Boron Nitride Nano-Photocatalyst Membrane Filters for the Degradation of Aqueous PFAS to CO_2 and Fluoride

PROJECT ID:
635

Flow reactor that will be used in the demonstration of photocatalytic degradation of PFAS. (Photo credit: Patrick Fedick, PhD)

OBJECTIVE

The objective of this effort is the optimization of a photocatalytic degradation system, converting polyfluoroalkyl substances (PFAS)-impacted waste streams, such as impacted drinking water, saltwater, bilge water, and Aqueous Film Forming Foam (AFFF) concentrates, to carbon dioxide (CO_2) and inorganic fluoride using boron nitride nanomaterials.

PROBLEM STATEMENT

Recent studies have underscored the need to evaluate byproduct formation when using incineration for PFAS remediation. Other emerging PFAS remediation technologies are either expensive or only focus on PFAS separation from the media/waste stream, leaving the chemicals intact.

DESCRIPTION

This project focuses on the development of a continuous photocatalytic system to degrade aqueous-phase PFAS into harmless byproducts—CO_2 and inorganic fluoride—using ultraviolet (UV) light and hexagonal boron nitride nanomaterials (BNNMs). Unlike thermal methods, which often produce incomplete degradation and secondary waste, this approach ensures complete breakdown. High surface area BNNM filters—comprising nanotubes, flakes, sheets, nanocages, and more—will be fabricated and optimized for enhanced catalytic activity and durability. These membranes will be integrated into a continuous flow reactor system with real-time mass spectrometry monitoring to track degradation products and reaction progress.

In the first year, membranes will be created through electrospinning BNNM/polymer fibers, followed by removal of the polymer or conversion into hybrid ceramic matrices for improved catalytic performance. Two reactor designs—internal and external UV sources—will be tested. Real-time degradation monitoring will be conducted using continuous flow nano-electrospray ionization mass spectrometry (cf-nESI-MS), enabling precise tracking of PFAS breakdown, intermediates, and reaction pathways. Initial testing will focus on aqueous

Perfluorooctanoic acid (PFOA) solutions, with the goal of achieving continuous, real-time PFAS destruction by the end of the first year.

Year two will expand testing to a broader range of PFAS compounds, mixtures, soil extracts, AFFF reserves, and real DoD waste streams. Kinetic data and degradation products will be cataloged to build a reference database, enabling non-experts to operate the system. The project will also aim to remediate 100 gallons of PFAS-impacted water, explore reactor multiplexing, and assess the scalability, durability, and reusability of larger BNNM membranes.

RETURN ON INVESTMENT

Though initially designed for treating PFAS-impacted water, this technology has the potential for broader applications. It can be adapted to remediate PFAS residues in firetrucks and fire suppression systems—common sources of issues due to historical AFFF use. With the addition of liquid extraction steps, it can also be applied to treat impacted soils, further expanding its utility at impacted sites.

The system's low cost, modular design, and portability make it well-suited for deployment across a variety of Navy installations, including remote or resource-limited locations. Its versatility and effectiveness offer a scalable solution that could save the Navy tens of millions of dollars in cleanup, disposal, and long-term liability costs. Importantly, it also fills a critical gap in managing and disposing of legacy AFFF stockpiles.

NAVY BENEFITS

The proposed system is scalable and adaptable to Navy site needs, with BNNM reactor multiplexing offering a cost-effective alternative to other PFAS cleanup methods. It fully breaks down PFAS into harmless CO_2 and fluoride, avoiding harmful byproducts often produced by thermal destruction. BNNM membranes can also degrade other tough chemicals of concern, like chlorinated compounds and hydrocarbons, in water.

Real-time monitoring using advanced mass spectrometry will track chemical concentrations, measure system performance, and guide the cleanup process.

TRANSITION DESCRIPTION

A final report and standard operating procedure (SOP) will support easy implementation across Navy sites.

CONTACT

For more specific information about this project, contact the Principal Investigator at patrick.w.fedick.civ@us.navy.mil.

ABOUT THE NESDI PROGRAM

The Navy Environmental Sustainability Development to Integration (NESDI) program is the Navy's environmental research and development demonstration and validation program, sponsored by Office of the Chief of Naval Operations (OPNAV) Compliance and Mission Readiness Division (N4I1) and managed by the Naval Facilities Engineering Systems Command (NAVFAC) from the Engineering and Expeditionary Warfare Center (EXWC) in Port Hueneme, CA.

The mission of the NESDI program is to support Fleet readiness by minimizing operational constraints associated with environmental and human health risks and to reduce cost of environmental compliance by demonstrating, validating, and integrating innovative technologies, processes, materials, and by filling knowledge gaps.

For more information, visit the program's web site at www.navfac.navy.mil/nesdi
or contact the NESDI Program Managers at NESDI.fct@navy.mil