PROJECT TITLE

Combination of electrochemistry with sono-chemistry to destroy and detoxify PFAS from environmental materials

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BACKGROUND

Per- and polyfluoroalkyl substances (PFAS), along with their precursors and derivatives, have been widely used in such activities as clothing, upholstery, carpeting, painted surfaces, food containers, cookware, surfactants in Aqueous Film-Forming Foam (AFFF) etc. The reason for their wide usage is because that they exhibit unique physical and chemical properties, such as hydrophobicity and simultaneous oleophobicity, which are not evident in other components, mainly due to their fluoro-carbon skeletons. Unfortunately, those fluoro-carbon skeletons are extremely stable with respect to thermal-, chemical- and bio-degradation. That is, under natural environmental conditions, they are inert / resistant / persistent to degradation and thus accumulate in the environment, if released into our environment. This has in turn raised serious concerns about their impact on the environment and public health.

Actually, PFAS contamination is more widespread than point-source pollution at airfields due to the application of AFFF, as they have also been detected in domestic vacuum dust, landfill leachates and smog dust as well. They are thus categorised as an emerging contaminant recently because we do not know too much about them yet. Added to this problem is that currently only a few PFAS among >3000 PFAS family can be quantitatively monitored. The rest are called as PFAS precursors originating from initial ingredients, by-products, or residual intermediates. All PFAS, including their precursors and derivatives, should be taken into account and remediated.

Currently, perhaps no other emerging contaminant (or persistent organic pollutants) gains as much attention as PFAS. That is because that these substances, which have had major impacts on a variety of industrial and safety needs, are found in almost every water body and thus become a major environmental concern, not just only in Australia, but also the whole world. Most of the present remediation technology can only remove PFAS, such as from water streams, by adsorption. However, the adsorbed PFAS is not destroyed but merely transferred from one matrix to another. Our proposal is to promote active destruction of PFAS to complete the full mitigation process and thus clean up the substances from our environment.

However, the inert fluoro-carbon skeletons of PFAS can be destroyed only under specific conditions, e.g., high-temperature (>1100 °C). Sono-chemical (or ultrasound) and electrochemical advanced oxidation can also destroy PFAS, but either a) their efficiency is low, or b) the electrodes are expensive, or c) the resulting intermediate substances and products from existing PFAS destructive processes are toxic and secondary contaminants, or d) the various backgrounds from sites to sites.

Our research recently made progress in this field. In this proposal, we will develop a process to destroy PFAS synergistically by combining two powerful technologies - electrochemical advanced oxidation and sono-chemistry. This combination intends to enhance the degradation efficiency of PFAS including precursors. The extra sono-chemistry onto the electrochemical advanced oxidation can accelerate PFAS desorption for destruction, speed up mass transport for oxidation, avoid electrode fouling and to directly destroy PFAS.

OUR OBJECTIVES

1. Explore economic materials for electrochemical advanced oxidation,
2. Combine electrochemical advanced oxidation with sono-chemistry,
3. Optimise process towards efficiency enhancement,
4. Scale-up application, from lab to trial, and towards field.

OUR PRELIMINARY RESEARCH

We have developed electrochemical setup to destroy PFAS at lab-scale and are currently improving it towards field-site application. The addition of sono-chemistry onto the electrochemical advanced oxidation enables in-field applications due to the sonication's "cleaning function" in preventing electrochemical electrode fouling, which usually hampers scaling-up application in field. The driving force of electricity (for both electrochemistry and sono-chemistry), rather than chemicals, means a cleaner approach.

OUR TEAM

Our team has a complex backgrounds to be complementary to each other, including electrochemistry, sono-chemistry, interface science, toxicity, biology, environment science, risk assessment, etc. Working as a team, fuelled by industry partners, we will maintain our leadership in this field, develop technology to destroy PFAS and benefit Australia environment.

For example, Cheng Fang (University of Newcastle) will lead the research into electrochemical-sonication destruction mechanisms, including the reaction on sono-probes and electrochemical electrode surfaces, evaluate catalysis activities, improve the efficiency, and design, fabricate the electrochemical-sono device for the laboratory and trial tests.

Fang has more than 20 years of experience in the fields of water treatment and electrochemistry in China, Germany, Singapore and Australia, and specialises in advanced electrochemistry. His experience in electrochemistry, PFAS monitoring and degradation and expertise on PFAS / Fluoro-chemistry, equip him well to lead this project.

We have other team members including Prof. Megh Mallavarapu. He has >30 years of experience on environmental remediation and ecotoxicology of contaminants, and environmental fate and toxicity of AFFF / PFAS, for the past 10 years. He has published 350 peer reviewed journal papers with an H-index of 59 and total citations of >12,600. He will also contribute to metabolite identification and detoxification of PFAS.

The third team member is Prof. Naidu. He is a leading scientist in the field of environmental science, not just in Australia but also globally. He has published >600 refereed journal papers, 75 book chapters, 11 edited books, 13 patents, >100 conference proceedings and > 60 keynote addresses, with a H-index of 82, i10 index of 461. He established CRC CARE and led a group to identify environmental contamination issues including PFAS. He has strong links with industries including the Department of Defence, Australia. He will supervise this research towards field application by scaling-up lab results, liaising with industry partners and arranging research manpower / facilities.

Together we will deliver the aims in 3 years.

EXPECTED OUTCOMES

- Effective technology for PFAS destruction to clean up PFAS-contaminated sites in Australia, and other co-existent persistent organic contaminants.

- Detoxification of PFAS, including precursors, destruction intermediates, end products as well.

- Advancement of the fundamental knowledge on electrochemical interface science, electrochemical-sono combination, PFAS chemistry/oxidation.

- Research advice and methodologies successfully adopted by water industry end-users, government regulatory agencies and private remediation industries.