Evaluation of PFAS Treatment Technologies

Prescriptive Groundwater Remediation

The PFAS Problem

Per- and polyfluoroalkyl substances (PFAS) are ubiquitous contaminants that are found in groundwater, soil, humans, and the environment. PFAS are released into the environment through a variety of consumer and industrial products, including firefighting foams, fast food packaging, waterproof textiles, pesticides, non-stick cookware, paints, and mining surfactants. Many PFAS treatment technologies are being explored; a qualitative representation of the current practicality and stage of development of these technologies is shown in Figure 1.[1] Current treatment strategies typically involve sorption onto activated carbon or ion exchange resins followed by incineration. The high cost of incineration as well as questions regarding the effectiveness of PFAS destruction under these conditions has led to significant efforts to develop alternative destructive methods.

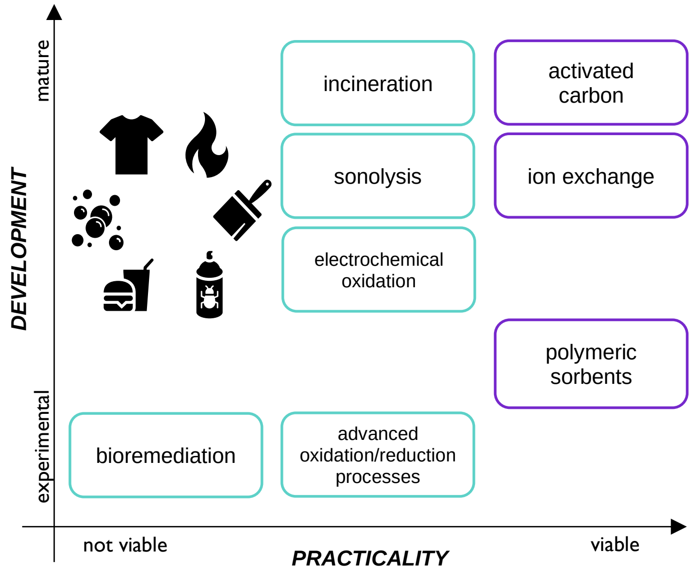

FIGURE 1. PFAS treatment technologies plotted in terms of stage of development and range of practicality. Destructive technologies are outlined in teal while sorptive technologies are outlined in purple. Adapted from ref. 1.

AxNano, a wholly owned subsidiary of Triad Growth Partners, is located in Greensboro, NC. North Carolina is currently dealing with PFAS contamination, most notably GenX and AFFF. In 2017, NC DEQ identified Chemours as the party responsible for releases of GenX into the Cape Fear River.[2] Fire-fighting activities at the Piedmont Triad International Airport have been identified as a source of PFAS contamination in the Greensboro watershed. In 2019, Greensboro Water Resources installed an emergency response powdered activated carbon system to manage intermittently high PFAS levels. AxNano is committed to identifying and developing solutions to the PFAS problem that affect our local, state, and national communities.

The RemRx™ Solution

AxNano develops innovative products to address environmental challenges. Our current product offerings include technologies for groundwater remediation. We have extensive experience leveraging small busines research funding and university partnerships to develop and commercialize ground-breaking products in the remediation space. RemRx™ CRP (Controlled Release Pellets) is a patented controlled release system that provides a prescriptive oxidant dosage for sustained delivery into the subsurface. RemRx™ CRI (Controlled Release Injectable) is an injectable permanganate formulation designed for treatment of low permeability zones. RemRx™ ZVI (Zero Valent Iron) features highly reducing ZVI on a carbon support for improved transport and longevity in the subsurface.

A combination of sorptive and destructive techniques will be necessary to concentrate and mineralize PFAS. Recognizing that the PFAS problem will require multiple solutions, we are evaluating technologies in the following areas: advanced oxidation processes, advanced reduction processes, and novel sorbent materials. These strategies can be combined in a treatment train to achieve more significant PFAS destruction than a single treatment alone. As shown in Figure 2, we anticipate that a treatment train approach involving pre-treatment, concentration through use of selective sorbents, PFAS degradation, and post-treatment phases will improve the likelihood of achieving total PFAS destruction.

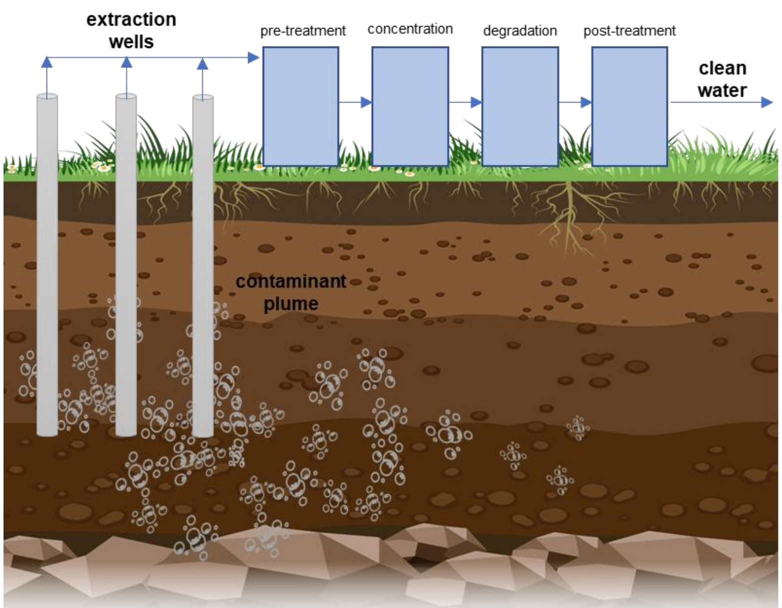

FIGURE 2. A representative PFAS treatment train. PFAS is extracted from groundwater and passed through subsequent treatment stages, including pre-treatment (e.g. adjustment of hydrological conditions), concentration through selective sorption agents, degradation, and post-treatment to prepare the effluent for discharge.

Emerging technologies for emerging contaminants

Sorbents: Sorbent technologies for PFAS remediation are generally practical and well-developed. Activated carbon and ion exchange resins are currently the most widely investigated sorbent materials for PFAS (Figure 3). While inexpensive, easy to implement, and moderately effective, activated carbon sorbents can suffer from poor sorption of PFAS mixtures and decreased longevity in the field. Polymeric and/or surface-modified sorbents that are highly selective for PFAS are under investigation as a potential solution to these problems.[3,4] PFAS-laden sorbents need to be further treated to destroy sorbed PFAS. Thus, sorbent materials that can be easily degraded are also desirable.

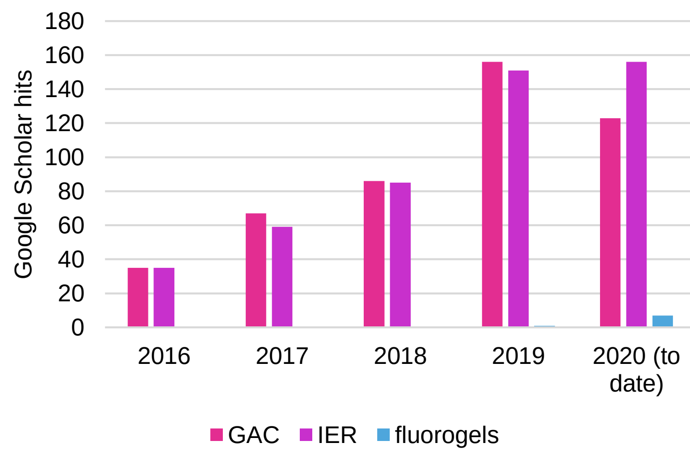

FIGURE 3. Frequency of Google Scholar literature hits over time for keywords including PFAS and GAC, IER, and fluorogels.

AxNano is developing PFAS-selective technologies in order to improve PFAS removal from contaminated water and generate a more easily processable waste stream to decrease human health risk from PFAS exposure. AxNano envisions that these PFAS-selective sorbents can be used in complex matrices with high concentrations such as wastewater and groundwater, as well as more simplified, dilute streams such as drinking water.

Advanced oxidation processes (AOP): While chemical oxidation of PFAS has been demonstrated with limited success under ambient conditions, electrochemical oxidation and aggressive oxidation processes like hydrothermal alkaline treatment, supercritical water oxidation, sonolysis, and plasma have proven effective at degrading a range of PFAS.[5-7] Thermal oxidizing treatments including incineration and smoldering are also gaining traction.[8,9] AxNano has investigated the efficacy of these technologies, evaluating the extent of PFAS mineralization, reaction conditions, treatment costs, throughput, and waste stream compatibility. As a result of this evaluation, we have identified a promising aggressive oxidation process for further evaluation.

Preliminary studies indicate that this process will be useful for broad spectrum contaminant degradation, including PFAS mineralization. A complex waste stream containing a mixture of acrylic polymers and PFAS was treated in a continuous flow unit. PFOS concentrations were reduced from 3100 ppt in the feed to 71 ppt in the effluent (97.7% reduction following treatment). Further optimization of reaction conditions will be investigated to achieve more complete removal and understand mass balance.

Advanced reductive processes (ARP): Zero valent iron (ZVI) is a well-developed reductant used to remediate a variety of contaminants, including chlorinated ethylenes, heavy metals, nitrates, dyes, and phenols. Literature reports suggest that ZVI has potential for PFAS degradation. While highly reactive, nano-ZVI is short-lived in the subsurface and exhibits poor transport due to agglomeration. To overcome these challenges, we designed RemRx™ ZVI. We are currently investigating RemRx™ ZVI as a promising technology for PFAS degradation. Preliminary data shows ~80% removal of PFOS under unoptimized conditions (Figure 4A). A bimetallic ZVI composite reported by Professor Linda Lee (Purdue) demonstrates rapid PFOS transformation with stoichiometric formation of fluoride and sulfate (Figure 4B).[10] We anticipate that RemRx™ ZVI will be a competent reductant for PFAS degradation.

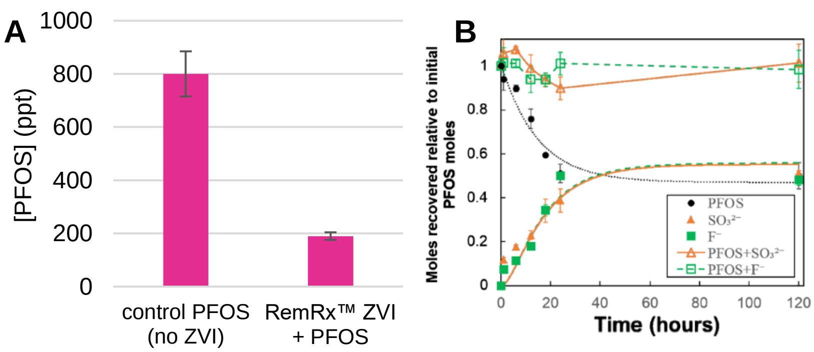

FIGURE 4. (**A**) PFOS removal by RemRx™ ZVI compared to a control after 24 hours at 50 °C. (**B**) PFOS mass balance in a reaction containing NiFe nanoparticles on activated carbon at 60 °C. The sum of relative moles of sulfite and fluoride with residual PFOS achieves near mass balance (reproduced from ref. 10).

Partners AxNano is currently seeking partnerships to continue R&D efforts in the area of PFAS removal and destruction. We have partnered with universities and received SBIR funding from federal agencies.

References

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