Improving conventional household greensand treatment for efficient Mn(II) removal from drinking water

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Abstract

Geogenic contaminants pose a global threat to ensuring access to safe drinking water. Manganese (Mn) is a naturally-occurring redox-active element which in its reduced form, Mn(II), is a widespread groundwater contaminant. Prolonged consumption of water containing high levels of Mn has been linked to adverse effects on memory, attention, motor skills, and nervous system function, particularly in vulnerable groups including pregnant individuals and young children. In addition, Mn can lead to aesthetic issues such as altered taste, clogging, and damage to plumbing systems. While Mn has historically been regulated as an aesthetic concern, a mounting body of evidence linking health issues to Mn exposure through drinking water has heightened the challenges of using groundwater to meet drinking water needs. Recently, Health Canada established a health guideline which set a maximum acceptable concentration for total Mn in drinking water of 120 µg/L. Greensand (GS) filters are commonly used in conventional drinking water treatment systems for Mn(II) removal due to their cost-effectiveness and high exchange capacity. However, under certain conditions conventional GS systems may have a low Mn(II) removal efficiency (Galangashi et al. 2021) and encounter challenges related to Mn leaching (Outram et al. 2018), resulting in failure to meet health-related standards. Furthermore, GS filters typically undergo regeneration using potassium permanganate ($KMnO_4$), a mild oxidant that results in the release of additional Mn waste byproducts during the regeneration of the filter. Recent research suggests that Mn-containing materials can effectively activate peroxymonosulfate (PMS) and produce reactive oxygen species (ROS) that facilitate contaminant degradation. This study aims to investigate whether PMS may be used to improve greensand treatment systems and enhance Mn(II) removal from drinking water. Batch experiments were performed to test the Mn(II) removal efficiency across a range of PMS concentrations (0-500 µM) and GS mass (0.1-3 g). Aqueous Mn concentrations were measured over time using inductively coupled plasma optical emission spectrometry (ICP-OES). Solid-phase reaction products were characterized by X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS). The mechanisms of Mn oxidation were identified by quenching experiments and electron paramagnetic resonance (EPR) spectroscopy. The activation of PMS by greensand significantly increased the removal efficiency of Mn(II) compared to the conventional method (e.g., 96.83(±3.77)% at PMS = 500 μM vs. 5.77(±11.1)% at PMS = 0 μM). Our results attribute the mechanism underlying increased Mn removal in our improved treatment method to advanced oxidation processes that involve free radicals (e.g., hydroxyl radical (·OH) and sulfate radical ($SO_4^{\cdot-}$)) and non-free radical pathways, with Mn oxides as the main oxidation products. This study provides a new treatment method for more efficient Mn(II) removal while simultaneously reducing Mn wastes produced during the regeneration cycle which allows for a more sustainable and holistic management of invaluable groundwater resources.

Keywords

Groundwater quality, Mn(II) removal, greensand, peroxymonosulfate, reactive oxygen species

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Conflicts of interest

The authors have declared that no competing interests exist.

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