

EGU21-4959

<https://doi.org/10.5194/egusphere-egu21-4959>

EGU General Assembly 2021

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## Remediation of antibiotic and heavy metal pollution in marine environment

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Pollution of marine environment by antibiotics and/or heavy metals is a serious global issue. Remediation of polluted marine environments is urgently needed for achieving the United Nations Sustainable Development Goals (SDGs) to end poverty and protect the planet from degradation. Biochar, as an environmentally friendly material, has been widely used as adsorbents to remediate contaminated soil or fresh water. However, application of biochar in remediation of marine environment is poorly understood. Therefore, a batch of biochars produced from pyrolysis of two marine algae residues, *Enteromorpha* (*Enteromorpha prolifera*) and blended seaweed wastes, at 300–700 °C was used to investigate their performance in sulfamethoxazole (SMX) sorption in seawater. Additionally, a modified biochar (MBC) was prepared by pyrolyzing AlCl<sub>3</sub> pretreated sawdust to improve their performance in remediating a marine sediment contaminated with heavy metals and antibiotics using two mesocosmic experiments. The results showed the algae-derived biochars had relatively low C content, but high contents of O- and S-containing functional groups and crystalline minerals associated with S, Ca, K, and Mg. The maximum adsorption capacity of these algae-derived biochars to SMX was 4880 mg kg<sup>-1</sup>, equivalent to a commercial coconut shell derived activated carbon. Potential mechanisms responsible for the SMX sorption mainly included pore-filling, cation bridging, negative charge-assisted H-bond [(-)CAHB], and π-π EDA interaction. The surface of MBC was rough with layered homogeneous sheets, and the nano-scale Al minerals formed on the C matrix. Moreover, its settling properties and adsorption capacities to Cu, Cd, SMX, and tetracycline (TC) were highly improved relative to the unmodified sawdust derived biochar (SBC). As a result, addition of MBC at 4% (w/w) performed better in improving the survival rate and condition index of the clams in the contaminated sediments than SBC. Furthermore, MBC application decreased bioaccumulation of Cu and Cd in the clams. Both SBC and MBC increased the microbial abundance and diversity in the contaminated sediments, and MBC decreased the abundance of Cu resistant bacteria (e.g., Firmicute and Gemmatimonadetes). For the sediment contaminated by antibiotics, lower content of SMX and TC in the overlying water and pore water was observed in the sediment amended with MBC than SBC, leading to the reduction of total antibiotic resistance genes. Therefore, these findings show the

potential of functional/modified biochar to remediate marine sediments contaminated with heavy metals and antibiotics.