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Optimizing Fenton process for efficient destruction of energetic compounds in insensitive munitions explosives (IMX) wastewater

Danhui Xin[1,4], Jiwon Choi[1], Daniel K. Cha[1], Brian P. Hubbard[2], Steven M. Sheets[3], Pei C. Chiu[1]

[1]*Department of Civil, Construction, and Environmental Engineering, University of Delaware, Newark, DE*
[2]*U.S. Army Joint Program Executive Office Armaments & Ammunition, Picatinny Arsenal, NJ*
[3]*U.S. Army Combat Capabilities Development Command Armaments Center, Picatinny Arsenal, NJ*
[4]*Southern California Coastal Water Research Project, Costa Mesa, CA*

ABSTRACT

IMX-104 is a new insensitive munitions explosives (IMX) formulation consisting of three main munitions compounds (MCs), 3-nitro-1,2,4-triazol-5-one (NTO), 2,4-dinitroanisole (DNAN), and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). The high water solubility and acidity of NTO render existing wastewater treatment technologies, such as granular activated carbon adsorption, ineffective for IMX-104 wastewater. We investigated Fenton oxidation as a potential alternative treatment technology for IMX-104 wastewater, using an aqueous solution saturated with DNAN, NTO, and RDX as a surrogate. For a given quantity of Fenton reagent, the extents of NTO and DNAN destruction and mineralization were strongly influenced by the order of Fe^{2+} and H_2O_2 addition and the Fe^{2+} dosing rate. Optimal results were achieved by (1) adding H_2O_2 prior to Fe^{2+} and (2) decreasing Fe^{2+} dosing rate. These adjustments improved NTO destruction efficiency from 48 % to 95 % and from 95 % to 100 %, respectively. Both beneficial effects were attributed to the greater utilization efficiency of hydroxyl radical (·OH), which was achieved by minimizing non-productive ·OH consumption by Fe^{2+}. Through process optimization, complete degradation of all three MCs and >90 % removal of total organic carbon were achieved within 15 minutes. This study demonstrates that the Fenton treatment efficiency for IMX wastewater is highly variable and tunable, and that the dosing sequence and dosing rate can greatly impact treatment outcome. Our findings suggest a general strategy to improve the efficiency of Fenton oxidation – a strategy that is likely applicable to other, non-IMX wastewaters.