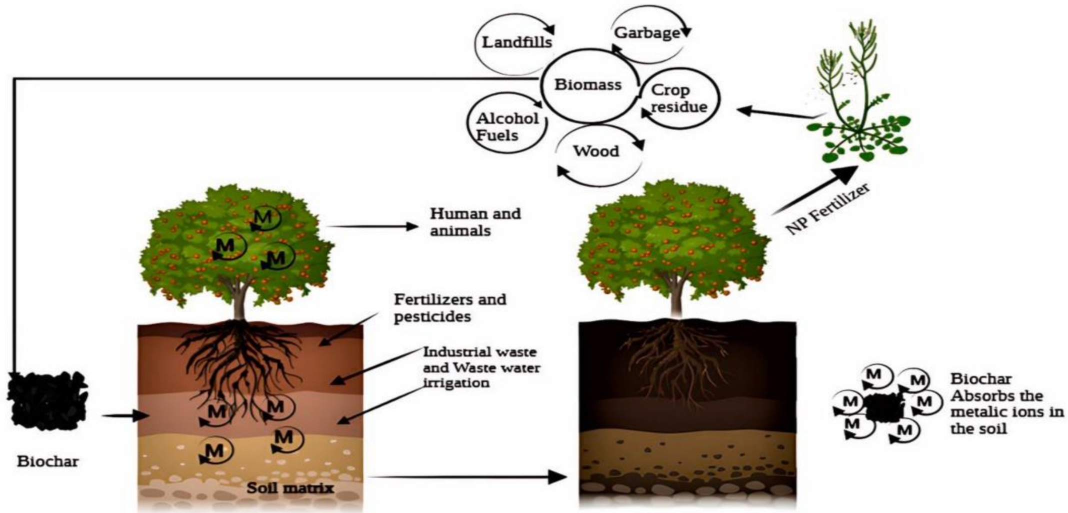
Applications of the biochar using different techniques

Soil and Agriculture

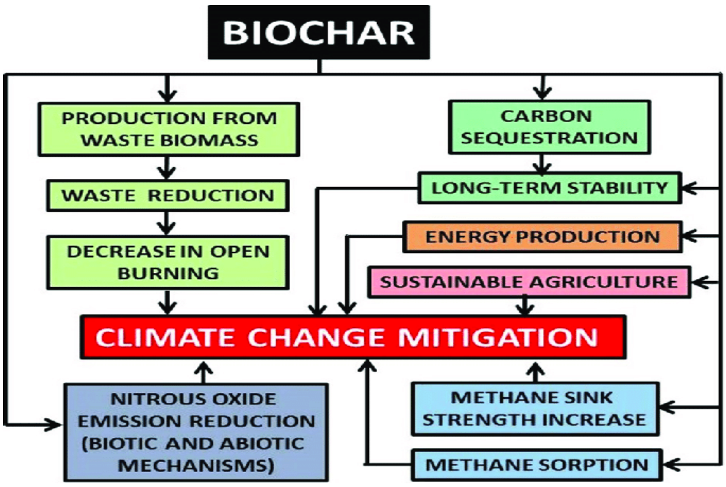
It is employed as a part of chemical fertilizer, microbial action of soil, amendment for altering the soil usage for crop productivity based on nutrient availability and water retention. Biochar has been described to reduce the dispersion of special metals in the soil as well as exhibiting a constraining property that contributes to raising the pH of strongly acidic substrate. : Notably, biochar is also another type of soil conditioner; however, it differs from compost through the production routes. Biochar is developed by pyrolyzing of food, horticultural and municipal solid wastes with heat under conditions of limited or no air access while composting is the natural biological evolution of organic matter through the action of the microbial community under aerated conditions. The other one is; compost decomposes quickly hence it provides a shorter TEE compared to biochar, which has a long residence time in the soil. It also serves to wash out soil salinity, thus enhancing the nutrients, and therefore finding its way into higher yields. Biochar can also have qualities of eradicating or even controlling diseases and pests in the crop field. A 3-5% biochar application reduces the fungal pathogens and pests' growth rate by inhibiting the plant hormones responsible for stimulating its growth. Moreover, the result recorded on weed management and crop yield indicated that biochar has a potential value-added use for faba beans production. Additionally, several field trials and pot studies indicated that the augmentation of different types of biochar positively affected the yield and growth of various crops including haseolus vulgaris, Cucumis sativus, Fragaria × ananassa, Solanum lycopersicum, Zea mays, Citrullus lanatus, and Piper nigrum.



Metal contamination remediation with biochar implication is depicted schematically by adsorbing the metallic impurities

Climate Change mitigation

The most important environmental issue of modern society is the issue of global warming due to the rising level of greenhouse gases (GHG) and the key role of carbon (C) in the process of its formation and reduction. Bio char has excellent characteristics of physical and chemical for appropriate usages in the various sectors to enhance the eco-natural quality. It is essential to note that biochar can be used to catalytically degrade contaminants because it collects transition metals. It is therefore important for the treatment of organic wastes to be conducted in a proper way in order to have an added effect of reducing methane emissions from dumps, industrial energy usage and other greenhouse emissions which are indirectly beneficial in combating climate change. It is lighter in mineralization than the raw material it was derived from, and reduces system CO_2 emissions, central to climate change. Biochar application on the global scale could decrease emissions of greenhouse gasses by approximately 12%. Preventing climate change could also be another indication that using biochar composites in the soil instead of virgin biochar is another way. First, it was suggested that augmentation of biochar with compost would enhance the capability to decompose; enhance the stable carbon input and yield a by-product (the biochar compost mix) that would negate the considerate demerits of the pyrolysis biochar technology (such as low macronutrient content, composting system, CH_4 emission). Second, it has said that rates of OM accumulation in the soil and reductions in CH_4 and N_2O, the factors with high global warming indices, are connected with biochar. Perhaps, more plant growth or low emission of greenhouse gases in the soil level would be needed for the biochar system to have a better emission balance than doing it as charcoal fuel. A study shows that biochar influences rice fields' methane emissions by supporting methanotroph (methane-consuming bacteria) populations and reducing the distribution of methanogens (methane-producing bacteria).



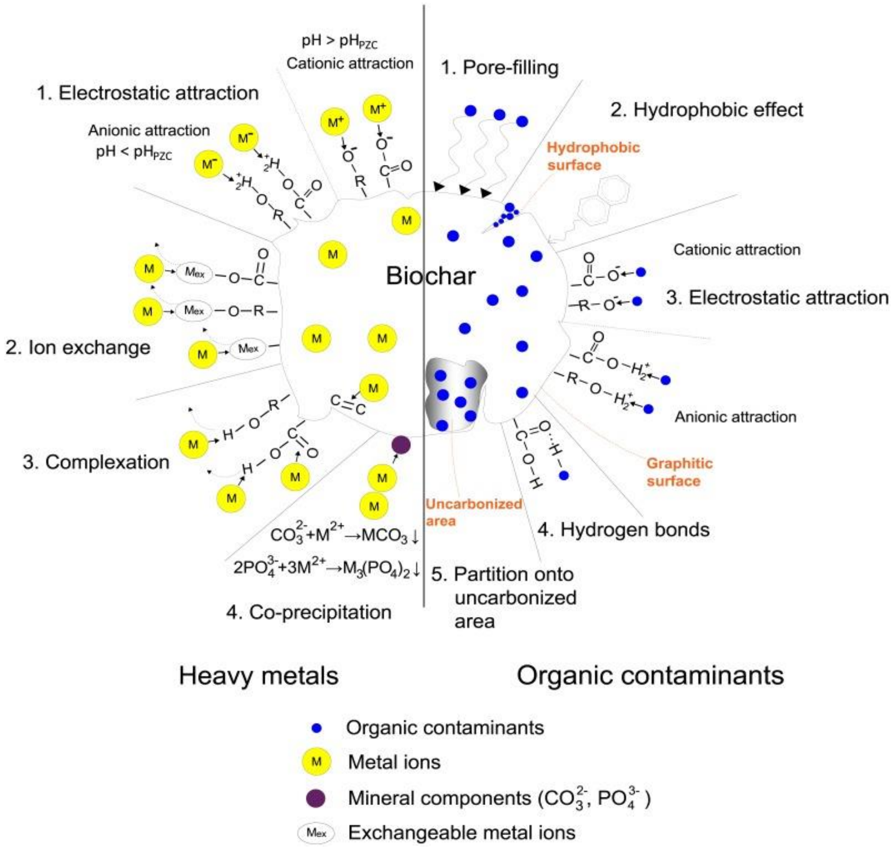
Mechanisms through which biochar can help in the mitigation of climate change

Construction

Biochar is currently used in construction and as an additive. It is possible to see this in new filling materials and pedestrian/vehicle pavement blocks. Although the study found that the addition of biochar had a positive effect on cement hydration, it was noted that the size examined could cause micro cracks and reduce strength. Additionally, the addition of biochar can improve the neutralization of pollutants and toxic substances in the sediment, which is crucial for low-quality products. Therefore, biochar obtained from wood can be used as a green mixture for cement-based recycling of solid waste. Using biochar in materials used to capture atmospheric carbon dioxide in the building can also reduce greenhouse gases by 25%. Biochar's high pH and high water stability allow it to absorb some of the water in the concrete mix, thus reducing the amount of free water in the concrete.

Remediation of gaseous air pollutants

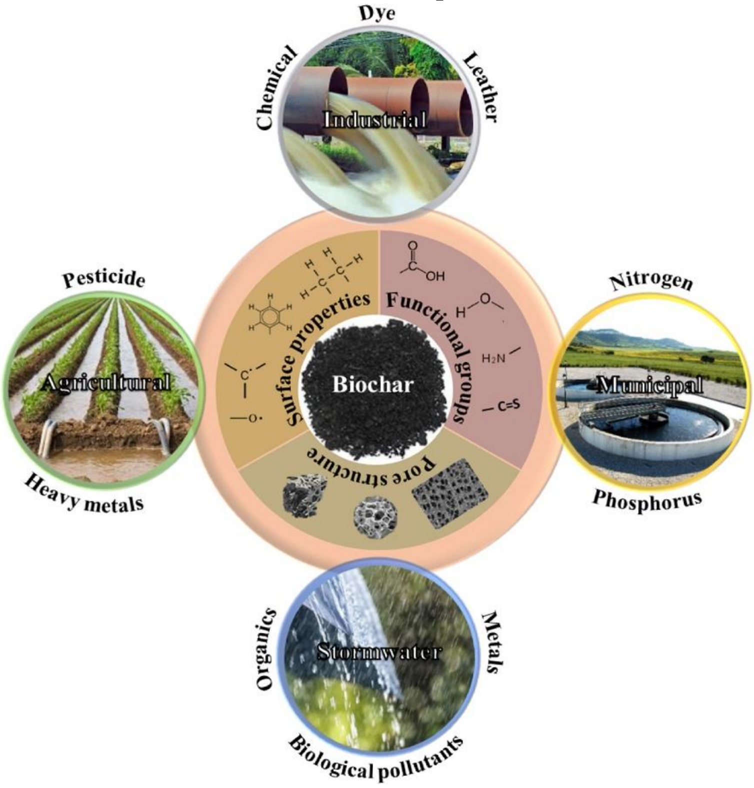
Biochar can also be employed for the abatement of poisonous gases like; NOx, CO_2, SO_2, ozone, H_2S, Hg, VOCs and other gaseous pollutants. H-bonding, pore-filling, van der Waal interaction, electrostatic/additional covalent interaction of the pore wall and the solute, π–π electron interaction, and partitioning are responsible for the removal mechanism. NOx, CO_2 and ozone is biochar adsorbed or sequestrated. It can be noted that though these gases could be removed using the pristine biochar, the efficiency could be improved by processes such as heteroatom doping or surface modification. Due to the highly obnoxious nature of H_2S and the hazardous property of SO_2, their removal is necessary, which has been perfectly done by the biochar that was characterized by well-developed porosity and surface functionality. Dispersive biochar is hydrophilic and hydrophobic; the polar volatile organic compounds such as aldehydes and ketones are preferably removed by hydrophilic biocharge while non polar volatile organic compounds are removed by biochar with low hydrophilicity. It could be deemed that biochar materials will thermo-catalytically and photo-catalytically remove VLCs through mass transport of volatile organic compounds on the adsorbent surface, through formation of reactive oxidative species radicals, through oxidative reactions between adsorbed volatile organic compounds and reactive oxidative species; and through desorption of products to regenerate the sorbent. It is actually known that among several parameters of biochar which can be as criteria of its interaction with CO_2, the porosity is one of necessary conditions and that the micropores defining the CO_2 capture ability of biochar are studied widely. Hence, activation is an important factor in developing the conditions of porosity of biochar used. The two widely used techniques of activating biochar are through physical activation and chemical activation. Former is achieved to add gases like CO_2 and H_2O to interact with biochar at high temperatures and take out the volatile to create a large number of porosity. But it is imperative that the physical activation of biochar is slightly moderate and environmentally friendly than the chemical one although it has less activation strength. There is, however, chemical activation of biochar where there is a reaction between active chemical substances such as alkaline, acid and molten salts with carbon in a bid to create pores.



Sorption mechanisms of heavy metals and organic contaminants on biochar.

Contaminant remediation from water

Biochar can also be used to adsorb organic and inorganic pollutants from wastewaters and waste streams originating from industries. The elimination of pollutants might be impacted on by factors such as differences in feedstock and conditions during the production of the biochar, type and form of the target contaminant as well as solution pH, contact time, temperature, ionic strength and the kind of dose used. Biochar has application for the removal of organic pollutants including furans, phenolic compounds (catechol and naphthalene), drugs and antibiotics, Congo red, anionic brilliant blue, methylene blue, persistent organic pollutants, agrochemicals such as fertilizers, pesticides and insecticides, volatile organic compounds and endocrine disruptor compounds. Additionally, the removal of inorganic pollutants with biochar has also been established with cations (Cd^{2+}, Cr^{6+}, Cu^{2+}, NH^{4+}, Pb^{2+}, and Zn^{2+}) and anions (F^{-}, NO^{3-}, and PO_4^{3-} has also been reported. In addition, it is known that biochar sorbs crude oil originating from oil leaks. Biochar as a product from municipal biowaste, can be applied in the course of biofiltration of municipal wastewater. Biochar possesses a large surface area and hence through the interconnecting porosity it behaves as a biofilter of municipal wastewater. Wastewater's COD, TSS, TKN and TP decrease to 90%, 89%, 64% and 78% respectively, after it has gone through the biochar biofilter. Septage from the residential units that were not connected to any MSTP was treated with biochar at OSSFs. It is quite evident that incorporation of biochar enhances the removal rate of some of the polar and hydrophilic molecules. OSSFs therefore can then be retrofit with low cost biochar adsorbent. Through pyrolysis, biomass produces biochar with several exchangeable cations on its surface and some of them are alkali or alkaline earth metals that may be exchanged with heavy metal ions during the sorption. The desired minerals parts in biochar are also effective in the removal process; it functions as other sorption sites and also has a contribution to the heavy metal sorption through precipitation.

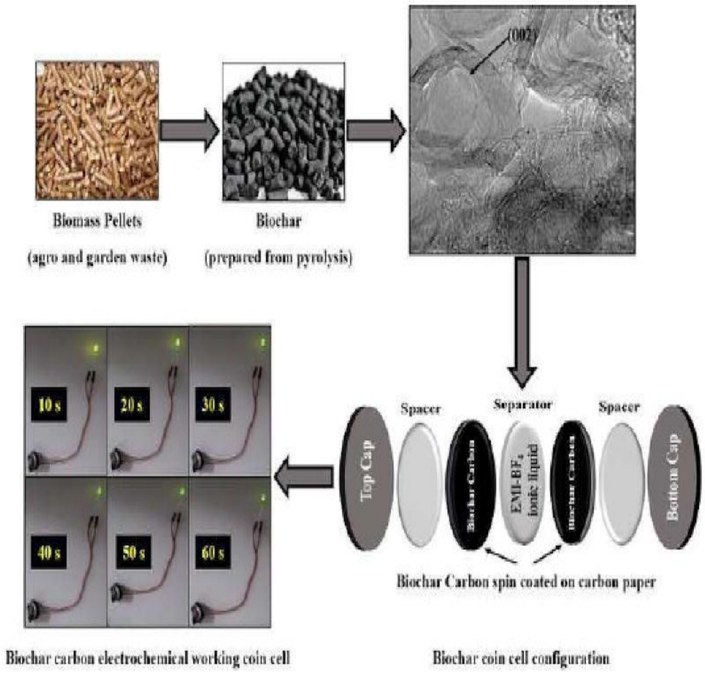


Biochar application in wastewater treatment.

Supercapacitors

Biochar from waste biomass has been identified as the most efficient sorbent for the treatment of heavy metals in wastewater. However, the disposal of such a biochar containing a heavy metal is a bit cumbersome, proper one to be precise. The major goal is to design a reuse way for the biochar originated from the heavy metal such as converting the biochar into supercapacitor. Two biochars are prepared from dairy manure and sewage sludge and the Ni sorption ability of the biochars was determined successively; the Ni-loaded biochar was used to fabricate a super capacitor by means of microwave treatment. Such specific capacitance of get enhanced with increasing of Ni loading and the supercapacitor based on Ni-loaded biochar further treated with microwave increased more than 2 times as compared to that of the initial biochar supercapacitors. A margin increase in the capacitance of the Ni-loaded biochar supercapacitor was achieved from microwave treatment because of the redox transformation of Ni to NiO and NiOH. Among the prepared biochar supercapacitors, microwave treated Ni loaded biochar supercapacitors has great stability of specific capacitance, which decreased less than 2% after 1000 charge discharge cycles. Ni-loaded biochar could be applied for the generation of supercapacitor and, thus, exhausted carbonaceous sorbents may be effectively reused.

Supercapacitor application of biochars derived from Litchi chinensis (Litchi) seeds, Syzygium cumini (Jamun) seeds and pine cone was investigated. Indisputably, the preparation temperature and the type of feedstock impact the physicochemical and electrochemical properties of the obtained biochar. Out of the three feedstocks, Litchi seed derived biochar has the highest specific capacitance of 190 Fg^{-1} at 1 Ag^{-1} for the symmetric cell configuration. N and O heteroatom functionalities in Litchi seed derived biochar, high SSB and PV for electrolyte adsorption are attributed to improved capacitive performance over Jamun seeds and pine cone biochar. Self-co-dopes N (3. 65%) and O (6. 44%) porous biochar are obtained by pyrolysis of the biomass pellets prepared by using garden wastes and are analysed for their use in energy storage. The incorporation of co-doped-heteroatoms in the carbon matrix of biochar helped in increasing the surface hydrophilicity, electrochemical double-layer formation, increased electrical conductivity and lowered interfacial charge transfer resistance. As for the pseudo capacitive nature, biochar prepared at 800 °C, namely biochar-800 evidences self-co-doped heteroatoms. The two-electrode test in 1M H_2SO_4 showed that the specific capacitance of biochar-800 was 228F g^{-1} when the test current density was 1 Ag^{-1}. Furthermore, energy density in biochar-800 is also high which is 7.71 and 91 Wh kg^{-1} in aqueous electrolyte and comparably good cycling stability 88% capacitance retention after 5000 cycles at 10 A g^{-1}. Biochar-800 with self-co-doped heteroatom improved the capacitive performance of the electrode was due to the large SSA, the self-formed mesopores, and pertaining pore size of around 15.2 nm. Porous biochar from the biomass pellets are excellent candidates to be used as low-cost electrode material in high-performance energy storage system.



Schematic diagram of supercapacitor device and its individual components.

Hydrogen storage

The H_2 storage capacity of a microporous biochar synthesized from KOH activated woodchips was reversible and measured up to 5 wt% for cryogenic temperatures. Activation strategies are also essential while gaining the better microporous nature for the storage of H_2 also. Catalyst prepared by impregnation using KOH and $ZnCl_2$ on tangerine peel biochar had a higher H_2 capacity of 0. 2 wt% (at 25 °C, 30 bar) in $ZnCl_2$-activated biochar; the specific surface area has a higher value. Since it was concluded that the hydrogen sorption was through Van der Waals force, the biochar provided full reversible capacity. The findings of this literature also reveal that the incorporation of oxygen functionalities enhances the hydrogen storage tendency in biochar. Activated by KOH and oxidized by ozone to introduce the O-functionalities, the olive stone biochar. The preference undergone in the decreasing order in the hydrogen absorption tendency included the specific surface area, the average micropore size the surface functionality and pore size distribution.

Thus, the H_2 storage capacity of the resultant biochar-based material is lower than that of metal hydrides such as MgH_2. However, when biochar was added during ball milling with Mg, it enhanced the H_2 capacity through the below influences: Metal dispersal, conversion of Mg to metal hydride and decreasing the temperature of hydride decomposition. Another application of metal hydrides and biochar is the utilization in the reversible hydrogen storage material with fairly good compositing ratio. The MgH_2 biochar composite sorbed 6.13 wt% of H2 at 225 °C and 30 bar H_2 pressure that is relatively close to the value for pure MgH_2. In addition, the measured reversible hydrogen storage capacity in the hybrid was over 98% up to 10 cycles, it was revealed. Conversely, the dehydrogenation of MgH2 led to convert it to Mg with a particle size that has a problem of reconverting it back to MgH2 through agglomeration of Mg particles. However, the process of incorporating biochar in the storage of H_2 is new and the improvements of these properties still need to be researched, developed and implemented to improve the capacity, economic viability and safety of using H_2.