Conductive and Redox-Active Molecularly Imprinted Polymer for Direct Quantification of Perfluoroalkyl Substances

Lead Investigator

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Background and Unmet Need

The per- and poly-fluoroalkyl (PFAS) class of chemicals, also known as 'Forever Chemicals,' has been a growing contaminant of concern throughout the last decade. PFAS present a significant human health risk, including an increased risk of cancer and reproductive defects.[1] Because these chemicals are extremely hydrophobic and do not naturally break down in the environment, they contaminate many of our ecosystems. Scientific models suggest that PFAS are present in 45% of the United States drinking water supply.[2] Further, studies have found that PFAS are present in the drinking water of 200 million Americans.[3]

The US Environmental Protection Agency has set maximum contaminant levels (MCLs) for six PFAS in drinking water, PFOA (4ppt), PFOS (4 ppt)[4], PFHxS (10ppt), PFNA (10ppt), HFPO-DA (10 ppt), and PFAS mixtures containing at least two or more of PFHxS, PFNA, HFPO-DA, and PFBS (hazard index of 1)[5]. These new standards have fueled a strong demand for developing novel technologies to quantify and to identify PFAS at or below regulatory standards.

The current standard for detecting PFAS are liquid chromatography-triple quadrupole-tandem mass spectrometry (LC-MS/MS). This technology is expensive to obtain and operate, requires specialized operator training, and is labor and time intensive. There is a growing consensus among the scientific community that technologies for rapid PFAS detection at and below the regulatory concentration are critical but lacking.

Experts believe the demand for rapid, mobile, and economical PFAS detection will continue to grow as global governmental agencies evolve regulatory requirements on monitoring PFAS contamination.

[1] *Our Current Understanding of the Human Health and Environmental Risks of PFAS.,* EPA, n.d.
[2] *Per- and polyfluoroalkyl substances (PFAS) in United States tap water: Comparison of underserved private-well and public-supply exposures and associated health implications.*, Elsevier, June 2023.
[3] *Population-Wide Exposure to Per- and Polyfluoroalkyl Substances from Drinking Water in the United States.,* ACS Publications, October 2020.
[4] Parts per trillion (ppt)
[5] *Final PFAS National Primary Drinking Water Regulation.*, Environmental Protection Agency, n.d.

Opportunity

Dr. Wenqing Xu has developed a novel Molecularly Imprinted Polymer (MIP)-enabled electrochemical platform for rapid and direct quantification of non-electroactive PFAS at sub ng L^{-1} concentrations in water samples.[6] The technology provides a rapid ex-situ and/or real-time in-situ PFAS quantification solution by creating a conductive and redox-active MIP, thereby eliminating the need for external redox probes. The platform's detection limit exceeds the newly implemented regulatory requirements of 4 ppt for PFOA and PFOS by orders of magnitude, which is enabled by a "lock and key" strategy that binds to target PFAS molecules while reducing false positive readings. The technology is also capable of detecting multiple PFAS's within water and wastewater samples simultaneously. The reproducibility of the sensor fabrication process has been demonstrated in laboratory-scale tests. Consistent results were shown in the reusability test.

This proprietary MIP technology is a platform for future PFAS sensors. The technology may be integrated into a compact mobile electrochemical platform, enabling on-site sample collection and detection. At present, given current, state-of-the-art methods and sensors, on-site detection of PFAS contaminants is not technically feasible. As a result, the technology platform presents the opportunity to be advanced into a first-of-its-kind field-deployable sensor to provide real-time detection of PFAS compounds while in the field.

Unique Attributes

- Rapid detection and quantification of PFAS at sub ng L^{-1} concentrations in water.
- Platform technology compatible with the development of mobile sensor apparatus.
- Economical solution to PFAS detection in varying environments.
- Direct quantification of PFAS enabled by a novel and redox-active Molecular Imprinted Polymer platform that eliminates the need for external redox probes.

Applications

A redox-active molecular imprinted polymer for the rapid ex-situ detection of PFAS contaminants within drinking water resources.

Stage of Development

The technology has achieved Technology Readiness Level 5, with an operational benchtop prototype validated in surface water and stormwater samples. The platform has demonstrated sub-ppt sensitivity exceeding regulatory requirements. We are now seeking strategic research investment or licensing to optimize detection conditions, expand validation to additional water matrices, and refine the prototype for field deployment.

[6] *Novel Conductive and Redox-Active Molecularly Imprinted Polymer for Direct Quantification of Perfluorooctanoic Acid.,* Sumbul Hafeez, Aysha Khanam, Han Cao, Brian P. Chaplin, and Wenqing Xu, Environmental Science & Technology Letters, 2024 11 (8), 871-877, DOI: 10.1021/acs.estlett.4c00557

Intellectual Property

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Publications

Novel Conductive and Redox-Active Molecularly Imprinted Polymer for Direct Quantification of Perfluorooctanoic Acid., Sumbul Hafeez, Aysha Khanam, Han Cao, Brian P. Chaplin, and Wenqing Xu, Environmental Science & Technology Letters, 2024 11 (8), 871-877, DOI: 10.1021/acs.estlett.4c00557

Licensing and Collaboration Opportunity

Villanova University is seeking a licensee or collaborators to commercialize the invention.

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