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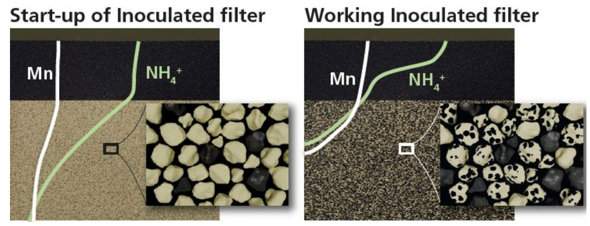

Enhancing manganese removal in rapid sand filters used in drinking water production through inoculation

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Long start-up times and incomplete manganese removal in rapid sand filters are a challenge for drinking water companies treating anoxic groundwater. Manganese needs to be removed early in the treatment to prevent discolored water and clogging of water distribution networks. However, the role of microbial versus chemical manganese oxidation and the interactions with ammonium oxidation in rapid sand filters are not yet fully understood.

Here, we investigated the chemical and microbial removal of manganese in full-scale filters and pilot columns during the startup phase of new sand filters. Through detailed analysis of the mineral coating of sand filters that successfully remove manganese with X-ray spectroscopy (XANES, EXAFS), we show that the manganese oxides always have a structure similar to δ-MnO_2, suggesting a dominant role for microbial manganese oxidation. Inoculation of sand filters with ~20% biologically-active metal oxide-coated sand improves the removal of manganese during the start-up of rapid sand filters, both in full scale filters and pilot columns. In pilot scale filters, inoculation improves manganese removal by >80% when ammonium concentrations in the incoming groundwater are low (<40 µM). Importantly, both in full scale and pilot filters, inoculation is less efficient and only enhances manganese removal by 30–50% when ammonium concentrations are higher (>100 µM). The overall start-up time is not reduced upon inoculation, which we attribute to the time needed for manganese-oxidizing bacteria to grow in the filter. Concomitant changes in 16S rRNA gene profiles, combined with qPCR and solute profiles, suggest a key role for *Nitrospira* in both nitrification and manganese oxidation in full scale filters. This is further supported by metagenomic sequencing, as *Nitrospira* MAGs identified in the filters encoded the manganese oxidase MnxG and the outer membrane c-type cytochrome Cyc2. We show that inoculation with biologically active filter medium enhances manganese removal. Temporal changes in the removal efficiency of manganese depend on the distribution and concentration of ammonium in the filter. Hence, improved ammonium removal in rapid sand filters will likely also enhance manganese removal, which may help optimize manganese removal in drinking water production.