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Meta-analysis of biochar potential for pollutant immobilization and stabilization in contaminated soils

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Biochar is the pyrolysis product of biomass, preferably from agricultural and forestry residues and waste materials. Characterized by a polyaromatic structure rich in carbon, it offers a microporous structure with a high specific surface area and active functional groups as binding sites. Because of the high sorption capacity for organic and inorganic soil pollutants biochar is an interesting tool for in-situ soil remediation. Especially if the reduction of contaminant bioavailability and the protection of groundwater from pollutants in the vadose zone are the most relevant issues for remediating a polluted site without excavation and removal of the soil, an in-situ application of biochar may offer a promising remediation strategy.
The resulting interest of deploying biochar as sorbent for soil contaminants has stimulated a wealth of studies to develop successful applications for environmental technology. However, the existing studies do not always agree on the efficacy for different pollutants and on the most relevant char and soil characteristics that determine the rate of success when using biochar as sorbent. This makes it necessary to apply advanced literature assessment techniques to allow for the recognition of the extent and the significance of the efficacy of a given pollutant treatment technique.
A meta-analysis is a study assessment technique that allows extracting a harmonized answer to a specific research question that has been studied more often than one time, even if the results are partially conflicting. Such a technique also allows getting an overview about the degree of consensus or contradiction in the answers to the question if biochar can be applied successfully for immobilizing certain soil contaminants. The meta-analysis results can also be used to quantify the average extent of effects of a certain treatment, depending on the characteristics of the sorbent and on the application rate.
By checking 104 published papers in the peer-reviewed literature about the immobilizing potential of biochar for pollutants, we could use about 1300 comparisons of biochar application versus no application for a range of organic and inorganic pollutants in a soil environment. Our assessments have shown that in the average of all studies biochar decreased the availability of cationic heavy metals and organic pollutants significantly by 40-50 %. We could confirm that an increasing biochar application rate also increases contaminant sorption. The only exception was found for anionic heavy metals like As or Mo that are clearly mobilized by biochar applications. Differences in sorption efficiency depend on the type of biochar, on different pollutants and on the compartment where the reduction of bioavailability has been studied.