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Direct and indirect effects of biochar on the mobility of metals and nutrients in contaminated soils: a two-column leaching experiment

Frédéric REES (1), Marie-Odile SIMONNOT (2), and Jean-Louis MOREL (1)

(1) Université de Lorraine / INRA, Laboratoire Sols et Environnement, Vandoeuvre-lès-Nancy, France, (2) Université de Lorraine / CNRS, Laboratoire Réactions et Génie des Procédés, Nancy, France

Biochar has been claimed to be not only a promising carbon sequestration or fertilizing agent in soils but also a high capacity sorbent, of particular interest for the management of contaminated soils. Several studies have described its positive effects on the mobility of different potentially toxic elements in soils, but many doubts remain about the underlying mechanisms. In particular, the distinction between the actual adsorption of elements on biochar and their biochar-induced retention on soil particles is often impossible to achieve.

We studied here the dynamic interactions between one biochar produced at 450°C from a mix of hard wood and soft wood, and two soils contaminated by Cd, Pb and Zn which were sampled near a smelter and only differed from their pH. In order to distinguish between the actual immobilization of elements on biochar and their modified retention on soil particles, we developed a two-column leaching experiment using calcium nitrate as the initial leaching solution. The first column was filled with one of the two soils, and was linked in a closed loop with the second column containing a mass of pure biochar equivalent to 10% of the soil mass. The leaching solution circulated first in the soil column, then through the biochar column and again in the soil column and so on, so that it became progressively equilibrated with both soil and biochar. Each experiment lasted for 12 days at a flow rate of 1 mL/min. The pH and electrical conductivity of the leaching solution was continuously monitored at the outlet of the biochar column, and samples of the leaching solution were regularly taken for further analysis, both before and after having passed each of the columns.

Our results show that the chemical equilibrium between soil and biochar was obtained in a short time for major elements such as Na, K and Mg, whereas for heavy metals and other elements as well as for pH and dissolved carbon, the equilibrium was still not reached at the end of the experiment. This observation highlights the slow, diffusive nature of biochar chemical interactions with the soil. The comparison of samples enabled us to quantify the immobilization of elements on biochar from its indirect effect on the retention capacity of the soil, mostly due to the increase of pH and the dynamics of inorganic and organic carbon in the solution. Altogether, these results provide new information about the complex effects of biochar on soil properties and about its efficiency in the context of soil remediation.