PFAS Degradation Technologies for Decontaminating Water

ADMIN ACSGCI
Community Manager

0 0 623

10-31-2024 09:01 AM

Contributed by Ashley Baker, Scientific Content and Community Manager (Contractor), ACS Green Chemistry Institute

This website uses cookies. By clicking Accept, you consent to the use of cookies. Click Here to learn more about how we use cookies. Accept Reject

As our virtual Clean Water Summit approaches on December 11, we had the privilege of speaking with Dr. Kimberly Heck about the promising results of boron nitride as a photocatalyst for the degradation of PFOA (perfluorooctanoic acid) in water. Dr. Heck is currently a lecturer in Rice University's Chemical and Biomolecular Engineering Department and a research scientist/lab manager in Prof. Michael Wong's research group. Her previous research includes developing catalysts for the aqueous-phase degradation of chlorinated organic contaminants in groundwater, spectroscopic identification of reaction intermediates on model catalysts via surface-enhanced Raman spectroscopy, and the development of Au-based materials for hydrogen sensing.

Q . What inspired you to pursue research on catalysts for water treatment and, specifically, PFAS degradation?

A. It started with my PhD project around 2004. We were looking at catalysts to clean up trichloroethylene, a major, widespread contaminant. We then leveraged that technology to look at getting rid of nitrates and nitrites in water. We also looked at dioxane, which is a co-contaminant with trichloroethylene.

Then, PFAS emerged. PFAS is going to be a problem for a long, long time. There's so much of it in the environment and it's so mobile. It can even be airborne. There is so much water that needs to be treated that it will take multiple different technologies working in a variety of ways.

We want our water to be safe. It's good for human health and the environment. But why do this through catalysis? My work in catalysis differs from conventional treatment like ion exchange or activated carbon because those methods grab the contaminant and leave you with contaminated media. By catalytically transforming it to something that's now non-toxic you completely eliminate the threat so it's never a problem again.

When we first realized PFAS was problematic, everyone who does catalysis for water treatment was trying to use all the usual suspect catalysts to remove it, but nothing was working. Fortuitously, we discovered boron nitride (BN) was photocatalytically active for this reaction.

So far we've been able to treat almost every water we've thrown at it. One downside is that since it's photocatalytic, we have more trouble with water that is colored or opaque because the light can't penetrate through to the catalyst. However, at the lab scale, we've shown it to be effective in the presence of salts, and soon we're going to pilot it at a site with briney water. We can also work in very clean water. For electrocatalysis, you need a certain amount of salts because you need conduction. But the boron nitride catalyst works in everything from deionized water to stuff that's as salty as seawater. If other organics are present of course it slows down the reaction a little bit, but it's still effective with PFAS. It's so effective it has been surprising to us.

Q. How do you ensure there aren't harmful byproducts generated from the PFOA photodegradation?

This website uses cookies. By clicking Accept, you consent to the use of cookies. Click Here to learn more about how we use cookies. Accept Reject

adsorb to the catalyst as well as the longer-chain hydrophobic material. With these shorter chains, we're looking at a variety of different technologies to incorporate into a treatment train with our catalyst. For example, UV/sulfite can reduce these species. We think a combination of technologies will be effective for all these contaminants.

Q . What are the current concerns and challenges with PFAS contamination in water?

A. In April this year, the U.S. Environmental Protection Agency set the maximum contaminant levels (MCLs) for PFOA and PFOS in drinking water at 4 parts per trillion (ppt). These two PFAS were used widely as firefighting foams. The thing about firefighting foams is people think they're only used to fight fire, and that's not true. They've used these foams at air force bases, airports have them, and a lot of industrial processes, too. A lot of firefighting teams would train with them meaning that once a week or more they would spray this stuff, not thinking it was doing any harm. But actually, it was. That's one of the major reasons for the widespread contamination. Once it gets into the soil it's pretty water soluble, so it transports quickly into the waterways. That's why it's such a problem now. And, of course, you have discharges from point sources and PFAS factories like we've seen in Michigan and North Carolina.

The new regulations limit these contaminants to 4 parts per trillion. That's like a drop of water in an Olympic-sized swimming pool. Trying to detect that is very, very challenging. It can be done reliably, but it requires expertise and expensive instrumentation. People are working on developing alternative techniques, but it's currently state-of-the-art analysis. It's about $1,000 a sample, a huge burden to municipal water treatment facilities that are now being required to monitor for PFAS. The monitoring requirement is coming into effect before the enforcement of the MCL because treatment technologies are lacking. There are some conventional ones that you can use, but they're based on adsorption. So you can run the water through a carbon bed like in a Brita filter and that removes the PFAS, but now you have this PFAS-contaminated carbon. There is a lot of debate over what you do with that and whether it's going to be considered hazardous waste.

Q. Do you think the cost of analysis is a big barrier to addressing water pollution globally?

A. I'm sure that because PFAS is such a problem, people will create better ways to detect it with simpler, more low-tech techniques. But the current gold standard is pretty inaccessible for a lot of people. Our group is blessed in the sense that we have facilities that can measure this for us economically. We could not do this research if we had to send every sample to specialized labs.

Q. What role does computational chemistry play in your research?

A. We collaborate with a full-time density functional theory (DFT) expert, Prof. Tom Sentfle. Computational chemistry is absolutely important to us. We can come up with a mechanism and think we're right, but to have the DFT there to support that our thinking is correct – that a reaction is thermodynamically favorable, for example – gives us many, many more insights. He's able to show how the molecule lays on the surface, like if it's standing up or lying flat. With those insights we can better understand how it's reacting with the catalyst. We can then refine the catalyst, like putting different functional groups or metals that might

This website uses cookies. By clicking Accept, you consent to the use of cookies. Click Here to learn more about how we use cookies. Accept Reject

adsorb these things better and direct the reaction path a certain way. It's great because we can have an experiment, the DFT can confirm it, and it provides essential feedback. We're so grateful to work with their group.

Q. In what ways does having an interdisciplinary team benefit your research?

A. The whole is really greater than the sum of its parts. As a chemical engineer, I work with environmental engineers, chemists, and applied physicists, and I feel we all bring knowledge to the table that improves the technology and our understanding.

I have great respect for chemists and from working with them I notice we approach things from different angles. Chemists absolutely have a better grasp of what is going on at a fundamental level, whereas engineers are asking how things fit into an overall puzzle. Engineers care about the fundamentals, but we want to understand how pieces fit into the bigger process and what might happen downstream. For example, you don't want to generate a byproduct that could mess up equipment. One of the chemist research scientists in our group is great at understanding fundamental molecular interactions, and that's added great insights into our projects.

With the environmental engineers, I've proposed solutions where they've said, no, that's going to mess everything up. They know so much about different types of water. The environmental engineer's approach and knowledge of water treatment processes like reverse osmosis enables them to come up with different creative ways to employ our catalyst. For example, into an ultrafiltration membrane.

Q. In the group's recent paper about the effectiveness of BN, the connection between the research and addressing a real-world problem was very clear. What's your advice to researchers who want to improve how they communicate about their research and make clear ties to sustainability goals?

A. I'm still constantly learning how to distill things down. As scientists we are taught to communicate in a very precise, very jargon-heavy way. For me, I think the best thing any scientist can do is to try to explain their work to their friends and relatives, especially why it's important.

A couple things helped me do this better. I worked with a former graduate student who was really into entrepreneurship. We went through NSF's Innovation Corps program which is like a bootcamp to learn the basics of startup businesses and business models. He started competing in startup competitions. We started with a pitch deck, and by the final revision about 90% of the words had been slashed because the judges weren't getting it. You lose people if you get too technical. For me, trying to distill it into what the problem was and what we were doing about it was very valuable.

Our sincere thanks to Dr. Heck for speaking with us about her research! You can find more of her publications on Scopus, and learn more about Rice University's Wong Group here. Registration is now open for the virtual summit, "Putting Chemistry to Work for Clean Water," on December 11, 2024.

This website uses cookies. By clicking Accept, you consent to the use of cookies. Click Here to learn more about how we use cookies. Accept Reject

Labels :

Research

Tags:

catalysis chemical engineering environmental chemistry research water

0 Kudos

Terms of Use
Security
Privacy
Accessibility

Contact
Help
ACS Staff login

FOLLOW US

1155 Sixteenth Street, NW, Washington, DC 20036, USA | service@acs.org | 1-800-333-9511 (US and Canada) | 614-447-3776 (outside North America)

Copyright © 2025 American Chemical Society

This website uses cookies. By clicking Accept, you consent to the use of cookies. Click Here to learn more about how we use cookies.

Accept Reject