Deployment of a Supercritical Oxidation Technology to Destroy Per- and Poly-Fluorinated Alkyl Substances in Aqueous Film-Forming Foam

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Background/Objectives. Aqueous film-forming foam (AFFF), containing per- and polyfluoroalkyl substances (PFAS), has been in use for fire training and firefighting operations by Department of Defense (DoD), municipal fire departments in the United States and around the world since the 1960s. Many of the legacy AFFF formulations were produced using an electrochemical fluorination (ECF) process that mainly contained perfluorooctane sulfonate (PFOS) (referred to as C8 formulations). These formulations were discontinued in 2002 due to health concerns of PFOS and perfluorooctanoic acid (PFOA). The ECF chemistry was replaced by a fluorotelomerization process that resulted in legacy formulations that contained fluorotelomers. These fluorotelomers have been found to degrade in the environment to form a variety of PFAS including PFOA and other perfluoroalkyl carboxylic acids (PFCAs), but not to PFOS or other perfluorosulfonic acids (PFSAs). Newer formulations for modern fluorotelomer AFFF have been formulated to include shorter fluorinated carbon chain length fluorosurfactants (referred to as C6 formulations) that do not transform or break down to PFOS in the environment. Recently, fluorine-free formulations are being researched and developed that may replace many of the historical AFFF formulations. As these newer AFFF formulations come to market, there is a need to dispose or destroy the older formulations. Although incineration and landfills can be used, both have come under increased public scrutiny and regulations in recent years due to environmental impacts associated with them. Hence, cost-effective innovative technologies are needed to destroy PFAS in AFFF, eliminating on-going risk to human health and the environment.

Approach/Activities. Battelle has developed a PFAS destruction technology based on supercritical water oxidation (SCWO) that mineralizes PFAS in aqueous media to carbon dioxide, water, and inert salts. This technology has been demonstrated to effectively treat various PFAS-impacted materials including aqueous investigation derived waste, landfill leachate, AFFF and others. Recently, Battelle has demonstrated the efficacy of SCWO to destroy PFAS in AFFF in bench-scale tests and an on-site field demonstration. Bench-scale tests using a laboratory SCWO system were performed using several AFFF formulations at various dilutions. Bomb calorimetry combined with a freeze-drying process was used to estimate heat of combustion for the AFFF to determine safe treatment concentrations. Multiple experiments were conducted to optimize and evaluate PFAS destruction efficiency to (a) optimize oxidant dosage, (b) quantify target PFAS in aqueous and gaseous effluents, and (c) evaluate byproduct formation in the aqueous and gaseous phases. These experiments were designed to evaluate and overcome challenges specific to treating AFFF using SCWO. A field demonstration was conducted at a commercial site to further validate the efficacy of SCWO to treat AFFF. This demonstration focused on treatment of an alcohol-resistant fluorotelomer-based AFFF ranging from 6 to 16 percent concentrations. The demonstration also assessed the treatment of other types of AFFF formulations.

Results/Lessons Learned. Both bench-scale tests and on-site field test demonstrated that greater than 4 to 5 orders of magnitude reduction of PFAS in AFFF samples could be achieved outside of a laboratory environment. Results as well as challenges encountered during AFFF treatment and resulting mitigation approaches will be presented. The lessons learned from these efforts, which will also be presented, were incorporated into enhancements to a larger mobile system, which is being field deployed in spring 2023.