

Initial immobilization of heavy metals in shooting range soil with biochar and lignin followed by citric acid application improves metal phytoextraction with *Conocarpus erectus* L.

MUHAMMAD IQBAL¹, SHAHBAZ ALI KHAN², HAFIZ MUHAMMAD TAUQEER²

¹Department of Environmental Sciences and Engineering, Government College University, Faisalabad, 38000, Pakistan.

²Department of Environmental Sciences, University of Gujrat, Hafiz Hayat Campus, Gujrat 50700, Pakistan.

Shooting ranges are the second most important anthropogenic contributor of heavy metals (HMs) contamination to the environment due to leaching and runoff hazards. Phytoextraction of HMs from the shooting range soil (SRS) seems challenging as the establishment of plants is not easy due to HMs toxicity. However, the initial establishment of the plants can be achieved by immobilizing these HMs with suitable immobilizing agents. In our experiment, we used lignin (LN) and biochar (BC) to immobilize HMs in the SRS to facilitate the establishment of *Conocarpus erectus* and reduce HMs leaching. Upon the successful establishment of plants, citric acid (CA) was applied with an interval of 30 days to slowly solubilize HMs necessary for their enhanced phytoextraction. The treatments involved in this study were control, BC, LN, BC+LN, CA, BC+CA, LN+CA, and BC+LN+CA. Results revealed that application of BC and LN significantly reduced HMs bioavailability in the SRS, whereas, CA application enhanced their bioavailability, compared to the plants in control treatment. Data related to the concentrations of HMs in the shoots and roots of *C. erectus* and percentages of HMs removal revealed that significantly the highest concentrations of Pb in shoots and Cd, Cu, Cr, and Ni in roots were reported in the BC+LN+CA treatment, compared to control. A similar trend was found for soil enzymes, plant antioxidant enzymes, and soil health parameters in this treatment. Moreover, the least concentrations of Pb, Cd, Cu, Ni, and Cr were found in leachates of BC+LN+CA treatment that were below the critical limits according to international guidelines. We suggest using BC+LN+CA treatment in SRS to initially immobilize HMs and later enhanced phytoextraction with *C. erectus*.

Keyword: *Conocarpus erectus* L., heavy metals, immobilization, leachates, plant antioxidant enzymes.