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A systematic review of biochar as a soil amendment and bioremediation tool in agricultural management

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Abstract

In arid and semi-arid regions limited water inputs, lower soil organic matter and carbon decreases the soil moisture retention which make soils of these regions difficult to sustain healthy crop. Moreover, intensive agricultural practices are depleting the soil of its organic matter and nutrients which is reducing the soil fertility even further. Pakistan has high rainfall variability during different seasons. The regions which remain dry in all seasons due to low precipitation are greatly vulnerable to drought. Organic farming provides a solution to mitigate this problem to some extent but in this case the yield is less as compared to the conventional agriculture system. Biochar serves as a novel method for increasing soil carbon content due to its enhanced carbon stability. Biochar being highly porous material has large surface area and it causes significant changes in soil physical properties such as water holding capacity, porosity, drainage and bulk density. Adding the biochar in soil have many advantages from reduction of pollutants and heavy metals concentration in soil, increasing soil carbon sequestration as a strategy to mitigate climate change and increased soil microbial diversity due to substrate enhancement. The incorporation of biochar in soil has a great impact on the soil texture, density, particle size distribution, and soil density and can be used as fertilizer to increase the crop yield due to its ability to slow release of the nutrients in soil.

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Introduction

The massive industrial development and various anthropogenic activities including extensive cultivation in developing countries have led to the immense degradation of soil. This degradation has caused many environmental, economic and health issues. In order to resolve the problems related to soil pollution various approaches have been suggested. Among many techniques a recent and practical approach is employment of biochar for the bioremediation of soil in terms of nutrient loss and heavy metal removal. In Pakistan after harvesting of wheat crops, farmers are burning the crop residues and problem of smog is very common in Punjab. From December to February smog problems and in winter air quality is bad and lots of accidents. A research was conducted on biochar in 2017 and the aim was to prepare a biochar from crop straw-residues and the goal was to mitigate the climate change and greenhouse gas emissions by augmenting carbon storage in soil and improving crop production and soil fertility (Iftikhar *et al.,* 2018: Zahid, 2017). The aim of research was to provide a sustainable and cost effective approach for the improvement of soil fertility of arid (Thar) and semi-arid (Rawalpindi) regions of Pakistan. In 2017, biochar was prepared by waste of wheat straws by low- cost retort kiln. The biochar effect was studied on both types of soils in reference to physical and chemical properties of soils. Biochar is a carbonaceous material generated from the pyrolysis of biomass in inert atmosphere. It is widely employed to enhance the soil fertility by holding nutrients (El-Naggar *et al.,* 2019). The main advantages of biochar are depicted in following Fig. 1.

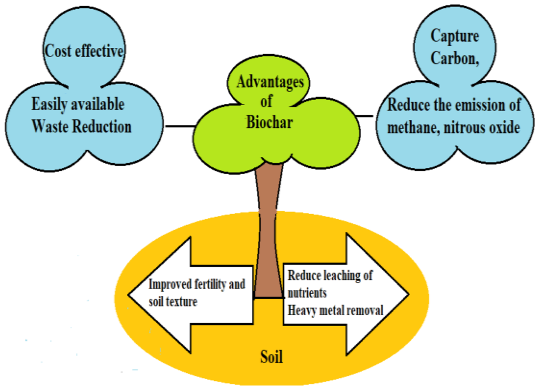

Fig. 1. Main advantages of biochar above and below soil.

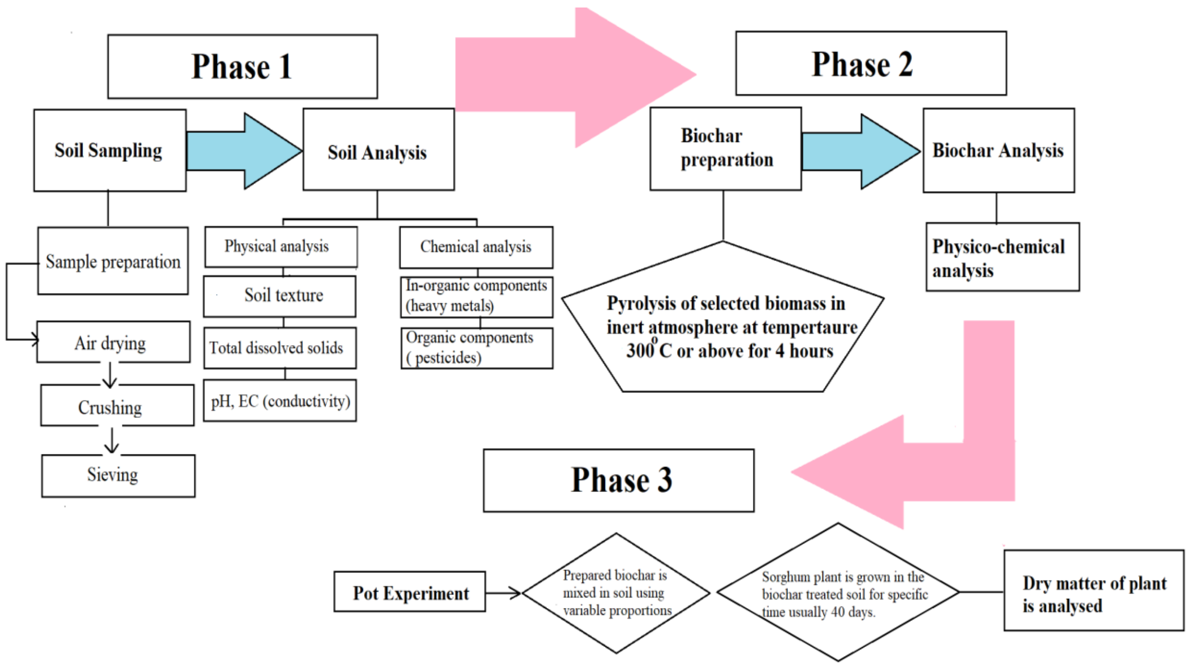

Fig. 2. Flow diagram depicting methodology adopted in biochar experiments (Zahid, 2017).

The experiments conducted for the evaluation of biochar in terms of remediation and increasing fertility, usually comprises of three phases. In first phase soil sampling and analysis is done. In second phase biochar preparation and characterization is conducted whereas in third phase soil is mixed with biochar and growth of any selected experimental plant is conducted. The general methodology that is followed in biochar experiments conducted for soil remediation is depicted in Fig. 2. In order to increase the productivity of soil specifically for various cash crops, application of biochar is recommended by many researchers (Fouda *et al.,* 2020). Soils such as sandy desert soils are very tricky and poor in nutrients. Growth of many plants that have an agro economic importance are difficult to thrive on such type of soils. In a study effect of multiple concentrations of biochar on sandy soils in terms of plant growth was evaluated.

Fig. 3. Layout for biochar formation and its application in arid (Thar) and semi-arid (Rawalpindi), Pakistan soils for enhancing plant growth (Iftikhar *et al.,* 2018).

The soils that were used as a sample for sandy soils were taken from the Inner Mongolia, China and Thar Desert, Pakistan. Biochar applied on these soils was made from the burning of pine sawdust and the growth of sorghum plant was studied as a test entity. After eight weeks of applying and maintaining experimental setup, results depicted that application of pine saw dust biochar at the rate of 22 t/ha lead to the significant increase in water holding and retention capacity of soil. A remarkable increase of 18% and 22 % of sorghum dry mass in the biochar treated soils of Mongolia and Thar was also observed. This increase in mass was associated with increased concentration of nutrients such as carbon, potassium, phosphorus and calcium in the biochar treated soil as compared to the control soil sample (Laghari *et al.,* 2015). In another study soil samples taken from the two regions of Pakistan (Rawalpindi and Thar) were adulterated with wheat straw biochar. The soil of Rawalpindi and Thar is semi-arid and arid respectively. The effect of biochar produced at 300°C was evaluated at different doses (0%, 1%, 3%, and 7% by mass). The experimental plant selected to check the effect of biochar was *Sorghum bicolor* (fig. 3). In order to check the effect of biochar on the growth of plants they were harvested after 40 days. Evaluation of plant growth, and dry matter yield of the biochar treated soil indicated enhanced soil fertility and plant growth (Iftikhar *et al.,* 2018). The aim of the previous research was to improve the soil quality of deserts by local and cost effective technology and to secure the food safety by soil improvement and soil fertility (Iftikhar *et al.,* 2018; Zahid, 2017).

Temperature plays a very important role for the production of biochar. Like leftover biomass of many plants, biochar prepared from the shoots of *Vitis vinifera* commonly known as grape's plant can also be employed for the enhancement of poor soil. A study was conducted to evaluate the effectiveness of the vine shoots biochar prepared at different temperatures for enhancing the plant growth in sandy loam and clay loam soil types. The crop selected for experiment was sorghum. Results depicted that application of biochar formed at 400°C considerably amplified the dry weight of plant's roots in the sandy-loam soil. Grain yield was also increased that could be because of higher water holding capacity and enhanced availability of nutrients such as calcium and magnesium (Videgain-Marco *et al.,* 2020). Another study conducted in sandy soil of Indonesia showed the importance of variable biochar concentrations on the overall productivity of crops. The plant selected was sorghum because of its extensive usage in the preparation of animal fodder. In the research various concentrations i.e. 3, 6, 9, 12, 15, ton ha^{-1} of biochar were applied. Effect on sorghum was evaluated in terms of the number of leaves, plant height, forage, dry matter, and seed production per hectare. Results depicted that the biochar dosage of 9 ton ha^{-1} delivered the best output in terms of production of fresh forage, dry material and seed production per hectare (Yudiastari *et al.,* 2019). Iftikhar *et al.* (2018) and Zahid (2017) reported that the chemical composition of crop residues has important elemental composition after pyrolysis at low temperature. The physical and chemical properties of the soil increased by carbon based biochar. The aim of researchers was to see the multiple positive impacts of feed stocks in reference to soil quality, crop production, food security, decontamination of soil and improvement of air quality.

Table 1. Biochar Characterization.

Applications of Biochar on soil properties		
Biological	Physical	Chemical
Improve beneficial soil microbiota	Decrease bulk density	Adsorb heavy metals
Provide additional nutrient sites for soil bacteria	Decrease soil losses	Improve soil CEC
Improve crop stability	Improve soil stability	Enhance soil total organic carbon
Enhance composting	Improve soil water retention	Improve soil carbon sequestration

Biochar and soil fertility

Drought and low amounts of organic matter are two main constraints in arid and semiarid regions and their adverse effects on soils and plants (as they negatively influences plant physiology, development, growth and yield) can be alleviated by biochar (Gavili *et al.*, 2018). Qambrani *et al.* (2017) reported that biochar produced at low-temperatures (300 or 400°C) is acidic, whereas at high temperature (700°C) it is alkaline in nature. This is an important finding as the agricultural use of biochar is twofold. If the soil intended for biochar application is acidic in nature, then the biochars produced at 700°C or higher can be used to neutralize the soil and improve soil fertility. Alternatively, biochars formed at lower temperatures might be suitable for alkaline soils to correct for alkalinity problems and is best suitable for arid and semi-arid regions.

Fertilizers play the role of back bone in terms of enhancing economy of agricultural countries. Most of the agriculture based countries are developing countries due to which use of fertilizer in every field is a very "expensive but necessary choice". Biochar has proved to be an effective substitute along with or even without the employment of fertilizer. One such study was conducted to determine the effect of biochar in combination with mineral fertilizer and soil microbes. Biochar was prepared from *Acacia Saligna*, *Simcoa Jarrah* and *Wundowie Jarrah*. The experimental plant to study the effect of various combinations in glasshouse experiment was wheat and in field application sorghum was selected. Results revealed that the combination of biochar, mineral fertilizer and soil microorganisms could increase *Mycorrhizal* colonization, plant growth and nutrient (nitrogen, phosphorous, potassium, sulfur and zinc) uptake by wheat. The field experiment revealed that application of biochar and mineral complex at a rate of 300kg ha^{-1} had the potential to increase the yield of sorghum on a loam soil as compared to the application of fertilizer alone (Blackwell *et al.,* 2015). Energy generation from the biomass results in enhanced creation of byproducts. Biochar is one of the nutrient rich byproduct of various plant residues and can be applied on areas that are used for the cultivation of bioenergy crops such as sorghum. Extensive fertilizer usage for cash crops has led to the issues of nitrogen leaching in soils and surrounding water bodies.

A study conducted in South America revealed that the use of low nitrogen concentration fertilizer along with biochar could minimize the issues related to nitrogen leaching, nutrient recycling and enhanced water retention in soil over which crop rotation of crash crops such as cotton and peanut with the bioenergy crop of sorghum is done (Reyes-Cabrera *et al.,* 2017).

Likewise, soil inorganic carbon (SIC) plays an important role in terrestrial ecosystem carbon cycling, especially in arid and semi-arid areas. So, biochar in this context also proves itself to be beneficial as a research conducted by Dong and his colleagues in 2019 revealed that biochar can increase field soil inorganic carbon content five years after application and can help in carbon sequestration. In context to promote plant growth and improve soil fertility status in arid and semi-arid regions, a successful study was designed by Iftikhar *et al.,* 2018. The finding came out that biochar incorporation (made up of wheat straw) increases nutrient availability and water retention in soil and enhanced growth of *Sorghum bicolor* plant.

A 3-year field experiment was conducted on the semi-arid Loess Plateau in northern China, and biochar derived from maize-straw feedstock was applied to a spring maize monoculture cropping system at different rates. The results indicated that incorporation of biochar into the soil improve the physical and hydraulic status of semi-arid agricultural soils (increased soil permeability and improved water retention capacity), thereby leading to an increase in plant available water (Luo *et al.,* 2020; Xiao *et al.,* 2016). Gavili *et al.* (2018) conducted research to analyze the potential of cattle-manure biochar on physiological traits of spinach and physical characteristics of postharvest soil. Drought decreases stomatal conductance, water use efficiency, shoot dry matter yield, soil water repellency and saturated hydraulic conductivity. But addition of cattle-manure biochar in lesser amount solves the typified problems. Recently, a research with an objective to understand the effect of biochar and a biochar-compost mixture on the performance of *Phragmites karka* plants grown on an arid and semi-arid soil was carried out.

It was found that there was a significant increase in soil respiration in the treatments with biochar-compost, which stimulated microbial interactions. The increase in soil water-holding capacity after this beneficial amendment caused significant improvements in plant water status and plant ion (K^+, Mg^{2+}, and Ca^{2+}) contents, leading to an increase in net photosynthesis and a higher energy-use efficiency of photo-system. Along with that, greater improvement in growth, leaf turgor potential, photosynthesis, nutrient content and soil gas exchange was also seen (Abideen *et al.*, 2020). Another study was planned in 2020 to investigate the interactive effect of biochar and silicon (Si) nutrition on morpho-physiological and biochemical traits of *Zea mays* L. under semi- arid conditions. The positive effect of sole application of biochar and silicon was observed in improving physio-biochemical traits. In addition, better results were obtained with combined application of biochar and Si in enhancing maize growth such as shoots by 25%, roots (40%), and seedlings by 27% as compared to normal semi-arid soil (Sattar *et al.*, 2020).

Biochar , crop stability and yield

Biochar in general has positive effect on crop yields but becomes more effective when applied to medium low fertility soil and degraded soil (El-Naggar *et al.,* 2019). But good yield also depends on the type of biochar and its dose in soil, time and adaptation to local conditions. Usually it would take years to generate positive results in highly degraded soils. Steiner *et al.* (2007) observed that 11t/ha of biochar application to rice and sorghum increased yield upto 75 % after two years. Similar observations were made by Feng *et al.* (2014) who did not observe immediate enhancement in yield of maize and winter wheat but cumulative yield were higher for first four growing seasons with the application of biochar. Deng *et al.* (2017) observed that biochar application increased the soil carbon but has no effect on sorghum yield. This may be due to low dosage and competition for water and nutrients with *Acecia seyal* tress. Biochar full potential for the enhancement of yield requires long term studies to fully understand it potential and limitation in croplands.

Arid regions soils are effected by salinity can also benefit from biochar application. Biochar can reduce the salinity stress indicators in wheat such as sugars, superoxide dimustase and proline (Iftikhar *et al.,* 2018; Kanwal *et al.,* 2018). Salinity induced stress to potatoes also ameliorated by applying the biochar as observed by Akhtar *et al.* (2015). It absorbs the sodium ion in soil and increase potassium in xylem tissue. Biochar amended soil has shown to improve the yield in drought conditions by enhancing the permanent wilting point (Liu *et al.,* 2016). In sandy soil biochar improved the leaf osmotic pressure and stimulated photosynthesis by increasing electron transport rate of photosystem both in drought and well-watered conditions (Haider *et al.,* 2014).

Another benefit of biochar in agricultural farmlands is the improvement of soil stability through aggregation of colloidal material. That helps in reducing the loss of potassium by controlling soil erosion (Soinne *et al.,* 2014). This property of biochar would also help in the sorption of harmful agrochemicals applied to the soil. Clay mineral plays important role in sorption desorption of harmful chemicals present in soil. The functional groups which include carboxylic (–COOH), hydroxyl (–OH), lactonic, amide and amine groups forms stable chemical bonds with pesticides and other organic contaminants that lead to surface adsorption (Antón-Herrero *et al.,* 2018) .

Feedstock sources and biochar production

Modern biochar production incorporates low oxygen thermochemical conversion of agricultural and forestry biomass source across a range of temperatures (Diatta *et al.,* 2020). Generally, three types of process are associated with biochar production i.e. pyrolysis, gasification and torrefaction (Fig 4) that can be used either at large or small scale (Boateng *et al.,* 2015).

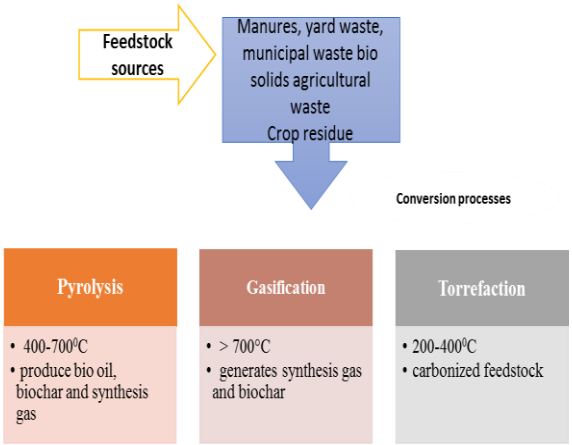

Fig. 4. Illustrated representation of biochar process and products.

Variety of biomass sources can be used to produce biochar including animal manure, husk, corncob, and other agricultural waste materials (van Zwieten *et al.*, 2010). The nature of the original material (feedstock) has a great impact on biochar properties and its end use. The low temperature pyrolysis yields more biochar as compared to the high temperature pyrolysis, which yields biochar with high carbon content, large surface area and high adsorption (Jindo *et al.*, 2014). Biochar properties vary depending on the type of feedstock used and the production process. Its characterization is important for determining its application rate and site (Major, 2010). According to Ma *et al.* (2018) the structure of biochar depends on the lignin content of feedstock biomass for example in case of the pore size of biochar produced from sludge was 12.35 times smaller than biochar produced from rice husk. Similarly, different types of biochar showed variance in the content of K, Ca, Mg, and Na with manure biochar having highest concentration that biochar from woody and herbaceous plants (Chen *et al.,* 2019).

The pH of wheat straw biochar produced at 500˚C in biochar reactor was reported as 10.51 by Song *et al.* (2012). The low pH value, found in study is due to reason that the biochar produced below 400˚C are found having low pH (Lehmann, 2006). Also, the biochar produced through pyrolysis have alkaline pH values (Alburquerque *et al.*, 2014). Also, electrical conductivity of wheat straw biochar was reported to be as 2810µS/cm. Presence of high soluble salts in biochar resulted in higher EC values (Chintala *et al.*, 2014). However, slow and fast pyrolysis techniques are conventional or traditional methods for producing biochar. Now advancements have been made and biochar is being produced through latest technology such as gasification, electro modification, microwave and vacuum pyrolysis (Ghabane *et al.*, 2020). Furthermore, colloidal sized biochar from agricultural waste is also being produced by ultrasonic radiation which is a green and non-mechanical method.It has been reported that biochar produced by wood pellets and sewage sludge can reduce maximum nitrogen emission and enhance dissolved organic carbon in soil (Yang *et al.*, 2019). On the contrary, microwave activated biochar can act as an excellent bio sorbent for controlling agricultural waste leachate in soil (Lam *et al.*, 2019). Also, thallium contamination of agricultural soils is an under reported issue, but recent study suggested that biochar derived from pomelo peel can actively adsorb and remove thallium within few days from the crops and soil (Gao *et al.*, 2020).

The biochar produced from wheat straw has ash content equivalent to 25.7%, as reported by Alburquerque *et al.* (2014), whereas Zhao *et al.* (2013) reported presence of 18.0% ash content. The biochar produced from crop residue show relatively low ash content as compared to biochar produced by using manure and sludge as a feedstock. Low concentration of mineral constituents in the feedstock indicates the presence of low ash content (Zhao *et al.*, 2013).

The pyrolysis conditions including the duration and temperature also determine the diverse range of biochar applications depending on its properties. Usually, the biochar produced through low temperature pyrolysis have high volatile matter content and its substrate could be decomposed easily. Thus, such biochars are efficient to support plant growth. With the increase in peak pyrolysis temperature during conversion of feedstock to biochar, its degree of carbonization increases, which is indicated by the increased carbon content and decreased hydrogen and oxygen content (Wang *et al.*, 2015a).

Biochar produced in kiln has shown positive effects on plant growth. Another similar method "Kon-Tiki" can also produce biochar by pyrolysis of layer after layer of feedstock in a conical openly built metal kiln (Schmidt and Taylor 2014). Production of biochar produced in kiln (fig. 5) has shown positive effects on plant growth (Iftikhar *et al.,* 2018). The side products from biochar synthesis can be used for energy and as a bio pesticides (Meng *et al.*, 2013; Allaire *et al.*, 2015).

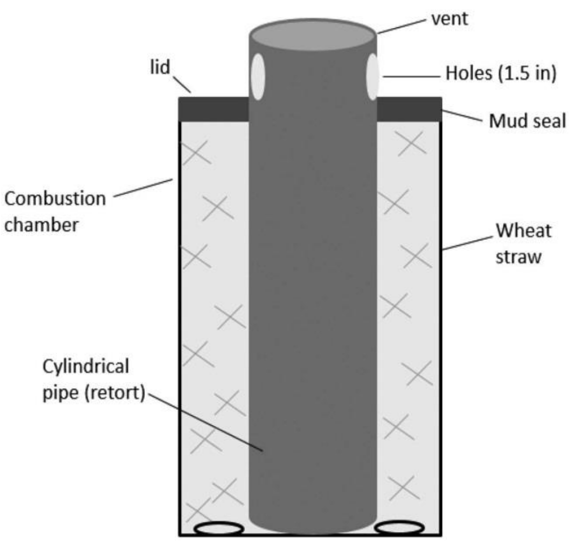

Fig. 5. Graphical cross-sectional representation of the retort kiln built and utilized in experiment (Iftikhar *et al.,* 2018).

The biomass can easily be converted into fuel using other thermochemical conversion techniques like gasification, and combustion (Kim *et al.*, 2012). Biochar can also be lost by erosion after its addition in soil. This problem is aggravated by the sloppy terrains and even in flat areas receiving heavy rainfall. However, changes in pyrolysis temperature can alter hydrophobicity and hydrophilicity of biochar which can help in reducing erosion (Kumar *et al.*, 2019). In addition to this, it has been reported that biochar produced with low pyrolysis can greatly enhance crop yield (Purakayashtha *et al.*, 2019). Moreover, the soil inorganic carbon content which has an essential role in managing global biogeochemical cycles has been reported to increase by 20% if biochar is applied to the soil (Dong *et al.,* 2019). Also, it is a well-established fact that biochar reduces wilting capacity in crops and enhance crop available water content in soil (Razzaghi *et al.*, 2020). Another contribution of biochar to soil productivity is that it enhances soil cation exchange capacity specifically with reference to K^+ ions, thus improving phosphorus mobility (Hailegnaw *et al.*, 2019).

Biochar based nano composites

Bioremediation is a process used to treat contaminated sources, such as water, soil, and other environmental materials, by stimulating growth of microorganism for the removal of contaminants by in situ and ex situ bioremediation practice (Vimal *et al.,* 2017). But, some new reported approach is being used in the bioremediation such as agricultural waste-biochar (raw pine chips, peanut hulls and pecan shells, forage plant biomass, rice husks etc.) that can remediate the contamination (organic and heavy-metal contaminants) through their adsorption properties due to unique surface and internal structure, etc. (fig 7).

Recently, the synthesis of biochar-based nano-composites has caught the attention of several researchers. Biochars were combined with nano-materials to obtain metal-oxide biochars, magnetic biochars, and biochars coated with functional nano-particles, that increase the levels of surface functional groups, improve pore properties, impart magnetic separation capabilities, and catalytic properties for the degradation and treatment of wastewater by adsorption, separation, or catalytic degradation of organic and inorganic compounds (Tan *et al.*, 2016). These nano-composites have specific properties that target particular chemicals in wastewater where several chemicals are present.

Several studies report the removal of heavy metals including As(III, V) using iron-impregnated magnetic biochars (Wang *et al.*, 2015a; Hu *et al.*, 2015), Cr(VI) using zinc and chitosan-modified biochars (Huang *et al.*, 2016; Gan *et al.*, 2015), Pb(II), Cu(II), and Cd(II) using a KMnO4-treated-wood biochar (Wang *et al.*, 2015b), and Hg(II) using a graphene-treated biochar; Pb(II) and As(V) are the most studied of these heavy metals.

Adsorption capacities for Pb(II) of 4.9–367.6mg–¹ were reported for a ZnS-biochar (Yan *et al.*, 2015a). Removal of phosphorus has also been reported in several studies using oxides of Ca, Mg, and Al-modified biochars (Liu *et al.*, 2016; Jung *et al.*, 2015). The use of catalytic and degradative nanoparticles, such as nanoscale zerovalent ions and graphitic C_3N_4 has been reported to remove several organic chemicals (Yan *et al.*, 2015b). The use of nano-composites is clearly a promising technology for the treatment of aqueous media, but it is in its infancy and requires a lot of further research, especially regarding the re-use, desorption and disposal of these metal-attached nano-composites (Qambrani *et al.*, 2017). Another study revealed that the effect of biochar on soil CH_4 or N_2O evolution can be potentially altered when labile exogenous C sources (e.g. crop straw) are added simultaneously. The addition of rice straw biochar produced at 300°C into soil alone can significantly increase CH_4 emission, whereas the CH_4 emission was significantly reduced when the rice straw biochar was co-applied with rice straw (Jiang *et al.*, 2020). According to research published in 2020, conventional carbon activation requires heating carbon at a temperature greater than 700°C for over 3h, consuming 18,600 kcal/kg of activated biochar. In contrast, the ultrasound treatment method is conducted at ambient condition for a very short duration (~30 s, which requires about 1135 kcal/kg of activated biochar produced. The advanced low-temperature acoustic-based surface modification method not only increases the porosity and surface functionality of raw biochar, but also is economically feasible and environmentally friendly (Sajjadia *et al.*, 2020).

Biochar and adsorption

Biochar has the ability to act as a cost effective adsorbent for the bioremediation of industrial effluents. It has been reported to be very effective against variety of heavy metals. Many researches have revealed actual removal of heavy metals from aqueous medium using biochar produced from variety of sources. Many factors are responsible for the adsorption of metals using biochar, the most dominating factor is the parent material of the biochar from which it has been originated. Variety of processes are responsible for the optimum removal of heavy metals using biochar. These processes involves physisorption, precipitation, complexation, ion exchange and electrostatic interaction (chemisorption). Biochar owns high surface area and a well-connected porous system. These pores physically attach metals in them. Commonly biochars are negatively charged and can bind positively charged metal ions. Sometimes ligands and functional groups present on the surface of biochar undergoes complex formation with metals and precipitate out the metal from the contaminated site (Inyang *et al.,* 2016). All the possible mechanisms of metal adsorption are depicted in following Fig. 6.

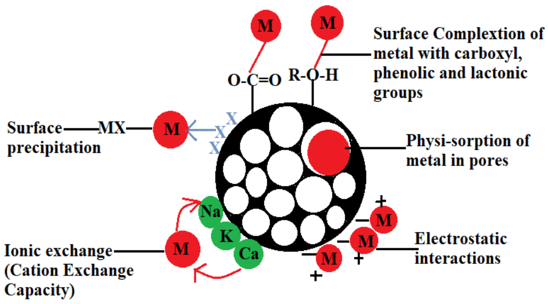

Fig. 6. Adsorption mechanism of heavy metals using biochar.

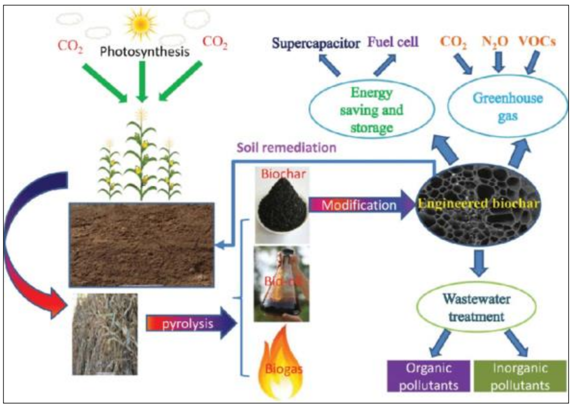

Fig. 7. Biochar production for environmental remediation.

In developing countries problems related to heavy metal contamination of soil are very common and leads to drastic effects on the growth of cash crops. Soil polluted with heavy metals are characterized as poor in nutrients and inappropriate for crop cultivation. Many studies have depicted the positive effect of adding biochar in such soils for the purpose of remediation and improving soil properties side by side. A study was conducted for knowing the effect of biochar produced from different sources on certain pollutants and plant germination. Biochar selected in that study was derived from four different sources that include bamboo, rice husk, ash tree and beech tree. Results revealed that the biochar derived from all the four sources had the potential to adsorb various heavy metals such as cadmium, copper and lead. The reduced toxicity was further confirmed with the germination of sorghum seeds in biochar treated soil whereas in non-treated soil no germination occurs because of the toxic effects of heavy metals. In terms of affectivity of individual biochar against the selected heavy metals; bamboo-derived biochar was less efficient for cadmium and copper whereas the rice husk derived biochar was less effective against lead (Soudek *et al.,* 2017). Biochar has the capability to act as a nutrient enriching tool in contaminated soil along with the remediation of pollutants. In a study effect of wood derived biochar was investigated for the growth of sorghum, planted on the heavy metal contaminated landfill site for the purpose of bioremediation. Firstly the sampling of soil was conducted from the three landfill sites present in Nigeria. Physico-chemical analysis and heavy metal contamination of samples were analysed according to the standard protocol.

The results depicted high concentration of copper and lead in the soils according to the standard guidelines for agricultural soils. For the purpose of bioremediation sorghum seeds were planted in five landfill soil pots, treated with wood biochar (0 to 20t ha^{-1}). The plants were reaped at 12^{th} week after planting. The biomass of plants was oven-dried followed by digestion and analysis. Results depicted that the application of Biochar at 10–15t ha^{-1} had increased the growth and tissue portion in the sorghum. The increased growth of plants proved the enhanced immobilization of metals from the soil. The study concluded that the use of biochar as organic alteration in polluted soils could play an important part in bioremediation of soil (Oziegbe *et al.,* 2019). Now a days there is an increased trend of modifying the surface of various substrates for enhancing associated capabilities. Surface of biochar can also be modified and increased adsorption of desired metals can also be achieved. Recently biochar derived from the corn stalk was modified using citric acid, sodium hydroxide and ferric chloride both in pre and post pyrolysis stage. The results depicted that the biochar modified by ferric chloride at pre pyrolysis stage exhibited superior adsorption capacity for chromium (VI), as compared to the rest of modifying agents. This could be because of presence of highly dispersed Fe_3O_4 particles and larger surface area (An *et al.,* 2018).

Conclusion

Biochar has important applications for soil remediation and is considered mitigation for climate change. Biochar help provides soil microbiota a kind of habitat where they become efficient nutrient source for soil and can help improve the soil pH, electrical conductivity, soil productivity, total carbon content and plant growth. Due to the small particle size, large amount of biochar dust is lost during its application in soil and this complicated situation is managed by moistening the biochar before incorporation to soil. Even little quantities of biochar present in soil can help reduce soil acidificasion and adsorb suspended particles including poly aromatic hydrocarbons, thus acting as an excellent adsorbent for removing impurities.

Declaration of interests

No potential conflict of interest among both authors.

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