

Role of Biochar

in heavy metal remediation

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Natural resource health is deteriorating at an alarming rate and it is estimated that by 2050, India will require 333 million tonnes of food grain to feed the growing population. Therefore, it's time to make better use of natural resources and clean up the contaminated agricultural land before planting crops. Pollutants of many types are contaminating the food chain and affecting soil and human health. Pre-treatment at the source point reduces the pollution load into natural bodies and allows for traditional and modern technology to be used to rehabilitate the polluted field. Importance of increasing farmer awareness for safe use of industrial waste, effluent and sewage during agricultural production is realized in this regard. Before cultivating food crops, organic and inorganic soil additives should be used to remediate contaminated soils and biochar seems to offer possible solution.

Keywords: Biochar, Metal, Production, Remediation

BY 2050, India's population is predicted to grow to 1.66 billion, requiring 333 million tonnes of food grain to feed the hungry stomach. Some of the known adverse effects of agricultural intensification include increased soil erosion, declining soil fertility, and decreased biodiversity at the local level; groundwater depletion and pollution; eutrophication of surface waters; changes in atmospheric composition and climate changes at the global level. Researchers and policymakers are striving in this area to increase food grain production without jeopardising the health of natural resources. Water is the most important resource for agricultural crop production system and its availability is decreasing year after year. Farmers are obliged to utilize low-quality irrigation water such as sewage, industrial effluent, saline/alkaline water and so on. These sources of irrigation water contain metal(s) and salt ions, which accumulate in soil after long-

term irrigation. They have a negative impact on soil health and crop production capacity. Human health is harmed by long-term ingestion of polluted dietary items. On the other side, increasing global climate change phenomenon is putting a lot of pressure on agriculture to feed the hungry mouth. By 2025, the average global temperature is expected to have increased by 1–3°C, at an alarming rate of 0.3°C per year. Additionally, it is anticipated that the amount of water required for irrigation will increase by 40–250% as the temperature rises. Globally, wheat, rice and maize yields have been found to decline by 6.0%, 3.2%, and 7.4%, respectively for every °C increase in temperature. To lower metal toxicity/availability to crop plants, several organic and inorganic soil amendments are used. Most of the Indian soils are having lower content of organic carbon, which is one of the reasons for lower crop yield. Biochar is a viable alternative among organic soil amendments in

the current context to reduce heavy metal bio-availability in soils.

Sources of heavy metals

Heavy metal(s) pollution is caused by geological and anthropogenic activities. Industrial effluents, fuel production, mining, smelting processes, agricultural chemicals, small-scale industries (including battery production, metal products, metal smelting and cable coating industries), brick kilns and coal combustion are all sources of anthropogenic metal contamination. The dumping of municipal waste is one of the major contributors to the rising load of soil contamination. These wastes are either thrown on the side of the road or used as landfills, while sewage is used to irrigate crops. Although useful as a source of nutrients, these wastes also include carcinogens and hazardous metals. Pesticides, fungicides and fertilizers might be applied in a hazardous or excessive manner. Irrigation water contaminated by

sewage and industrial effluent are the most common possible sources of heavy metals, resulting in contaminated soils and vegetables.

Toxic effect of heavy metals

Heavy metals including cadmium (Cd), copper (Cu), lead (Pb), chromium (Cr), mercury (Hg), arsenic (As), zinc (Zn) and nickel (Ni) are significant environmental contaminants, especially in places where anthropogenic pressure is considerable. By bioaccumulation and bio-magnification, these hazardous compounds are released into the environment and contribute to various kinds of deleterious effects on living creatures in the food chain. Furthermore, metals cannot be broken down, and when concentrations inside plant cells exceed threshold or ideal levels, they can cause direct toxicity by destroying the cell structure (due to oxidative stress induced by reactive oxygen species) and inhibit a variety of cytoplasmic enzymes. They can also have indirect harmful effects in plants by substituting critical nutrients at cation exchange sites. In human beings, significant concentration of heavy metals adversely affects the metabolic processes of the body. In higher concentration, they may lead to cancer or death of the organisms. Long term application of metal contaminated inputs in agricultural crop production system reduces the soil health and crop yield potential.

Biochar

Biochar is a type of super charcoal made from non-oxygenated biomass such as woody plant, corn cobs, husks/stalks, potato/soybean,

rice/wheat straw. The non-carbon components of the plant, such as cellulose and lignin, gasify and are burned away. Pure carbon remains, accounting to about 40% of the carbon originally contained in the biomass. Biochar is created by pyrolyzing at temperatures ranging from 300–600°C. Animal dung, sludge, and scrap wood are all examples of biomass in addition to living things like plants and animals. The biochar's source material, manufacturing temperature, metal shape and concentration, and soil conditions etc, all influence its efficiency. Biochar must be generated in a facility that catches and burns the gases released when biomass is burnt in order to ensure that it does not contribute to air pollution and greenhouse gases (GHG) emissions. These gases can be burned to produce heat, which can be utilised as a renewable energy source. From small engineered industrial-scale factories to gas stoves, biochar can be produced on a variety of scales. In order to manage trash, slow pyrolysis might be utilised in landfill systems or intensive animal production. It would produce sustainable energy and transform end-of-life biomass into useful stable carbon-based soil additives that help with nutrient recycling.

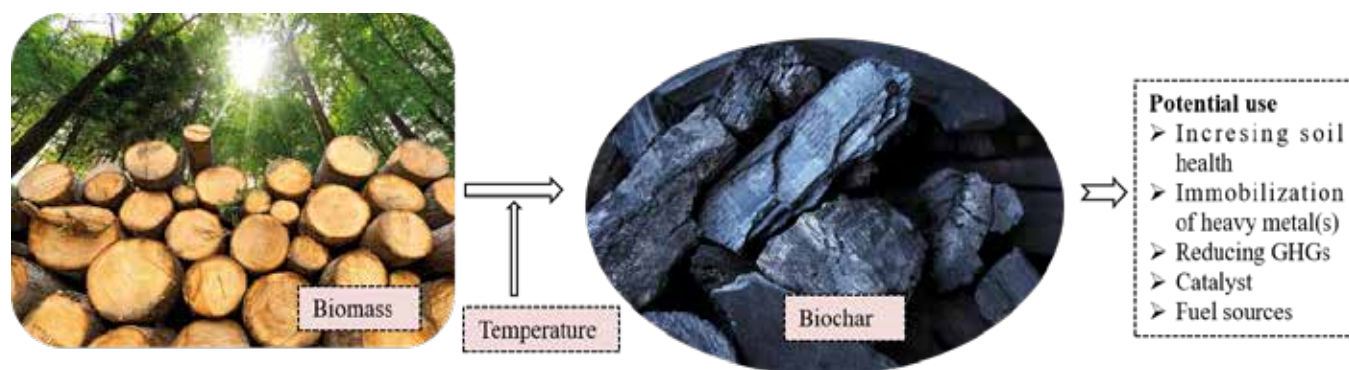
Preparation of biochar

Increasing the carbon content in soil is beneficial for mediating the plant nutrient efficiency and enhancing crop yield potential. It was observed that increasing the level of organic carbon, enhanced the soil microbial diversity and population over a period. In these

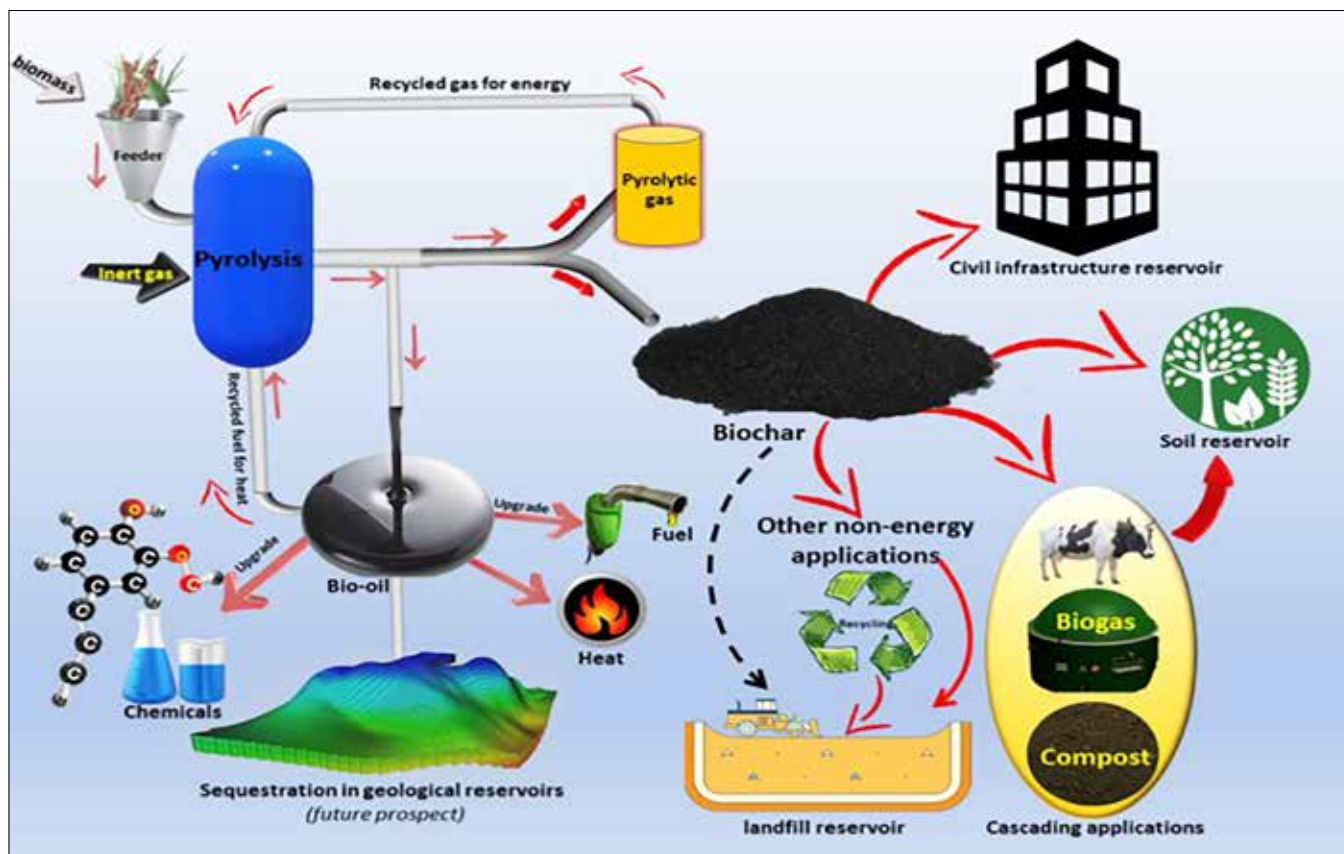
situations, plant nutrient dynamics need carbon content in sustainable manner to supply food material to the soil biota. Biochar is an organic containing material which improves the soil physico-chemical as well as biological conditions of soils. The most popular method for making biochar is pyrolysis, which is also used in the initial phases of combustion and gasification. During pyrolysis process, different by-products (bio-oil and gas) shall also be obtained. Carbon monoxide (CO) and hydrogen (H₂) make up the majority of the pyrolysis gas, with smaller amounts of CO₂, CH₄, H₂O and various volatile chemicals. Because pyrolysis gas is expensive to transport and store, it is often burned locally to supply the heat needed by the pyrolyser.

Role of biochar in heavy metal remediation

International Biochar Initiative described biochar as inexpensive, environment-friendly which can be used for a variety of purposes, such as soil remediation, waste management, greenhouse gas reduction, and energy production. The majority of heavy metal wastes that need to be handled have traditionally been disposed of in the soil. Currently, standard heavy metal polluted soil remediation approaches are both costly (physico-chemical methods) and less eco-friendly to the environment. The multi-metal adsorption pattern of trace metals in soil is influenced by the type of biochar used and the temperature at which it is formed. It was also discovered that metal cation forms were adsorbed more than metal anionic forms. Biochar



Biochar preparation and potential use



Commercial production sketch of biochar [Source: Fawzy et al. (2021)]

incorporation creates distinct carbon-metal complexes in soil and aquatic systems, lowering metal bioavailability.

Biochar mechanism in heavy metal remediation

Direct adsorption of biochar can remove heavy metals from polluted soils through a variety of mechanisms, including physical

sorption, ion exchange, electrostatic interaction, precipitation, and complexation. It's important to keep in mind that using biochar to remove heavy metals from damaged soils entails a number of steps. Recent biochar research, primarily describes two ways that biochar might adsorb substances, i.e. direct adsorption and through enhancing

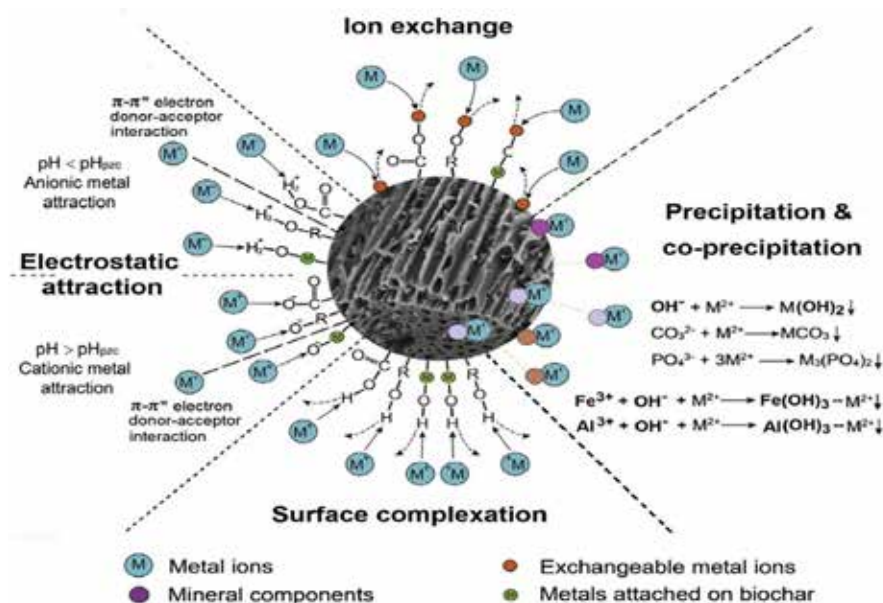
the physico-chemical characteristics of soil, such as *pH*, cation exchange capacity (CEC), mineral content, and organic matter content. In general, adding charcoal and raising the soil *pH* reduces the competition for sorption sites between hydrogen ions and metal cations, lowering the mobility and availability of heavy metals in the soil (Table 1). Heavy metals are also an important pollutant in water which require more scientific practices to remove/prevent themselves from contamination of the food chain. Researchers produce biochar from rice husk and it is used potentially for minimizing the heavy metal (Pb, Cu, Zn and Cd) concentration in aqueous solutions.

Limitations of biochar applications

- High biochar CEC may aid in the adsorption of heavy metal in biochar and aid in its release through root exudates during high crop development stages.
- High rates of biochar application may cause immobilization of plant nutrients and increased weed growth.

Table 1. Type of biochar and their effect on bioavailability of heavy metals in soil

Feedstock	Production temperature (°C)	Metal(s)	Effect/Reaction
Rice straw	--	Cd, Cu, Pb	Lower down the bio-availability of Cu, Pb, Cd
Cotton stacks	450	Cd	Enhance the adsorption and co-precipitation of Cd
Eucalyptus	550	As, Cd, Cu, Pb, Zn	Potential reduction of Cd, Pb, Zn and Cd; enhance CEC and water retaining capacity
Sewage sludge	500	Cu, Ni, Zn, Cd, Pb	Reduction in bio-availability of metals
Pigeon pea straw	--	Cu	Reduce Cu toxicity
Wood	450	As	Immobilization of As
Oakwood	400	Pb	Bioavailability reduced by more than 75% whereas bio-accessibility reduced by 12.5%
Chicken manure	550	Cr	Promote conversion rate of hexavalent Cr to trivalent Cr



Mechanisms of heavy metal with biochar for complexes [Source: Tan et al. (2015)]

SUMMARY

Heavy metal contamination in food is most commonly seen in raw materials sourced from

contaminated soils or effluent-irrigated fields. This is more prevalent in developing countries' peri-urban agriculture belts. Heavy

metal(s) alter soil physico-chemical properties and reduce soil health and crop yield. In various places, biochar is being used for metal clean-up. By functioning as an adsorbent, heavy metals are trapped in the porous structure of biochar. It works as a carbon sequestration mechanism, keeping the metal immobilized in long-term pools. Metal adsorption kinetics in soil were improved, and metal toxicity was reduced due to high surface areas. It is useful for soil health and crop production sustainability. The production of biochar has long-term advantages, including a large decrease in greenhouse gases that fuel global warming. It is widely recognized as a potent method of halting global warming.

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HANDBOOK OF INTEGRATED PEST MANAGEMENT

To reverse the loss of environmental resources and also to reduce biodiversity loss, the Government of India has Integrated Pest Management (IPM) as part of the National Agricultural Policy. Integrated Pest Management emphasizes the growth of a health crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. IPM is not new – mechanical, cultural and biological tactics were used by farmers for hundreds of years before chemical pesticides became available. Besides, there are IPM techniques that have been developed more recently and are effective in suppressing pests without adversely affecting the environment.



The task of spreading the message of IPM across is tough due to poor awareness about the subject among people in line-departments as also among the farmers. The information on integrated pest management as a whole is scattered. This *Handbook* comprehensively deals with all the aspects of integrated pest management in field crops, horticultural crops under traditional, protected systems. Information on basic strategies and tactics of different methods of management including mass production of biocontrol agents, IPM policy and pesticide registration is provided in comprehensive form.

The *Handbook of Integrated Pest Management* comprises 82 chapters which are well written in lucid language with crispy sentences by the renowned scientists. The role of IPM is elucidated with different pests like *Trichogramma*, *Bacillus thuringiensis*, *Nomuraea rileyi* etc. and agricultural crops like rice, wheat, maize, sorghum, pearl millet, pulses, soybean, rapeseed mustard, groundnut, minor-oilseed crops, sugarcane, cotton, jute and mesta, potato, vegetable crops, fruits, grapes, citrus, banana, pomegranate, coconut etc. This *Handbook* will provide information of available useful technologies to educate on how to reduce or judiciously use chemical pesticides, safeguard ourselves from chronic poisoning, save the National environment while also reducing input costs and raise farmers' income. This compilation will be useful to teachers, students, trainers, line-department personnel and policy makers.

TECHNICAL SPECIFICATIONS

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