Biochar for heavy metal removal from concentrated wastewater generated from a water purification process using gas hydrates

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Sustainable management of wastewater and exhaust gas are two crucial topics associated with the rising global demand for clean water and increasing greenhouse gas emissions. The United Nations incorporated these issues in their Sustainable Development Goals (SDGs) as the 6th goal directly aims for global access to clean water and the 13th goal demands actions towards challenging the climate change and especially its causes. Therefore, the innovative ECO Project was launched, combining the purification of wastewater and removing CO_2 from exhaust gas via a combined gas hydrate/adsorption technology.

This work specifically focuses on the usage of Rough Horsetail (*lat*.: equisetum hyemale, rawEH, Fig. 1) as a biochar precursor. The resulting biochar serves as an adsorbent for heavy metals using Ni^{2+} ions as representative contaminant. Rough Horsetail is a fast-growing abundant plant without significant commercial use which shows great adsorption properties for divalent heavy metals even without pre- and post-treatment. The production process is designed to use as little energy and chemicals as possible. Therefore, the dried and cut plant pieces are pyrolyzed at only 300 °C in air and the resulting biochar is washed with deionized water to remove any water-soluble residue resulting in clean EH biochar (designated as EH). Additional variants of the biochar were produced, where the material was ground after drying and pyrolyzed as is (designated as EHG). For comparison with typical pre-treatment methods, both the dried EH pieces and ground powder were also soaked in H_2O or 0.1 M NaOH (designated as EH(G)-H_2O/NaOH) prior to pyrolysis to potentially enlarge and activate the biochar surface and therefore adsorption properties. Interestingly, the untreated pieces showed similar or better properties in all experiments.

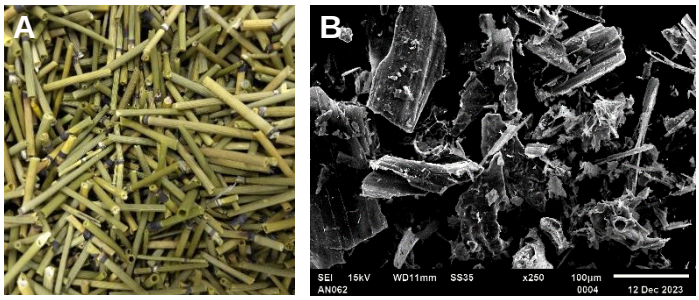

Fig. 2 (A) Dried Rough Horsetail cut in Pieces (3-4 cm). (B) SEM picture of the biochar from the pieces

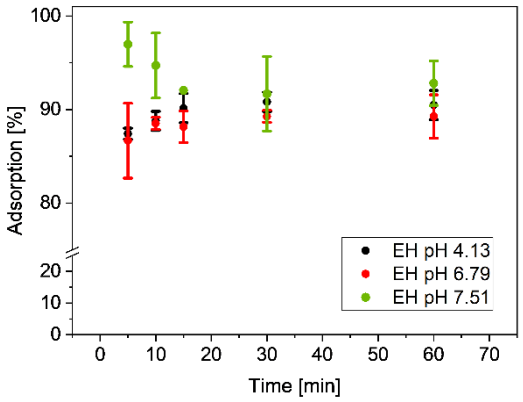

Fig. 1 pH dependant adsorption experiment with 100 mg EH Biochar, 2 mL Ni^{2+} solution (100 mg/L), shaken at 1600 rpm

Fig. 2 shows that Ni^{2+} adsorption is fast and largely independent of the pH, as the maximum adsorption of Ni^{2+} ions is already reached at around 15 min after mixing the biochar adsorbent and the Ni^{2+} solution. N_2 sorption analysis of EH shows an average surface area of 101 m^2/g which is larger than with the pre-soaking and grinding steps. IR measurements show the presence of (amorphous) silica which might contribute to the adsorption of (divalent) cations. XRD data show calcite reflections and a broad halo. Overall, we report a cheap, easy, and rapid process towards an effective adsorbent for Ni^{2+} that can be used in the combined ECO process described in the introduction.

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