PRINCETON UNIVERSITY

Grant Information: Institution, Principal Investigator(s), Contact Information, Grant Number	**Princeton University** **Project:** Enhancing Transport and Delivery of Ferrihydrite Nanoparticles via Polymer Encapsulation in PFAS-Contaminated Sediments to Simulate PFAS Defluorination by *Acidimicrobium* sp. Strain A6 **Project Leaders**: **Peter Jaffe**, **Bruce E. Koel** **Funding Period:** 2021-2025
Technology	Biostimulation of *Acidimicrobium* sp. sp. Strain A6 for the purpose of PFAS defluorination in soils/groundwater requires the supply of solid-phase ferric iron as electron acceptor, which is challenging. Here, we are developing a polymer encapsulated ferric iron phase that is transportable in a porous medium and bioavailable to *Acidimicrobium* sp. Strain A6.
Innovation	**Materials:** Ferric iron phases (ferrihydrite, goethite, hematite) encapsulated in polyacrylic acids (PAAs). **Biological: What is the biological component?** *Acidimicrobium* sp. Strain A6, an autotroph that used ammonium as electron donor and ferric iron as electron acceptor. The genome of this organism contains sequences for various dehalogenases, which seem to play a role in reductive PFAS defluorination. **Why is this technology/approach different than what is already in the market?** At this point there is no known method to biodegrade perfluoroalkyl acids (PFAAs), and biostimulation of *Acidimicrobium* sp. Strain A6 for this purpose is a promising technology for their degradation at selected environmental settings.
Contaminant and Media	**Contaminants: What contaminant(s) does your project target?** PFAS, including PFAAs such as PFOA and PFOS. **Media:** Porous media, including soils, sediments, and groundwater. At this point, we are focusing on acidic, iron-rich systems, which favor the presence of that *Acidimicrobium* sp. Strain A6.
Expansion Potential	**Looking Forward: What other contaminants/media would work for your technology?** We have shown that Acidimicrobium sp. Strain A6 is also capable of degrading *Acidimicrobium* sp. Strain A6 is also capable of degrading chlorinated organics, such as 1,2,3 TCP, although more study is needed. Hence, it might be possible to address sites that contain chlorinated and fluorinated compounds. **Combined Remedy: Would this technology work well with other treatment approaches?** Biological defluorination most certainly decreases the mass of contaminates; hence, even if biological methods might not be able to reach drinking water standards, combining it with methods such as sorption to activated carbon will make the sorbent last much longer.

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Sites/Samples	We are testing the technology in laboratory column studies using PFAS impacted sediments from two Department of Defense (DoD) sites: The Naval Air Station Oceana, Virginia, and the Lakehurst Naval Air System Command, New Jersey. Sediments from both sites are acidic and iron-rich, and that *Acidimicrobium* sp. Strain A6 is naturally present at low numbers; hence, we are testing if we can stimulate its growth using the technology developed in this project.
Technology Readiness Level	TRL 4 — Technology validated in laboratory

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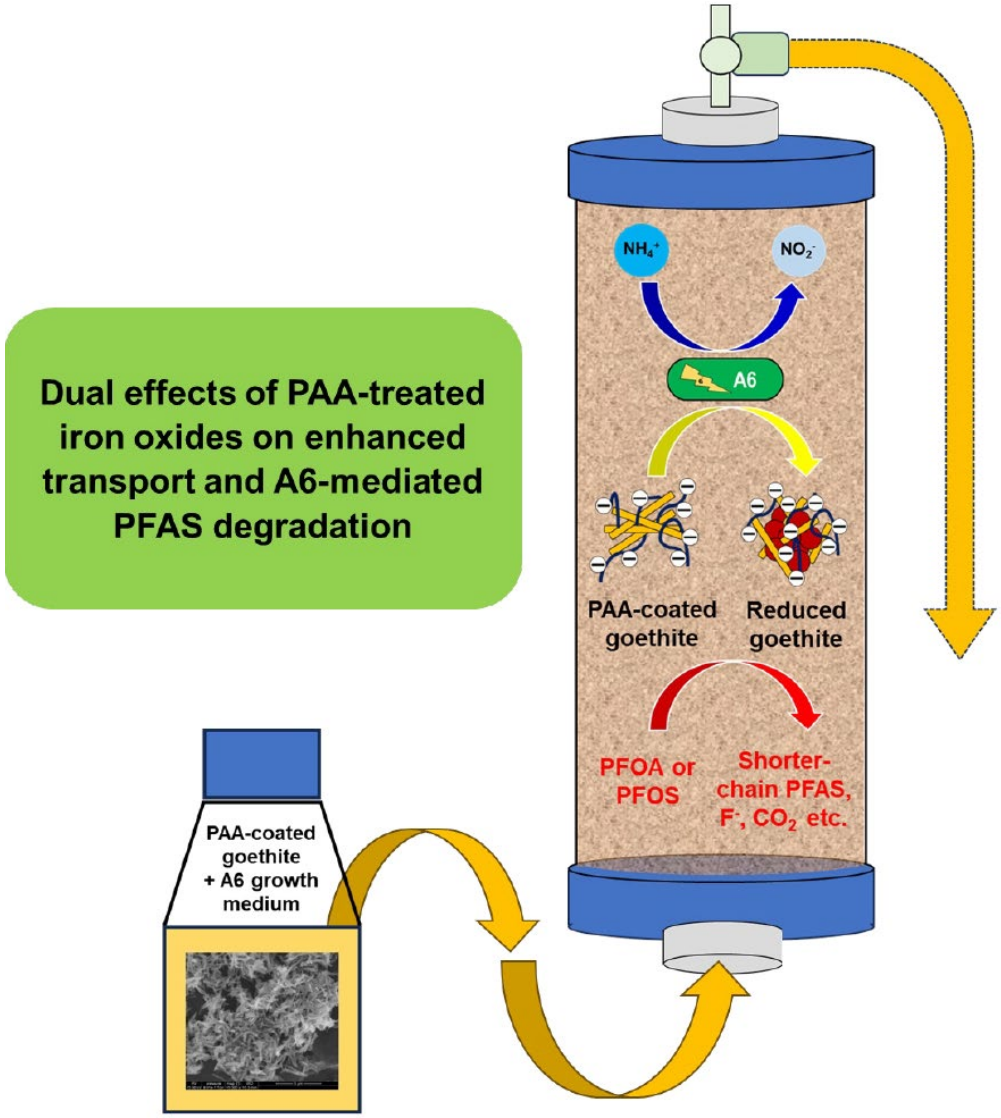

Supplying polyacrylic acid coated goethite to a soil column to stimulate PFAS defluorination by Acidimicrobium *sp. Strain A6.*

Update of Progress	The goal of this project was to (i) Determine if previous findings of PFOS, PFHxS, and PFOA degradation at the mg/l levels also occur at levels typically observed at PFAS impacted DoD sites; (ii) Gain further insights into the PFAA defluorination mechanism by *Acidimicrobiaceae* sp. A6 (A6); and (iii) determine if A6, which has been observed in many iron-rich acidic soils, is present in PFAS impacted soils with such characteristics at DoD sites, and if its activity can be stimulated. In terms of concentration effects, results have shown that the half-life of these PFAS is relatively constant over concentration ranges from 10 ppm to 1 ppb. Focusing on the defluorination mechanism, the production of H-PFOA is typically observed during incubations with PFOA. Preliminary results, needing additional confirmation, indicate that the missing fluorine is either from the alpha carbon and from the delta and/or epsilon carbon. If corroborated, this would explain the relative amounts of the shorter chain PFAAs that are being formed during the degradation of PFOA. To determine if A6 is present at different DoD sites that are iron-rich and acidic, PFAS impacted sediment samples were obtained from the Naval Auxiliary Landing Field Fentress, Virginia, (pH = 6.11); Naval Air Station Oceana, Virginia, (pH = 6.04); Lakehurst Naval Air System Command, New Jersey (pH = 6.57); and Joint Base Charleston–Air, South Carolina. Various incubations were performed, either by just adding DI water, or augmenting these sediments with either a medium containing NH_4^+ or a medium containing Fe(III) and NH_4^+. While A6 was either barely detectable or not detectable in the initial sediments, after 40 days of incubation, especially in the Fe(III) and NH_4^+ amended incubations, it became detectable, and the production of F- was observed. Incubations amended with PFOA or with PFOS did show a decrease in their concentrations during the incubations, as well as F- production. Based on these results, column experiments were conducted with sediments from Oceana and Lakehurst, which had the highest and lowest Fe(III) levels, respectively, of the sediments studies. The same treatment as for the batch incubations were applied, but Fe(III) was treated with polyacrylic acids to make it transportable in the soil columns. After Fe(III) breakthrough, columns were allowed to rest for 40 days, after which pumping was restarted. Effluent, especially for the columns with added Fe(III) showed significant decrease in NH_4^+ and F- production, as well as decrease in PFOS, indicating that biostimulation at these sites might be feasible, although the effect of many environmental factors (i.e., much lower soil/groundwater temperature than in the laboratory, different redox conditions, more complex microbial communities, etc.) would have to be investigated first.