FARMING PRACTICE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: HEAVY METALS POLLUTION

Reference 4

Tian X, Wang D, Chai G, Zhang J, Zhao X. 2021 Does biochar inhibit the bioavailability and bioaccumulation of As and Cd in co-contaminated soils? A meta-analysis. Sci Total Environ. 762:143117. 10.1016/j.scitotenv.2020.143117

Background and objective

NA Elaborate the effects and mechanisms of biochar application on inhibiting the bioavailability and bioaccumulation of As and Cd in co-contaminated soils, and to evaluate whether the efficiency of biochar can meet the food safety standards. Based on these purposes, the authors made the following hypothesis: 1) biochar application could inhibit the bioavailability of As and Cd in co-contaminated soils; 2) biochar application could decrease the accumulation of As and Cd in plants or plant tissues; 3) properties of biochar, soil and plant could directly influence the bioavailability and bioaccumulation of As and Cd in soil-plant system.

Search strategy and selection criteria

The relevant references were searched in the online databases of Web of Science (WOS) (http://apps.webofknowledge.com) and the Chinese National Knowledge Infrastructure (CNKI) (https://www.cnki.net/) on 27 October 2019 using biochar, arsenic (As), and cadmium (Cd) as keywords. 1) the study must be original research on the behaviors of As and Cd in co-contaminated soils in response to biochar application; 2) treatments and controls have at least three replicates; 3) original data are expressed as mean ± standard deviation (SD) or mean ± standard error (SE) and can be extracted from tables or figures. If the studies included multiple determinations throughout the experimental period, the results were collected from the last sampling period to meet the principle of meta-analysis.

Data and analysis

Mean effects and the 95% confidence intervals (CIs) of each group or subgroups were calculated with the bootstrapping procedure (999 iterations). There was a significant difference from control groups if the CIs of the mean effect did not overlap zero. Differences among subgroups were significant if their CIs did not overlap. A sensitivity assessment was conducted with successively and randomly reduced five observations from the datasets.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
52	Not specified	Soil amendment with biochar	No amendment	Metric: Bioavailability and plant accumulation of As and Cd; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	0.875

Results

- On average (field and non-field experiments), the bioavailability of As increased by 2.39% [−5.16%, 10.57%] in soils, while Cd bioavailability decreased by 50.09% [40.03%, 58.45%] in soils, compared with the controls without biochar application. Biochar from the manure presented the most significant reduction of available Cd (89.94%) and had a simultaneous inhibition of the bioavailability of As and Cd in soils. Biochar from the sewage sludge performed the most significant diminution of available As (40.32%).
- Biochar produced at ≤400 °C or >600 °C preferred to passivate As and Cd in co-contaminated soils. However, it was worth noting that biochar produced at 400–500 °C and 500–600 °C observably increased the bioavailability of As by 11.39% and 29.46%, respectively.
- Biochar application could synchronously inhibit the accumulation of As and Cd by 25.48% [22.06%, 28.76%] and 38.66% [33.18%, 43.69%] in plants, respectively. Biochars from the manure and sewage sludge presented the most significant reduction in the bioaccumulation of Cd (59.99%) and As (54.93%). Biochar produced at >500 °C had a notable effect on the bioaccumulation of As.
- Biochar was much more prominent for inhibiting the accumulation of As and Cd in the aboveground parts (28.73% and 41.70% for As and Cd, respectively) than those in the belowground parts (17.45% and 27.52% for As and Cd, respectively).
- Biochar was much more excellent to reduce the bioaccumulation of As and Cd in the edible parts (31.93% and 41.91% for As and Cd, respectively) than those in the inedible parts (21.92% and 36.96% for As and Cd, respectively). The reduced accumulations of As and Cd in grains (31.01% and 45.86%, respectively), leaves (30.73% and 34.29%, respectively), and stems (21.81% and 44.41%, respectively) were much more notable than roots (12.77% and 27.65%, respectively).

Factors influencing effect sizes

- Scale of experiment (Field, Pot, etc) : Biochar application significantly reduced the bioavailability of As and Cd in the field experiments, up to 23.28% [8.47%, 35.70%] and 47.40% [20.10%, 65.38%], respectively. In the non-field experiments, biochar application not only significantly increased the available As by 10.17% [1.08%, 20.08%], but also increased the concentration of As by 62.29% [−9.62%, 191.40%] in pore water. The efficiency of biochar on decreasing the accumulation of As in plants from the non-field experiments (27.33%) was higher than those from the field experiments (18.09%). On the contrary, the mean effect of biochar on inhibiting the accumulation of Cd in plants from the field experiments (52.98%) was much higher than those from the non-field experiments (34.37%). Besides, there were heterogeneities between non-field and field studies (e.g., available As ($p = 0.003$) in soils and accumulative Cd ($p = 0.001$) in plants).
- Biochar application rate : Biochar with various application rates exhibited a significant reduction in the bioavailability of Cd, while biochar with application rate at 2–5% and >5% enhanced the bioavailability of As by 14.56% and 89.46%, respectively. The application rate at 1–2% and >5% was excellent to weaken the accumulation of As (52.51%) and Cd (44.69%) in plants, respectively.

- Post-modification of biochar : Modified biochars had a higher capacity to decrease the bioavailability of As (8.35%) and Cd (56.82%) compared with the pristine biochars. Modified biochars hold a higher capacity to decrease the accumulation of As (36.5%) and Cd (46.16%) in plants, compared with the pristine biochars.
- Soil texture : The maximum inhibition effects on the bioavailability of As (15.48%) and Cd (73.30%) appeared in medium-grained soils. In acid and neutral soils, biochar application promoted the bioavailability of As. The maximum of inhibition on the bioaccumulation of As and Cd in plants was observed in coarse-grained soils (34.92%) and medium-grained soils (41.94%), respectively.
- Soil pH : With the increasing soil pH, the effect of biochar on inhibiting the bioavailability of Cd became to be less. Biochar was appropriate to adopt to decrease the bioaccumulation of Cd in acid soils and reduce the bioaccumulation of As in alkaline soil.

Conclusion

The meta-analysis results indicated that biochar applications could significantly reduce the bioavailablility and bioaccumulation of Cd and As compared to controls without biochar application.