Chronicle of Bioresource Management 2025, 9(2):045-048

Chronicle of Bioresource Management
An International E-magazine

June, 2025 *Popular Article*

Open Access

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Citation: Sainath et al., 2025. The Negative Effects of Biochar on Soil, Water, Plants, the Environment and Human Health. Chronicle of Bioresource Management 9(2), 045-048.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Biochar, environment, human health, negative effects, soil

Article History

Article ID: CBM6136
Received on 10th February 2025
Received in revised form on 01st May 2025
Accepted in final form on 10th May 2025

The Negative Effects of Biochar on Soil, Water, Plants, the Environment and Human Health

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Abstract

Biochar, a carbon-rich product derived from biomass pyrolysis, has been widely promoted for it's potential benefits in soil improvement, carbon sequestration and pollution mitigation. However, recent studies have raised concerns about it's negative impacts on soil health, water quality, plant growth, human health and overall environmental stability. This article explores the potential drawbacks of biochar application, emphasizing it's role in altering soil microbial communities, water retention, plant toxicity, human exposure risks and it's unintended ecological consequences.

1. Introduction

Biochar is a carbon rich, porous and fine grained product retained after pyrolytic conversion of plant biomass at high temperatures. It has the ability to improve soil fertility status. Further, due to its large surface area, it can retain more water and nutrients and supply the same to the crops. However, while many studies highlight it's benefits, it is crucial to examine the unintended negative effects that biochar can have on various environmental components and human health before it is upscaled and out scaled. Some of the negative consequences are furnished below.

2. Negative Effects on Soil

2.1. Alteration of soil microbial communities

Biochar's application in soil can significantly alter microbial communities, potentially suppressing beneficial microbes, impacting enzyme activity, and shifting community dynamics, which can be detrimental to plant growth and soil fertility, especially with high application rates (Lehmann et al., 2011).

• Suppression of Beneficial Microbes: High biochar application rates, like 116.1 t ha^{-1}, can lead to a significant decline in beneficial bacteria and fungi populations, potentially reducing soil fertility.

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• Shift in Microbial Communities: Biochar can alter the soil environment, creating conditions that favor certain microbial groups over others.

• Enzyme Activity: Biochar can disrupt soil enzyme activities (phosphatase), which are crucial for nutrient cycling and other important soil processes.

2.2. Changes in soil pH and nutrient imbalance

Biochar's alkaline nature (from 7.1 to 10.5) can raise soil pH, potentially leading to nutrient imbalances. Additionally, some biochars can immobilize essential nutrients like nitrogen and phosphorus, making them less available to plants (Lehmann et al., 2011). Hence, systematic studies should be conducted assess its effects on nutrient fixation, particularly regarding nitrogen and phosphorus availability.

2.3. Reduced soil aggregation and compaction issues

Although biochar is often credited with improving soil structure, excessive application can have the opposite effect. High doses (57 t ha^{-1}) of biochar may lead to soil compaction or reduced aggregation, which can negatively affect root penetration and aeration, thereby hindering plant growth (Jeffery et al., 2015).

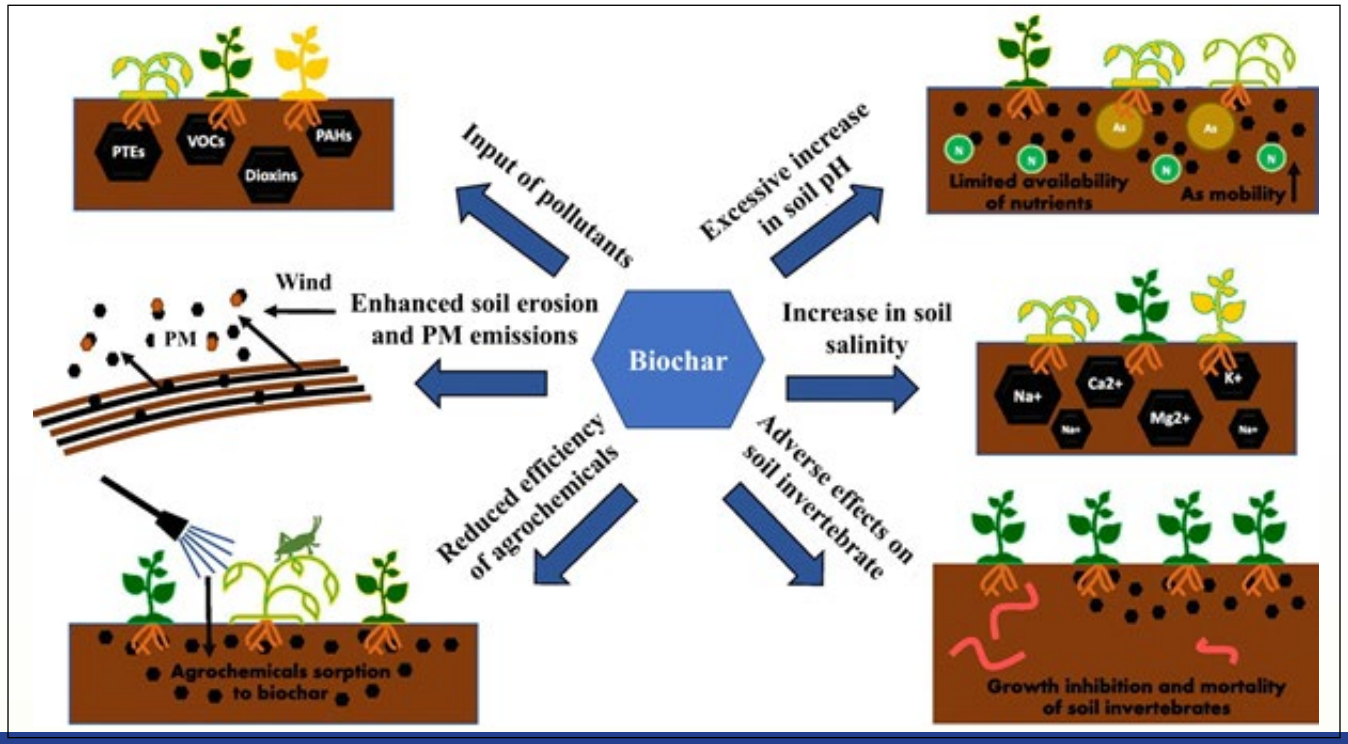

Figure 1: Negative effects of biochar on soil (Brtnicky et al., 2021)

3. Negative Effects on Water

3.1. Water retention and drainage issues

While biochar can enhance soil water holding capacity, excessive use can result in waterlogging, particularly in poorly drained soils. Conversely, certain biochars with high porosity can increase soil hydrophobicity, reducing water infiltration and exacerbating drought conditions (Major et al., 2010). Biochar is a costly input, nobody applies in excess quantity and should not be recommended also.

3.2. Leaching of contaminants

Biochar has a high sorption capacity, which can lead to the unintended leaching of contaminants. Depending on it's feedstock and production conditions, biochar may contain heavy metals (Cd and Pb), polycyclic aromatic hydrocarbons (PAHs) and other toxic compounds. These substances can leach into groundwater, posing risks to water quality and aquatic ecosystems (Singh et al., 2017).

4. Negative Effects on Plants

4.1. Toxicity from biochar-derived compounds

Biochar can release toxic organic compounds, such as volatile organic compounds (VOCs) and PAHs, which can be detrimental to plant growth. Some biochars may also contain high levels of salts, which can cause

osmotic stress and impair seed germination and seedling development (Singh et al., 2017). Hydrothermal carbonization and Gasification processes are best methods but it could be is costly affair.

4.2. Nutrient immobilization and deficiency

Some biochars can adsorb essential nutrients, particularly nitrogen, leading to nutrient deficiencies in plants. This effect is more pronounced in soils with low fertility, where biochar may compete with plants for available nutrients, negatively impacting crop yields (Biederman and Harpole, 2013). There is awareness that direct application of bio-chars has negative effect of soil properties. Moreover, this treated biochar should be integrated with other organic sources for better effect.

4.3. Growth inhibition and reduced yield

Studies have shown that excessive biochar application can inhibit plant growth by altering soil properties and reducing nutrient availability. Poorly prepared biochar or biochar with high ash content can create an unfavorable soil environment, leading to stunted growth and reduced agricultural productivity (Biederman and Harpole, 2013). The thumb rule is that: everything in excess is harmful. So, application of biochar during windy weather should be avoided. Further, use of safety masks *etc*., and granular or prilled form is recommended for easy application.

5. Negative Effects on Human Health

5.1. Inhalation of fine particles

The production, transportation, and application of biochar generate fine particulate matter that can be easily inhaled. Prolonged exposure to these particles can cause respiratory issues such as lung inflammation, reduced lung function, and increased risk of pulmonary diseases (Singh et al., 2017).

5.2. Exposure to toxic compounds

Direct exposure to contaminants through skin contact, ingestion, or inhalation may pose serious health risks, including carcinogenic and neurotoxic effects (Mohan et al., 2014). Workers involved in biochar production and application are at increased risk of occupational exposure to toxic emissions, including carbon monoxide (CO) and VOCs. Improper handling and inadequate protective measures can lead to acute poisoning and long-term health complications (Verheijen et al., 2010).

6. Negative Environmental Effects

6.1. Greenhouse gas emissions

Although biochar is often praised for it's carbon sequestration potential. However, improper use or degradation of biochar in the soil can lead to the release of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The stability of biochar varies, and it's decomposition under certain conditions can contribute to climate change (Cayuela et al., 2014).

6.2. Biodiversity disruptions

Biochar application can alter natural ecosystems by modifying soil properties and microbial communities. This can negatively impact soil-dwelling organisms, including earthworms and beneficial insects, leading to disruptions in ecological balance (Thies and Rillig, 2012).

6.3. Land use and resource competition

The production of biochar requires large amounts of biomass, which can lead to deforestation and competition for land resources. Increased demand for biomass feedstocks may result in unsustainable agricultural practices, ultimately threatening food security and biodiversity (Lehmann et al., 2011).

7. Conclusion

While biochar has been widely studied for it's agricultural and environmental benefits, it is essential to recognize it's potential drawbacks. Adverse effects on soil, water, plant health, human health, and the broader environment highlight the need for careful application and further research. Policymakers, scientists and farmers must consider these negative impacts and adopt best management practices to minimize risks associated with excessive biochar use.

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