MITIGATION - SCIENCE AND TECHNOLOGY ADVANCES FOR CHEMICAL AND BIOLOGICAL HAZARD MITIGATION

Plasma-assisted Destruction Of Fenitrothion By A Falling-film Plasma Reactor

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Surface water and environmental resources are susceptible to contamination by chemical warfare agents (CWAs) due to their potential use in terrorist acts. Organophosphate-based CWAs are among the most dangerous within the chemical threat space due to their high toxicity. Though organophosphates can be hydrolyzed by water, their degradation kinetics is limited by their low aqueous solubility in contaminated surface water in natural environments. Reactive oxygen species realized in non-thermal plasma-treated aqueous solutions have been demonstrated to be effective in the degradation of organic contaminants including pharmaceutical residues and perfluoroalkyl substances in contaminated water. However, their field applications are limited because of the inadequate efficacy of typical plasma jets and similar reactor designs or the requirement of noble gas in these demonstrations.

In this presentation, we report the efficacy of falling-film plasma reactors (FFPR) for destroying fenitrothion, an insecticide and a simulant for the nerve agents GB and GD. Our rationale for studying FFPR is that this type of dielectric barrier discharge reactor over a thin film has extremely high efficiency for oxidation processes over other configurations. Additionally, their robust design essentially mitigates the adverse effects of many variables, such as solution conductivity and overall discharge stability without the use of noble gases. In our study, the reactions between the atmospheric plasma with the water film on the reactor electrodes were observed to have high production rates of reactive oxygen species, especially hydroxyl radicals, and hence effective oxidation of fenitrothion and subsequent reaction by-products. The plasma-assisted destruction of aqueous fenitrothion of concentrations at and below 30 ppm was observed to follow exponential kinetics and had a destruction removal efficiency of up to 95% within 60 minutes. The concentrations of four identified transient intermediate products were observed to rise at the beginning of the reaction and then follow exponential decay kinetics. Quantum chemical computation showed that hydroxyl radicals likely reacted with fenitrothion through three major pathways via hydroxyl radical attack at the phosphorus atom, hydrogen abstraction by hydroxyl radicals at the methoxy groups on the phosphorus atom, or the methyl group on the nitrophenol ring of fenitrothion molecules. Lastly, our current pen-size reactor was demonstrated to chemically neutralize a 50 mL mixture of 1:1 fenitrothion: water at a rate of 5 mL per hour. These preliminary results indicate that, with further advancements, this type of reactor design has the potential to mitigate field forwarding bulk chemical threats, including CWAs, PBAs, TICs/TIMs, PFAs, and toxins, with its low SWaP-C design.

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Not Applicable.
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