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Practical guideline for applying carbon-based materials for restoration of degraded soil

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The application of carbonaceous materials for the restoration of degraded soil has been a field of active research for the last decades. Several studies show their ability to immobilize heavy metals and polycyclic aromatic compounds (PACs) in contaminated soils. However, there is still a lack of guidance to translate what has been demonstrated in the lab into practice. The possibility of immobilising a contaminant depends on the type of material used and its specific chemical and physical properties, as well as the quantity applied. The suitable sorbent selection from the variety of carbon-based materials available, including biochar and activated carbon, is one of the major difficulties for practitioners. Nevertheless, a generic assement of sorbent quantities needed for a specific immobilization at a given site is not possible, due to specific material properties, as well as differences in contamination scenario and soil properties. To overcome this bottleneck, we propose a workflow to evaluate the applicability of carbon-based materials for heavy metal- and PACs contaminated soil remediation, for scientists and practitioners alike.

We initially carried out a literature review collecting knowledge on the influence of feedstock, production temperature and possible modification steps on a material's physical and chemical characteristics. We further conducted expert interviews with practitioners and regulators in Austria. Thereafter, we performed laboratory scale experiments to complement the knowledge collected. For our experimental work, eleven carbon-based materials were used. A total of ten anonymized contaminated soil samples from existing remediation sites containing varying amounts of arsenic, antimony, cadmium, zinc, lead and PACs were used for batch and column experimentation to determine suitability and amendment rate of biochar for soil remediation. These experiments included the investigation of amendment scenarios at different scales (laboratory batch- to percolation column scale) to assess the suitability of small-scale batch experiments in our workflow. Batch tests with 5g of <2 mm sieved soil were performed according to OECD 106 (2000). Batch tests with 100 g of non-sieved soil were performed to maintain the heterogeneity of the sample at a solid/liquid ratio of 1:2 (EN 19529:2015-12) and 1:10 (EN 12457-4:2002). After 24 h shaking we centrifuged the samples and filtered the supernatant at < 45

µm for subsequent sample preparation and analysis via ICP-MS, GC-MS and LC-MS. At last, column percolation tests were performed according to EN 14405:2017, using columns with 6 cm diameter, 38 cm height and containing 1.5 kg of soil.

Our work will be summarized by a contaminant and site specific decision tree for suitability of biochar application. The decision tree will guide the practitioner through a series of questions that will assess whether the site is suitable for biochar-based soil remediation, which contaminants can be treated, what characteristics a suitable sorbent should have, what range in sorption affinity could be expected for a suitable sorbent, and what are potential application rates in the field.

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