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Development of an Innovative Treatment Method for Improved Mn(II) Removal from Drinking Water Supplies

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Geogenic manganese (Mn) contamination of groundwater is widespread and poses a global threat to ensuring access to safe drinking water. Around 21% of the American population relies on groundwater from private wells for drinking water supply. Ingesting water with elevated manganese levels may adversely affect motor function and cause neurological damage. Additionally, Mn in plumbing systems can lead to aesthetic issues. The World Health Organization has established a health-based value of 400 µg/L for Mn in drinking water, while the U.S. Environmental Protection Agency published a non-regulatory health advisory of 300 µg/L. In 2019, Health Canada introduced a stricter guideline with a maximum acceptable concentration of 120 µg/L for total Mn in drinking water. MnO_2-media are commonly used in conventional drinking water treatment systems (i.e., conventional greensand treatment) for Mn removal due to their cost-effectiveness and high exchange capacity. However, under certain conditions, conventional MnO_2-media systems may not meet health-related standards due to low Mn removal efficiency and Mn leaching. 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 the efficiency of MnO_2-media treatment systems for Mn removal from drinking water. Batch experiments were performed to test Mn removal efficiency across a range of PMS concentrations (0-500 µM), MnO_2-media mass (0.1-3 g), and initial pH (3-9). 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. Results showed that the improved PMS-catalyzed MnO_2-media method significantly increased Mn removal efficiency compared to the conventional method. The mechanism underlying increased Mn removal by ROS involves free radicals and non-free radical pathways, with Mn oxide precipitates being the primary oxidation products. This study provides an innovative treatment alternative for more efficient Mn removal which allows for a more sustainable and holistic management of invaluable groundwater resources.