SENATOR JESSE KIEHL

April 14, 2022

TO: Sen. Click Bishop, Co-Chair
Sen. Bert Stedman, Co-Chair
Senate Finance Committee

FROM: Sen. Jesse Kiehl

RE: PFAS Remediation Technologies

Here is an EPA overview of PFAS remediation technologies. It has a link to a list of primary research papers on the topic.

Most of the technologies available at scale filter contaminated water. No technology is currently able to remediate soil on site. There is technology which can slow the spread of PFAS contamination in groundwater, but it does not remediate. Promising ideas for site cleanup are being developed, but they are currently at benchtop or prototype scale.

Please feel free to reach out to my office with any additional questions. You can contact Cathy Schlingheyde at (907) 465-4947 or cathy.schlingheyde@akleg.gov.

For more information on Per- and Polyfluoroalkyl Substance (PFAS) Remediation, please contact:
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Per- and Polyfluoroalkyl Substances (PFASs)

Remediation Technologies

PFAS Strategic Roadmap
On October 18, 2021, EPA Administrator Michael S. Regan announced the agency's PFAS Strategic Roadmap—laying out a whole-of-agency approach to addressing PFAS.

Introduction

This section provides an overview of remediation technologies that have been used or are being evaluated to treat PFAS-contaminated media. Most of the available information concerns the treatment of drinking water, wastewater, and groundwater; treatment of soils and sediments has received less attention. The remediation technologies addressed below are primarily focused on PFOS and PFOA; however, researchers such as Liu et al. 2015 and Place and Field 2012 report that many other PFASs may be present in wastewater, surface water, and at firefighter training areas or other sites where aqueous film-forming foam (AFFF) was used. Technologies that are able to treat PFOS and PFOA effectively may be ineffective for other PFASs with different chemical and physical properties. In addition, co-contaminants such as hydrocarbons and chlorinated solvents may also be present at sites contaminated with PFASs. Oxidative technologies such as in situ chemical oxidation, which are often applied to these contaminants, may transform polyfluorinated precursors into PFOS and PFOA (Merina et al 2016). Air stripping, which is often applied to remove chlorinated solvents from extracted groundwater, may result in PFASs being released as aerosols (Oliaei et a. 2013). These potential impacts may affect the selection and implementation of remedies at PFAS sites.

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Technology Overviews

The following are summary descriptions of remediation technologies and are hyperlinked to subsections containing citations to relevant papers and reports for additional reading. Each citation in the subsection is followed by a brief description that indicates the focus or scope of the publication's content. The available information for some technologies is limited because remediating PFAS contamination has only recently been contemplated. EPA does not endorse any technology or the findings, conclusions, or recommendations of the publications. Readers are encouraged to consult the linked text for a description of results, conclusions, and recommendations.

Remediation Technologies Used for PFAS-Contaminated Media

Excavation and Off-Site Disposal. Excavation of soil and sediment with disposal at an off-site landfill has been selected as a means to remove and contain PFAS-contaminated media (MPCA 2008a, 2008b, and 2009).

Pump and Treat. Extraction of groundwater followed by treatment with granular activated carbon has been selected as a means to control the migration of PFAS-contaminated groundwater (MPCA 2008a, 2008b, and 2009).

Remediation Technologies Being Evaluated for PFAS-Contaminated Media

Adsorption. *Activated carbon* in either the powdered or granular form can be effective at removing PFOA and PFOS from water (USEPA 2016a and b). Bench- and pilot-scale studies are required to select the most effective product and contact time (Cummings et al. 2015) and to evaluate treatment costs (USEPA 2016a and b). Proprietary adsorbents such as RemBind™ and PefluorAd are being marketed as alternatives or complements to activated carbon (Birk 2016). Disposal and treatment of exhausted activated carbon or used adsorbents may also be an important consideration. *Ion exchange resin* has two broad resin categories: cationic and anionic. Cationic exchange resins may be effective for treating water containing positively charged PFASs (e.g., perfluoroalkyl sulfonamide amines). Anion exchange resins have been shown to be effective for treating negatively charged PFASs (e.g., PFOA and PFOS) and require periodic regeneration to restore uptake capacity (Dudley et al. 2015, USEPA 2016a and b).

Bioremediation. The microbial transformation of polyfluorinated precursors to yield perfluorinated compounds is likely to occur in aerobic environments (Dasu and Lee 2016, Liu and Avendaño 2013). A limited number of studies have found that perfluorinated compounds such as PFOS and PFOA are resistant to microbial degradation transformation in aerobic environments; few detailed studies under anaerobic conditions have been completed to date (Liu and Avendaño 2013).

Chemical Oxidation. Common drinking water oxidative/disinfection agents such as packed tower aeration, chloramination, chlorination, ozonation, potassium permanganate, ultraviolet (UV) treatment, and advanced oxidation processes (AOPs) have been shown to be ineffective for PFOS and PFOA (Dickenson and Higgins 2016, EPA 2016a and b). However, bench-scale work has shown the potential for some oxidants and oxidant systems to degrade some PFASs (Crimi 2016). There is a concern that polyfluorinated precursors may be transformed into oxidation-resistant perfluoroalkyl carboxylates during in situ chemical oxidation (Place and Field 2012).

Chemical Reduction. Preliminary research has shown that a number of chemical reduction techniques are capable of degrading some PFASs (Crimi 2016).

Electrochemical Oxidation. Bench-scale testing has shown that electrochemical oxidation of PFASs at concentrations of less than 200 mg/L is achievable for some anode and electrolyte combinations (Niu et al. 2016).

Incineration and Thermal Treatment. Research to date has focused on PFAS-containing solid waste showing that fluorotelomer-based acrylic polymer was destroyed in a laboratory-scale reactor designed to simulate municipal incineration conditions (Yamada et al. 2005). Other research has focused on the ex situ thermal treatment of PFOS-containing sludge (Wang et al. 2013).

Membrane Filtration. High pressure membranes, such as those used in reverse osmosis and nanofiltration systems, can reject particulates and dissolved species such as PFAS (EPA 2016a and b). *Reverse Osmosis* (RO) involves retaining PFASs on the pressurized side of a membrane and has been shown in both bench- and full-scale applications to remove PFOS and PFOA from water (Cummings et al. 2015, EPA 2016a and b). *Nanofiltration* is similar to RO, although it operates at lower pressures, and has been shown in bench-scale experiments to remove PFOS from water (Cummings et al. 2015). Disposal and treatment of the retained fluid (i.e., rejectate), which potentially contains high concentrations of PFASs, may also be an important consideration.

Solidification/Stabilization. There are reports of mixing adsorbents with soil to reduce the mobility of PFASs (Birk 2016).

Sonochemical Treatment. Bench-scale research has been completed demonstrating the applicability of treating PFASs in water by sonolysis (Merino et al. 2016).

Additional information on a wide variety of treatment technologies for drinking water, some of which may be applicable to **PFOS** or **PFOA**, can be found in EPA's **Drinking Water Treatability Database**.

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