 1990s (1.18 ± 0.08 Ppm/yr), despite the fact that lone 45% of consolidated anthropogenic outflows have stayed in the air, the rest being actually sequestered by physical and maritime frameworks. Notwithstanding checking the fossil fuel and concrete industry CO2 outflows, a few methodologies for CO_2 sequestration are being proposed. An extraordinary IPCC report on carbon catch and capacity (CCS) records seven environmental change alleviation alternatives: carbon catch and capacity, vitality proficiency, switch to low-carbon fills, atomic force, and renewable vitality, upgrade of natural sinks and lessening of non- CO_2 nursery gas emanations. Of these Bio singe is a charcoal-like material created by the thermo-concoction pyrolysis of biomass materials. It is being considered as a possibly critical method for putting away carbon for long stretches to moderate nursery gasses [1]. The anticipated development of worldwide economy and world populace soon will prompt a colossal interest for vitality. A significant part of the enthusiasm for bio char originates from investigations of Amazonian soils that seem to have been altered with bio burn, with huge changes in soil quality and constructive outcomes on harvest yields [2]. These progressions have persevered for hundreds, if not thousands, of years. It is not yet known to what extent it takes for bio char to coordinate with the soil and express its advantages. Be that as it may, the biohcar systems can be carbon negative by converting the carbon in biomass into stable carbon structures in biochar that can remain for hundreds and thousands of years by reducing the net CO_2 emissions to atmosphere [3]. Bio scorch is a result of biomass pyrolysis, one of the innovations used to deliver bioenergy. It is an exceedingly stable substance and has a high ability to hold supplements. As a nursery gas, carbon dioxide (CO_2) is one of the real benefactors to an Earth-wide temperature boost and is fundamentally created from anthropogenic sources. To diminish greenhouse gas emanation, CO_2 capture techniques are retrofitted to power plants post ignition in the electric-power part. Tragically, current CO_2 catch advancements have high vitality punishments and the strongest innovation, amine cleaning has huge negative human and ecological downsides. It is consequently important to create compelling CO_2 sorbents that are economical and renewable to create powerful CO_2 sorbents that are reasonable and renewable, for use in vast scale post ignition advances. Physical adsorbents, for example, carbon materials, can possibly catch CO_2 with higher security, higher recovery, and lower vitality utilization than routine compound procedures. A considerable lot of the adsorbents for CO_2 capture, in any case, are generally expensive and subsequently, there are requirements for the improvement of savvy ones. Bio char is an ease carbon material that can be delivered by low temperature pyrolysis of waste biomass. Bio char is frequently utilized as soil alteration for soil change and carbon sequestration. As of late, A.E. Creamer et al. demonstrated that bio char can catch CO_2 at levels equivalent to settled adsorbent [4]. In contrast with other usually utilized CO_2 catch adsorbents, bio char is more practical as a result of the accompanying focal points: (1) it can be created from waste natural material; (2) its generation is performed at generally low temperature; (3) the material can likewise be recovered at a low vitality, because of its physical adsorption conduct. Most as of late, studies examining bio char have concentrated on its moderating impacts on environmental change. It has been proposed that the utilization of bio char could be a potential technique to expand soil carbon sequestration and diminish nursery gas discharges from soils. Without a doubt, the generation of bio burn from biomass speaks to a net withdrawal of CO_2 from the environment. In light of late confirmation, the mean living arrangement time of bio char C in soil is more prominent than 1000 years. CO_2 is framed amid burning and the kind of ignition process specifically influences the decision of a suitable CO2 expulsion process. CO_2 catch advances are accessible in the business sector yet are exorbitant when all is said in done, and add to around 70-80% of the aggregate expense of a full CCS framework including catch, transport and capacity. There are three primary CO_2 catch frameworks partner with various ignition forms, in particular, post-burning, pre-burning and oxyfuel ignition.

II.PRODUCTION AND PROPERTIES OF BIO-CHAR – A PROMISING ADSORBENT

Bio char is charred organic matter. The international bio char initiative defines bio char as a solid material acquired from the thermochemical conversion of waste organic matter in an oxygen-limited environment. Bio char is produced in solid form by pyrolysis of biomass. Typical operating conditions and char yields of different thermochemical processes are shown in the table.

Process	Temperature °C	Residence time (s/h/min /days)	Char yield (wt %)	Reference
Slow pyrolysis	400-600	Min to days	20-40	[5-8]
Fast pyrolysis	400-600	~ 1s	10-20	[9,10]
Gasification	800-1000	5-20s	10	[11]
Hydrothermal carbonization	180-250	1-12h	30-60	[12,13]

Table1. Typical char yield from thermochemical processes.

It is extremely important to choose the appropriate method for the conversion of biomass into energy and varieties of useful products so that the maximum energy can be acquired at the minimum expense by keeping the environmental issues also in view. Generally bioenergy conversion techniques can be split into two groups namely biochemical conversion which involves the biological catalysts and biological organism to produce the energy form biomass while thermochemical conversion involves heat and a chemical catalyst to yield energy from biomass. Bio fuel produced using biomass is a feasible option to replace the ever ending energy demand which cannot be fulfilled by fossil fuels. Many developed countries like Germany, Australia, United Kingdom, Turkey and Finland are generating electricity with the help of Biomass [14]. It not only reduces the greenhouse gas emissions to atmosphere but also minimizes the quantity of waste to be disposed [15].

2.1 Types of Pyrolysis

Based upon the operating conditions, pyrolysis can be categorized into six subclasses. Each class of pyrolysis is having its own advantages and limitations. Table 2 summarizes the operating parameters of all these types of pyrolysis

	Slow	Fast	Flash	Intermediate	Vacuum	Hydro
Temperature (°C)	550-950	850-1250	900-1200	500-650	300-600	350-600
Heating rate (°C/s)	0.1-1.0	10-200	>1000	1.0-10	0.1-1.0	10-300
Residence time (s)	300-550	0.5-10	<1	0.5-20	0.001-1.0	>15
Pressure (Mpa)	0.1	0.1	0.1	0.1	0.01-0.02	5-20
Particle size (mm)	5-50	<1	<0.5	1-5	-	-
Refs.	[16-18]	[16-18]	[16-18]	[19,20]	[21,22]	[23,24]

Carbon content of bio chars is a function of a multitude of factors such as pyrolysis temperature, residence time, moisture content of the biomass, and the composition of the biomass, including whether they are primarily cellulosic (e.g. grassy) lignocellulosic (i.e. woody), or contain less amount of cellulose or lignin (e.g. algal biomass or well-processed biomass that is substantially of microbial origin) [25].

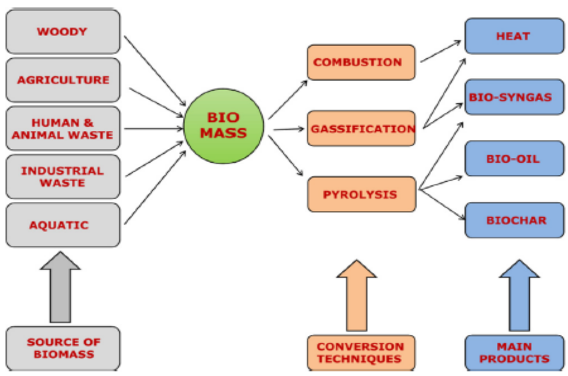

Fig.Conversion techniques of biomass obtained from different sources and their products

A.E. Creamer et.al reported that pyrolysis temperature will have a significant effect on capturing carbon dioxide, when the biomass underwent higher temperature pyrolysis, the surface area increased [4] which is steady with the literature that high pyrolysis temperature would create more micropores. Previous studies showed that adsorbents with high surface area may have large CO_2 capture capacity.

Microwave assisted pyrolysis (MAP) has been shown to reach higher efficiency levels in forming biochar, bio-oil and fuel gases. The advantage of microwave pyrolysis over conventional processing is the nature of very fast internal heating by microwave irradiation. B.Dutta et.al carried out experiments using the microwave pyrolysed maple wood biochar produced through microwave pyrolysis. The study demonstrates that the FTIR spectrum of maple wood was more complex and showed various peaks indicating the presence of variousheterogenous components compared to the biochars produced. It is observed that the microwave power level of 200W providing the maximum temperature of around 300^{o}C should be the best choice to produce the biochar form rice straw with the highest specific surface area.

Production of micro porous biochars by single-step oxidation is carried out in batches using isothermal fixed bed experiments. The author described that the single step activation leads to carbons with same or even better characteristics than the conventional two-step procedure, which means a new source for energy saving compare to the conventional two-step procedure [26].

Chemical modification with different acids (e.g. Hydrofluoric acid)[27] metal ions (oxyhydroxide) [1] has been often comparatively tested for enhanced CO_2 adsorption capacity. Creamer et al. concluded that the metal oxyhydroxide-composites can be a promising framework for CO_2 capture. However, no additive had been identified to be uniquely optimal [28].

III.APPLICATION OF BIO-CHAR FOR CAPTURING CO_2

3.1 Adsorption Isotherms

The kinetic parameters of CO_2 adsorption on the biochar are to be fitted with respect to the experimental data to regression lines. Most of the CO_2 adsorption experiments on biochar will fit into pseudo-second-order adsorption kinetics. The rate constant increases whereas the adsorption capacity at equilibrium decreases with increasing adsorption temperature. The initial adsorption rate generally decreases with increasing adsorption temperature. This would verify the physiosorption and exothermic behavior of the process [27].

Adsorption kinetics are mainly determined by using Thermo gravimetric Analysis (TGA) instrument at a flow rate of 50 ml/min following the procedures of CO_2 captures has been shown to be more effective under high pressures, so this low flow should provide an underestimate of the total capacity of the biochar for CO_2 adsorption.

3.2 Process Factors affecting adsorption

There are several parameters the effect the pyrolysis includes temperature, pressure, reaction time, particle size etc., which directly affects the adsorption. The higher the temperature higher will the surface area of the adsorbent and directly proportional to the amount of adsorption. Those parameters not only control the char yield but also affect the quality of the pyrolysis is to increase the product yield so it is important to discuss the effect of these process conditions on the biochar production.

3.3 Effect of residence time

Low temperature correlated with long vapor residence time is required for higher biochar production. Increase in the vapor residence time helps the repolymerization of the biomass constituents by giving them sufficient time to react. While if the residence time is lesser, repolymerisation of the biomass constituents does not get completed and biochar yield is reduced [12]. The effect of residence time is often dominated by the temperature,

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heating rate and other parameters which make it very challenging to give a straight idea about the role of residence time on the production of biochar.

3.4 Effect of heating rate

The rate of change of heat will affect the nature and composition of the end product of pyrolysis up to a certain extent hence, it plays an important role. The possibility of secondary pyrolysis reactions can be reducedat low heating rate. Low heating rate also results in more biochar yield by reducing thermal cracking of biomass High heating rate backs the disintegration of biomass and increases the gaseous and liquid yield of limiting the possibility of formation of the biochar. The effect of heating rate on the resulting biochar is more noticeable and potent at lower temperatures.

3.5 Effect of temperature

Increasing the pyrolysis temperature affects the biochar yield in a negative way because the increase in the temperature permits the thermal cracking of heavy hydrocarbon materials, leading to the increase of liquid and gaseous and decreases in the biochar yield. An Increase in pyrolysis temperature from 400 to 700^{o}C resulted in 10% reduction in the biochar yield for hazel nut [12] but the temperature increase also causes the increase in surface area of the biochar hence, resulting in higher adsorption.

Authors	Biomass	Temperature range (^{o}C)	Biochar yield (%)	Refs.
Williams and Nugranad	Rice husk	400-600	33-25.5	[30]
Aysu and Kusuk	Ferula orientalisL	350-600	40.26-26.29	[31]
Zhang et al.	Corncob	400-700	34.2-20.2	[29]
Sanchez et al.	Sewage slug	350-950	52-39	[32]
AyhanDemirbas	Olive husk	450-1250	44.5-19.4	[33]
AyhanDemirbas	Corncob	450-1250	30.6-5.7	[33]
Shabangu et al.	Pine	300-450	58-26	[34]

3.6 Mechanism of adsorption

The experimental and modeling results of various studies suggest that the adsorption of CO_2 onto biochar was mainly controlled by physiosorption, which a weak interaction is arising from intermolecular forces (e.g. Van der Waals forces). Although physiosorption of gas molecules on to a solid surface can be temperature dependent as it approaches equilibrium, it does not require activation energy. CO_2 has strong quadruple moment, but no dipole; it can interact with the biochar surface through polar bonds. Both induction and dispersion contributes to the attraction of CO_2 due to the either end of its linear shape.

In case of physical adsorption, it is important to have both high surface area and abundant adsorption sites to enable surface bonding [1].

IV. PROBLEMS, SUSTAINABILITY, AND POTENTIAL APPLICATION OF BIO-CHAR

4.1 Potential negative effects

As explained above, biochar has been successfully used in many applications, such as soil amendment and fuel cells. The use of biochar as soil amendment is still a concern even it offers several benefits because of the toxic compounds such as chlorinated hydrocarbons, polycyclic aromatic hydrocarbons, and dioxins that may present in biochar to a varying degree depending on the process and feed stocks. Heavy metal, inherently available in biochar, can also increase its availability in soil. Biochar can also worsen Eco toxicological effects on soil organisms [18] understanding biochar properties is crucial in mitigating its unwanted impacts while utilising its benefits as soil amendment.

In addition, life-cycle analyses of all biochar applications are needed to identify potential benefits and concerns for specific applications. However, optimum reaction conditions for the production ofbiochar and benefits are not always the same; hence, the conditions must be optimized based on the end products for specific applications.

4.2 Sustainable use of bio-char

It is clear that biochar has potential as soil amendment and its value as such would likely increase as social and regulative interest in carbon sequestration increases because of the longevity of carbon in the soil. The biochar used as an adsorbent to capture CO_2 can act as carbon negative and can store CO_2 for a long period. However, more significant increases in crop production need to be evaluated across a range of crops and soils that can add value to the farm at a level above the estimated value of biochar for carbon sequestration [35]. Under the current economic situation, farmers are unlikely to adopt biochar use without greater payback. Also at this time, even if farmers found biochar beneficial, they may face difficulty in sourcing quantities large enough for farm applications.

4.3Potential application

Many solid opportunities for biochar use are also possible, including soil amendment and compost use outside of agriculture such as gardens, lawns, parks and stadiums. Biochar can be suitable as a precursor to activated carbon commonly utilized in industrial filtration process like municipal waste water treatment and other water and air filtering systems. Biochar can also be used as an energy source; as combustion fuel to power the pyrolysis process; as a gasifier feedstock; or for water heating and cooking [36]. However, the process loses the added benefits of applying biochar to soils, such as profits in agricultural productivity due to soil quality improvement and payments for carbon sequestration.

V. CONCLUSION & FUTURE PERSPECTIVES

Recent studies in biochar utilization, production methods, properties and characterization techniques, properties of biochar, adsorption mechanism, factors effecting adsorption are discussed in this paper. The potential biochar applications include its use as catalyst, soil amendment for improving soil quality and carbon sequestration, as an adsorbent for removing pollutants from soil and water, material to store CO_2.Low-cost methods need to be developed with the help of available equipment to analyze CO_2 adsorption onto biochar.

Overall, use of char as sustainable high-value product seems to have a very bright future. However, in order to successfully utilize for various purposes, bio char properties need further improvement and modifications for the appropriate applications. Standards and methods used to determine structure and properties of bio char need further improvement so that its effectiveness as soil amendment, catalyst and sorbents can be realized.

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