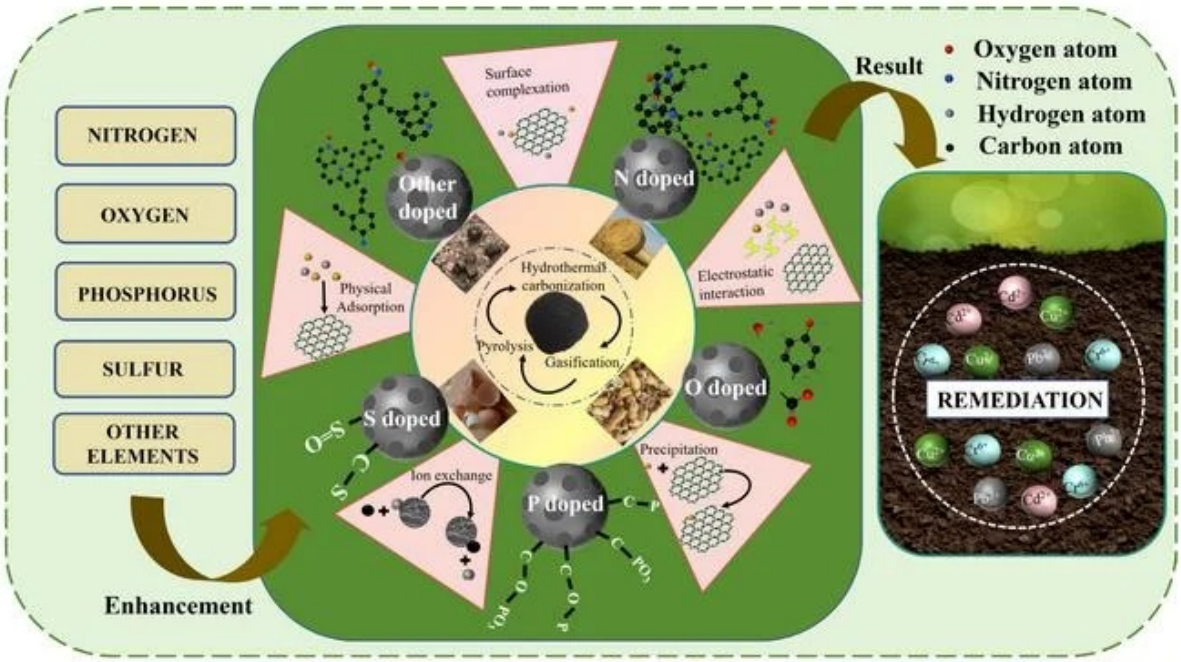
Combating Soil Contamination with Sustainable Materials

Reviewed by Laura Thomson Sep 22 2025

In a study published in *Agricultural Ecology and Environment*, researchers from Shenyang Agricultural University reviewed a promising strategy to combat heavy metal pollution in soils: the use of element-doped biochar to immobilize and neutralize toxic metals in farmland.



Synthesis, mechanism, and application of element-doped biochar for heavy metal contamination in agricultural soils. Image Credit: Jianhua Qu, Hongxuan Chu, Mengning Wang, Rui Yu, Siqi Wang, Tianqi Liu, Yue Tao, Siyue Han & Ying Zhang

Agricultural soils worldwide are facing increasing pollution from toxic heavy metals such as cadmium, lead, chromium, and arsenic. These dangerous elements often enter the soil through industrial wastewater, fertilizers, and manure.

The heavy metals can accumulate in crops, threatening human health through the food chain. Long-term exposure to these toxins has been linked to severe health issues, including kidney damage, osteoporosis, and even cancer. As a result, protecting the health of the soil and ensuring food safety have become urgent global challenges.

Biochar, a low-cost, eco-friendly material made from crop residues, has long been used as

a soil additive. However, regular biochar is not always effective at capturing heavy metals. To overcome this limitation, scientists are enhancing it by "doping" it with elements such as nitrogen, oxygen, sulfur, and phosphorus.

This process creates special chemical groups on the biochar's surface, providing additional binding sites for heavy metals. This improves its ability to lock contaminants in the soil and significantly reduces their mobility.

> *"Element-doped biochar changes the game. By modifying the structure of biochar, we can greatly improve its ability to stabilize heavy metals, making farmland safer and crops healthier.*
>
> *Ying Zhang, Study Corresponding Author, Shenyang Agricultural University*

The review explains how different dopants function to enhance biochar's effectiveness.

- Nitrogen-doped biochar - Presents active nitrogen groups that strongly bond with metals like cadmium.
- Oxygen-doped biochar - Increases carboxyl and hydroxyl groups, which attract lead and chromium.
- Sulfur-doped biochar - Fixes mercury and cadmium through stable sulfur–metal interactions.
- Phosphorus-doped biochar - Neutralizes heavy metals while simultaneously supplying nutrients that help crops grow.

Beyond laboratory studies, field applications have shown encouraging results. For instance, phosphorus-doped biochar successfully reduced the leaching of lead and cadmium in soils. Approaches using multi-element doping have been shown to improve crop growth by lowering the stress caused by metal toxicity.

The authors emphasize that element-doped biochar is more than a temporary fix; it is a practical, scalable tool for sustainable agriculture. By converting agricultural waste into a valuable soil amendment, this approach also promotes recycling, reduces pollution, and supports a circular economy.

Looking ahead, the researchers are calling for more real-world trials to evaluate the long-term stability of doped biochar under different farming conditions. They also suggest

exploring multi-element doping strategies to further enhance its performance.

> *This technology has the potential to transform contaminated farmland into safe, productive soils. It represents a step forward in ensuring both food security and environmental sustainability.*
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> *Ying Zhang, Study Corresponding Author, Shenyang Agricultural University*

Journal Reference:

Zhang, Y., *et al*. (2025) Synthesis, mechanism, and application of element-doped biochar for heavy metal contamination in agricultural soils. *Agricultural Ecology and Environment*. doi.org/10.48130/aee-0025-0004

Source:

Shenyang Agricultural University