The Development of Environmental Technologies: PFAS

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I. Overview

Per- and poly-fluoroalkyl substances (PFAS) are a large, complex group of manmade chemicals resistant to heat, water, and oil.[1] These properties have made them highly valuable in various industries and consumer products since their development in the 1940s.[2] Today, PFAS are found in numerous everyday items, including nonstick cookware, water-repellent clothing, stain-resistant fabrics and carpets, and some cosmetics and firefighting foams.[3]

PFAS molecules are characterized by a linked chain of carbon and fluorine atoms.[4] The carbon-fluorine bond is one of the strongest.[5] As a result, PFAS do not degrade easily.[6] This resilience poses significant environmental challenges.[7] Specifically, during PFAS production, usage, and disposal, these chemicals can migrate into soil, water bodies, and the air, leading to widespread environmental contamination.[8] Furthermore, PFAS are not easily broken down through conventional wastewater treatment processes. As a result, they tend to bioaccumulate in humans, meaning the amount builds up over time in the blood and organs.[9]

II. Issues

PFAS pose significant environmental and health challenges due to their widespread use and persistence.[10] Specifically, PFAS have been found at low levels both in the environment and in blood samples of the general U.S. population.[11] People are most likely exposed to these chemicals by consuming PFAS-contaminated water or food, using products made with PFAS, or breathing air containing PFAS.[12]

Studies in animals who were exposed to PFAS found links between the chemicals and increased cholesterol, changes in the body's hormones and immune system, decreased fertility, and increased risk of certain cancers.[13] Studies in which animals were given high levels of PFAS showed effects including low birth weight, delayed puberty onset, elevated cholesterol levels, and reduced immunologic responses to vaccination.[14]

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[1] *See Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)*, NAT'L INST. OF ENV'T HEALTH SCIENCES (Mar. 6, 2024), https://www.niehs.nih.gov/health/topics/agents/pfc.
[2] *See id*.
[3] *What are PFAS?*, AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (Jan. 18, 2024), https://www.atsdr.cdc.gov/pfas/health-effects/overview.html.
[4] *See Perfluoroalkyl and Polyfluoroalkyl Substances*, *supra* note 1.
[5] *See id*.
[6] *See id*.
[7] *See What are PFAS?*, *supra* note 3.
[8] *See id*.
[9] *See PFAS 101*, MICH. PFAS ACTION RESPONSE TEAM, https://www.michigan.gov/pfasresponse/faq/categories/pfas-101.
[10] *See What are PFAS?*, *supra* note 3.
[11] *See PFAS 101*, *supra* note 9.
[12] *See Perfluoroalkyl and Polyfluoroalkyl Substances*, *supra* note 1.
[13] *PFAS 101*, *supra* note 9.
[14] *Id.*

One report by the Centers for Disease Control and Prevention found PFAS in the blood of 97% of Americans.[15] Moreover, current research reveals possible links between human exposures to certain PFAS and adverse health outcomes.[16] These health effects include altered metabolism and body weight regulation, risk of childhood obesity, increased risk of some cancers, and reduced ability of the immune system to fight infections.[17]

Because of the adverse health outcomes associated with PFAS, the U.S. Environmental Protection Agency (EPA) has labeled PFAS as an emerging contaminant on the national landscape.[18]

III. Laws Enacted

In January 2024, the EPA finalized a rule preventing companies from processing 329 PFAS that have been inactive for many years (not manufactured, imported, or processed in the U.S. since June 21, 2006).[19] This rule mandates a complete EPA review and risk determination before any of these PFAS can be reintroduced into usage.[20]

Additionally, the EPA is working on regulating PFAS discharges into water bodies.[21] This approach includes expanding the scope of disclosure requirements for landfill discharges.[22] Moreover, the EPA is contemplating designating certain PFAS as hazardous substances.[23] Such a designation would require reporting releases of PFAS above specific thresholds, potentially holding facilities accountable for remediation costs associated with their release.[24]

On a state level, multiple states have passed legislation regulating PFAS. Maine and Minnesota are at the forefront, planning to ban all unnecessary uses of PFAS. California has banned PFAS in children's products and food packaging, while Colorado targets the ban of PFAS in cosmetics and other products. These state-level regulations, along with federal efforts, show an increasing effort to mitigate the health and environmental risks associated with PFAS.

IV. New Technologies

The primary route of human exposure to PFAS is through consuming PFAS-contaminated water.[25] This is a significant concern as conventional water and wastewater treatment facilities are incapable of removing PFAS.[26] In fact, water processed by a wastewater facility typically has higher amounts of PFAS than “natural” water due to the breakdown of PFAS precursor

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[15] *Perfluoroalkyl and Polyfluoroalkyl Substances*, *supra* note 1.
[16] *See id*.
[17] *Id*.
[18] *See PFAS 101*, *supra* note 9.
[19] *Key EPA Actions to Address PFAS*, U.S. ENV'T PROT. AGENCY (Feb. 6, 2024), https://www.epa.gov/pfas/key-epa-actions-address-pfas#:~:text=In%20January%202024%2C%20the%20EPA%20finalized%20a%20rule%20that%20prevents,EPA%20review%20and%20risk%20determination.
[20] *See id*.
[21] Andrew Kaminsky, *The State of PFAS Regulations in the United States and Around the World*, FISCALNOTE (Sept. 20, 2023), https://fiscalnote.com/blog/pfas-regulations-us-world.
[22] *See id*.
[23] *Id*.
[24] *Id*.
[25] *See Perfluoroalkyl and Polyfluoroalkyl Substances*, *supra* note 1.
[26] *See* Jay Meegoda et al., A Review of PFAS Destruction Technologies, INT. J. ENV'T RSCH. PUB. HEALTH (2022), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9778349/.

compounds during water treatment.[27] Consequently, researchers have sought to develop technologies aimed at capturing these pollutants in drinking water sources.[28] This review discusses several of these innovative technologies: (1) electrochemical oxidation, (2) plasma, (3) photocatalysis, (4) sonolysis, (5) supercritical water oxidation, and (6) thermal degradation.[29]

A. Electrochemical Oxidation

Electrochemical oxidation utilizes electrical currents to induce oxidative reactions (combining chemically with oxygen), leading to the breakdown of PFAS.[30] Electrodes are placed in PFAS-contaminated water.[31] When electricity is applied, oxidation reactions occur at the anode, breaking down PFAS molecules.[32] This method is effective for various PFAS compounds and can be designed for specific water treatment needs.[33]

B. Plasma

Plasma-based treatment employs highly energized, ionized gas to disrupt the chemical bonds in PFAS, resulting in their degradation.[34] This method is advantageous due to its non-selectivity and effectiveness at low concentrations, without the need for added chemicals.[35]

C. Photocatalysis

Photocatalysis uses light, typically ultraviolet, and a catalyst to break down pollutants like PFAS.[36] When the light interacts with the catalyst, it generates reactive species that can oxidize and break down PFAS molecules.[37] This method is environmentally friendly, often using sunlight, and does not produce harmful by-products.[38]

D. Sonolysis

Sonolysis involves the use of ultrasonic waves to treat PFAS contaminated water.[39] These waves create microscopic bubbles in the water.[40] As these bubbles collapse, they generate intense heat and pressure, breaking the chemical bonds in PFAS.[41] This chemical-free method can be used for a range of organic contaminants, not just PFAS.[42]

E. Supercritical Water Oxidation

For supercritical water oxidation, water is brought to a "supercritical" state where it exhibits unique properties that facilitate the oxidation and breakdown of PFAS.[43] To do so, the

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[27] *See id.*
[28] *See id.*
[29] *See id.*
[30] *See id.*
[31] *See id.*
[32] *See id.*
[33] *See id.*
[34] *Id.*
[35] *See id.*
[36] *See id.*
[37] *Id.*
[38] *See id.*
[39] *See id.*
[40] *See id.*
[41] *Id.*
[42] *See id.*
[43] *Id.*

water is heated and pressurized beyond its critical point.[44] In this state, it acts as a solvent for PFAS and as a medium for oxidation reactions.[45] This technique is extremely effective in breaking down PFAS compounds. However, it requires high temperatures and pressures.[46]

F. Thermal Degradation

Thermal degradation involves breaking down PFAS using high temperatures.[47] Specifically, PFAS-contaminated materials are heated to very high temperatures, leading to the breakdown of the chemical bonds in the PFAS molecules.[48] This method destroys PFAS completely.[49] However, it requires significant energy and there are concerns about potential emissions, including the release of harmful by-products.[50]

V. Conclusion

PFAS demonstrates just one environmental challenge stemming from past human actions. Fortunately, the development of innovative solutions, from advanced filtration to chemical treatments, is paving the way toward a healthier environment. Given the current rate of environmental degradation, the need for new technologies is becoming increasingly urgent to protect our environmental future.

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[44] *Id*.
[45] *Id*.
[46] *See id*.
[47] *See id*.
[48] *Id*.
[49] *See id*.
[50] *See id*.