2027

Task 1: Preview – Minor changes will be made in the Final Draft to items in blue italic type.

Resilient Water Supplies: PFAS Removal using Biological Materials

Task Sponsored by: Freeport-McMoRan

Task developed by: Freeport-McMoRan, USDA Agricultural Research Service (ARS), Los Alamos Technical Associates (LATA), UTHealth Houston

Introduction

Teams will explore practical, affordable approaches for removing PFAS from contaminated groundwater at a well in Alamogordo, NM. Although several accepted PFAS treatment technologies are currently available, each has significant limitations. Some are simple and inexpensive, but they only remove long-chain PFAS compounds efficiently. Others can remove both long-and short-chain PFAS, but media regeneration and disposal are problematic. Still others are effective at both, but are prohibitively expensive for many small, rural communities. To address these issues, researchers are now exploring biological materials as the next frontier in PFAS-removal, seeing the potential to provide sustainable, cost-effective removal solutions, particularly for short-chain molecules.

Problem Statement

Your team is invited to design a full-scale innovative treatment system to remove PFAS from contaminated water using biologically derived materials. The water retrieved from BGNDRF wells in Alamogordo, NM will be provided to your team in two forms: 1) raw well water and 2) RO concentrate. The composition of the water will be similar to that shown in Tables 1 and A-1.

The selected biological material(s) may be: 1) living or formerly-living (such as microbe, plant, animal derivative, or fungi); 2) modified to improve PFAS uptake; 3) used individually or in combination; and 4) incorporated at any stage of the treatment system.

Your design should develop a PFAS-removal system that:

- Is capable of removing both short- and long-chain PFAS compounds, but prioritizes the removal of short-chain molecules, such as PFBA and PFBS.
- Proposes system conditions and operating variables that optimize PFAS removal by the selected material(s). See suggested list of research variables below.
- Performs effectively in the presence of co-contaminants in the well water
- Is technically, economically, and operationally feasible
- Produces minimal PFAS-laden residuals or waste
- Maximizes media capacity and minimizes breakthrough potential
- Minimizes retention time while maximizing treatment rates
- Optionally considers media regeneration and reuse.

Research variables to consider:

- Type of biomaterial(s) used
- Competing-ion effects (anion interference)
- pH
- Pre-treatment methods
- Other variables, as determined by your team.

Background

Per- and **P**oly**f**luoro**a**lkyl **s**ubstances (PFAS), commonly known as "forever chemicals," contaminate water supplies across the U.S. and around the world, and they are difficult to destroy. They accumulate in the human body, and exposure has been associated with several adverse health outcomes [1].

While larger municipalities often have the resources to install advanced PFAS remediation systems, many small, rural communities face significant financial and technical barriers to addressing PFAS contamination. In some cases, contamination has had severe economic consequences for agricultural operations, including farm closures and the loss of livestock. Consequently, there is a need for cost-effective treatments that can help small communities, farmers, and ranchers address PFAS contamination in groundwater and irrigation water.

PFAS remediation research currently implements multi-stage technologies: upstream removal, optional midstream concentration, and downstream destruction. This task focuses on the removal stage of the treatment process.

PFAS Overview

PFAS removal and destruction has been a growing global concern for the last decade because the compounds have been linked to adverse health effects in humans including decreased fertility and high blood pressure in pregnant women, childhood developmental delays including low birth rate, accelerated puberty, bone variations, and behavioral changes; Increased risk of prostate, kidney, and testicular cancer; reduced immunity to infections and reduced vaccine response; natural hormone interference; and risk of obesity and elevated cholesterol levels [1].

The compounds have been widely used in products such as firefighting foams, water-repellent fabrics, non-stick cookware, polishes, waxes, and paints because of their exceptional heat, stain, and water resistance. Their strong carbon-fluorine (C-F) bond – one of the strongest known chemical bonds – is responsible for these highly valued properties. However, because of this stable bond, PFAS compounds are extremely resistant to degradation and can persist in the environment for decades. In fact, breaking the bonds requires temperatures of ≥ 1000^{o}C.

PFAS contamination is often found in proximity to manufacturing and processing plants, landfills, wastewater treatment facilities, and firefighting training sites. PFAS have been detected in groundwater, landfill leachate, surface waters, and even the atmosphere, allowing them to travel long distances from their source.

Once released into the environment, the compounds can accumulate in soils and be taken up by plants, including edible crops, raising concerns about food safety and environmental health. However, the observed uptake of PFAS by plants also presents an opportunity to investigate plant-based remediation strategies.

Long- and Short-Chain PFAS Compounds: PFOS, PFOA, PFBS, and PFBA

There are well over 4,500 known PFAS compounds, but they share several common molecular characteristics. Many of their properties, such as persistence, water solubility, mobility in groundwater, soil or plant adsorption, bioaccumulation potential, etc., can be linked to three key molecular features:

1. Chain length
2. Number of C-F bonds
3. Type of functional group attached to the chain.

PFAS properties are strongly influenced by their chain length because of their amphiphilic nature, meaning they exhibit opposing properties in their “head” and “tail” regions. The C-F chain (the tail) is hydrophobic, and the head is a hydrophilic functional group. The functional group varies according to the PFAS compound. It, in addition to chain length, influences a compound’s chemical behavior and environmental fate.

Long- and short- chain PFAS are distinguished primarily by the number of C atoms in the molecule. The most studied forever compounds are long-chain PFOA and PFOS:

- PFOA (perfluorooctanoic acid)
- PFOS (perfluorooctane sulfonate)

Both are considered long-chain molecules due to their 8-carbon chain (referred to as "C-8"), but they differ in their functional side groups. Note that both compounds have the root word, "octa", referring to the eight carbon atoms in the molecules (Fig. 1).

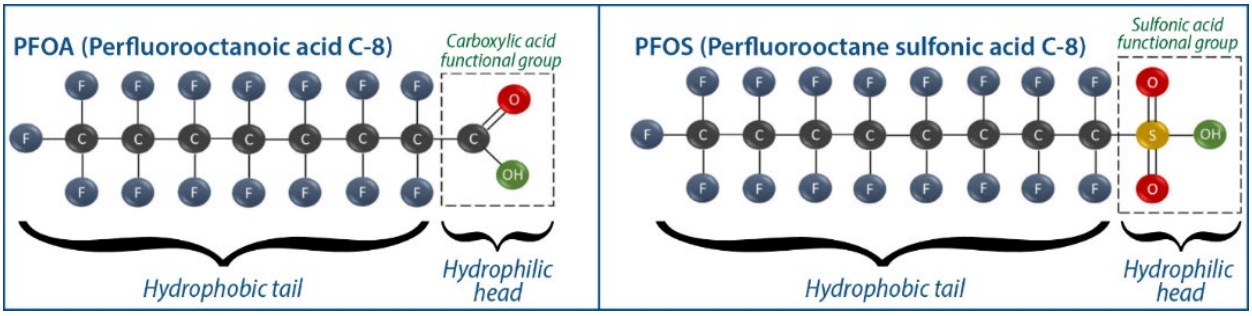

Fig. 1. Hydrophobic and hydrophilic regions of long-chain PFOA and PFOS compounds. In both molecules, the hydrophobic tail is comprised of 8 fully fluorinated carbon atoms (C-8). *Modified from Panieri et al. 2022* [2].

The longer the PFAS chain, the higher the hydrophobicity of the molecule. Therefore, long-chain PFAS molecules, such as PFOS and PFOA, have stronger hydrophobic properties, while short-chain PFAS are more hydrophilic. These tendencies become important as we explore remediation strategies.

Short-chain molecules were introduced as replacements for longer-chain compounds, with the assumption that they would be eliminated from the body more readily, thus reducing bioaccumulation and toxicity. However, being more hydrophilic, they are more water-soluble. This results in more efficient accumulation in plants and human tissue and also allows them to travel farther through ground and surface waters.

Two key short-chain molecules of interest are shown in Fig. 2. Note their structural similarities to the longer-chain compounds in Fig. 1. These are:

- PFBS (perfluorobutane sulfonic acid), a 4-C molecule with a sulfonic acid functional group
- PFBA (perfluorobutanoic acid), a 4-C molecule with a carboxylic acid functional group

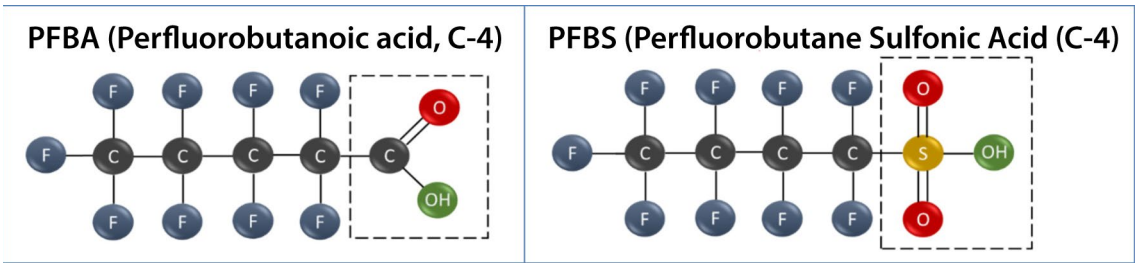

Fig. 2. Molecular structures of two short-chain PFAS compounds, PFBA and PFBS. PFBA has a carboxylic acid functional side group, similar to PFOA, and PFBS has a sulfonic side group, similar to PFOS. *Adapted from Panieri et al. 2022* [2].

EPA Regulations

The US EPA determined that 176 million Americans have drinking water contaminated with perfluorinated compounds in both municipal and rural drinking water systems. In April 2024, they released their *Final PFAS National Primary Drinking Water Regulation* (NPDWR), establishing the first national drinking water standards for PFAS. The regulation sets enforceable Maximum Contaminant Levels (MCLs) of 4.0 parts per trillion (ppt) for PFOS and PFOA. Although the original deadline for compliance was April 2029, it has been extended to 2031. This allows communities additional time to identify affordable treatment options [3, 4].

While this task does not focus directly on drinking water standards, the 4.0 ppt threshold is an important benchmark. It is an extremely low concentration and expensive to measure in the laboratory. These challenges make PFAS removal (and the study of its removal) both technically demanding and costly. A valuable first step in providing affordable means of achieving EPA's drinking water standards is identifying lower cost treatment trains.

PFAS Contamination Across the US

The Environmental Working Group (EWG) posts an online interactive map of PFAS Contamination across the US and around the world [5]. Their map shows higher PFAS levels in areas with greater population densities and extensive agricultural activity, but this may partly reflect sampling bias, as monitoring is often focused where highest PFAS concentrations are expected. The EWG map, current as of March 2026, is shown in Fig. 3. Sites discussed in this document (Songbird Farm, Stoneridge Farm, and the Brackish Water National Desalination Research Facility (BGNDRF[1]) were added to the map. BGNDRF will be the source of PFAS-contaminated water used in this design challenge.

[1]*Pronounced locally as "BIG - en – dorf" or "BERG - en – dorf" (The "R" is interjected by many to reflect the "R" in "BRackish.")*

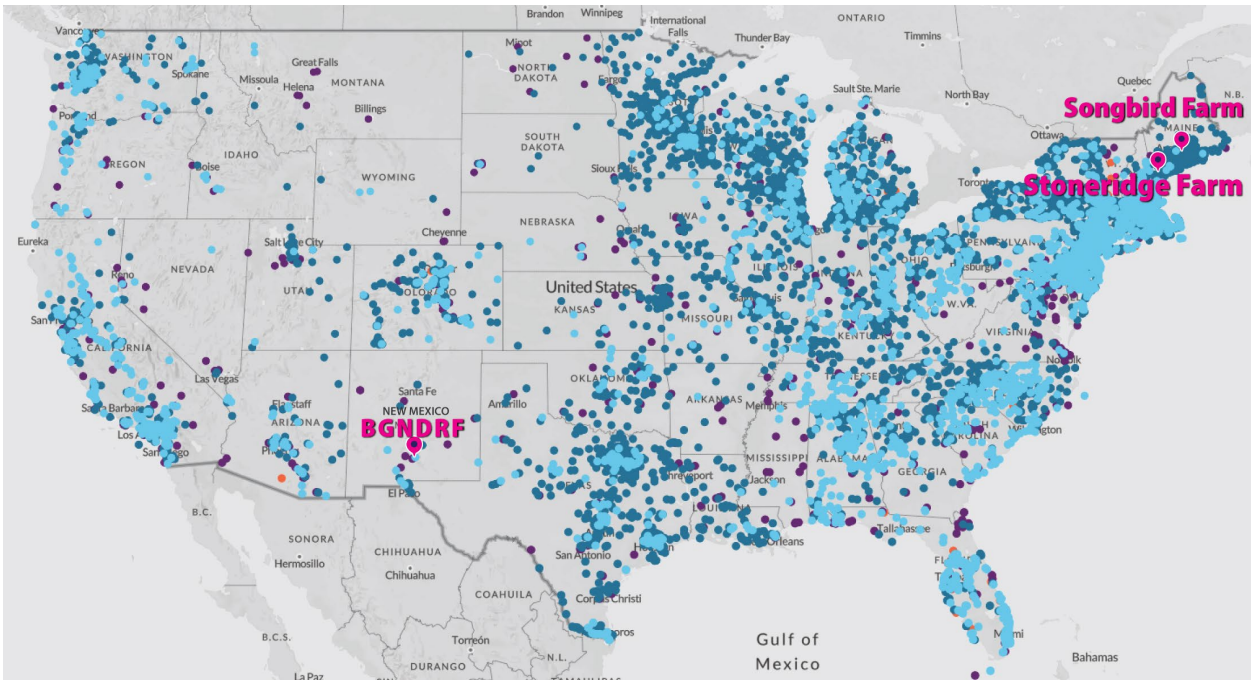

Fig. 3. EWG Interactive map of US PFAS data compared with the EPA MCL [5]. Key to locators: 1) Light blue – above EPA MCL; 2) Dark blue – below EPA MCL; 3) Purple – Military sites; 4) Red – other known sites where PFAS was found but not measured against drinking water standards. These can be industrial plants, landfills, or fire-fighting training sites.
Map modified from [5] to locate BGNDRF, Songbird Farm, and Stoneridge Farm, which are discussed later in this document.

Since 2016, when PFAS monitoring became more widespread, PFAS contamination has imposed significant financial burden on many farmers and ranchers across the US. Farmers have been forced to cease operations, and cattle ranchers have had to destroy contaminated livestock, in some cases numbering in the thousands.

For example, in Arundel, Maine, extremely high levels of PFAS were discovered in the water (50 ppt), soil, and cows' milk at *Stoneridge Farms* (labeled in Fig. 3). Its source dates back to 1983, when owner Frank Stone, a third-generation dairy farmer, and other farmers across the state, were encouraged improve their clay soils with free sludge from paper mills and wastewater treatment plants, but that sludge contained PFAS. Spreading it on the land for over 30 years resulted in an extremely high PFAS accumulation. As a result, Mr. Stone had to destroy 130 dairy cattle – a devastating loss, since each producing cow is valued at more than $3,000. Despite several remediation efforts, he has not yet reduced PFOS levels in the milk to permitted limits, and has lost his livelihood [6, 7].

About 100 miles NE of Arundel, Songbird Farm in Unity, Maine (labeled in Fig. 3), a small family-owned organic farm opened in 2014, voluntarily tested its soil, spinach crop, and groundwater in 2021 and found elevated PFAS levels in all three, as well as high levels in their bodies. Groundwater concentrations measured 8,000 ppt, while soil concentrations reached 390 ppb. State investigators determined that the contamination originated from biosludge solids applied to the land by the previous farm owner. At these high levels, the farm was shut down [8, 9]. With more than 90 of Maine's 7,000 farms and ranches affected by PFAS contamination, the state established $3 million in grants to support PFAS remediation research [10].

These two examples of PFAS contamination stemmed from using biosolids from wastewater treatment plants and paper mills to enrich the soil, but other farmers have lost their livelihoods due to other sources. For example, in Clovis, NM, owner of Highland Dairy, was required to euthanize 3,665 dairy cows, costing him an estimated revenue loss and increased expenses of $5,946,462 [11]. The source was the use of fire-fighting foams at Cannon Air Force Base, located 7 miles from the farm. In 2018, two wells on his property contained PFAS concentrations of 671 ppt and 1,649 ppt. The cows' milk was measured at up to 1,620 ppt PFAS [12].

Established PFAS Treatment Technologies

This design challenge highlights two short-chain compounds (PFBS and PFBA) and two long-chain compounds (PFOS and PFOA), all of which are commonly found in the environment. Note that PFOS and PFOA are no longer produced in the US, but they are expected to affect water and soils for decades.

Removal strategies for PFOS and PFOA have been studied extensively, and have demonstrated effectiveness in removing PFAS from water. However, each has limitations. The key characteristics, advantages, and drawbacks of these treatment approaches are summarized in Table 2 [13, 14].

Published results for conventional PFAS treatment technologies can provide a useful basis for evaluating your team's solution. However, exercise caution, as some reported removal efficiencies were measured using only PFAS and deionized water, rather than real-world water sources. Water chemistry in the BGNDRF wells is complex and may affect treatment performance and media life.

As shown in Table 2, no current treatment technology is ideal. GAC is a simple treatment that, due to its hydrophobic character, is highly efficient at adsorbing long-chain PFAS, but it has limited success on short-chain PFAS compounds. In addition, the presence of organic matter significantly reduces GAC's adsorption efficiencies. Ion exchange addresses these limitations, but the resins are difficult to regenerate. Therefore, they are usually treated as PFAS-laden waste, requiring stringent disposal methods [15]. Membrane technologies, such as RO and nanofiltration, are highly effective, but are often cost-prohibitive due to high capital costs, energy requirements, and membrane fouling issues [13].

Table 2. Primary PFAS Treatment Technologies

Method	Removal efficiency	Regeneration	Drawbacks
GAC	Up to 99% Selective: Effective for long-chain compounds, but not short-chains.	Yes, via thermal processes	• Stronger hydrophobic character, therefore, less effective at adsorbing short-chain compounds. • Organics and other constituents in the water can reduce removal efficiency.
Ion Exchange Resins	• Up to 99%; More effective than GAC in the presence of organics. • Effect on long- and short-chain PFAS is dependent on the hydrophobicity of the resin's functional group.	Not usually	• Regeneration requires a large amount of regenerant and produces PFAS-contaminated wastewater. • Disposal: landfills or incineration. Both risk environmental contamination in groundwater or air, respectively.
Membranes: Reverse Osmosis (RO); Nanofiltration	• Up to 99%; • Removes both long and short chains with comparable effectiveness.		• High capital costs; • High energy consumption; • Susceptible to scaling and organic fouling. • PFAS-heavy wastewater concentrate

Additional removal technologies, along with their potential drawbacks, include [13]:

- ***Electrooxidation.*** Drawbacks: technical scalability, long residence times, high energy consumption, electrode maintenance, low efficiency for short-chain compounds, and potential for incomplete defluorination resulting in the production of short-chain compounds.
- ***Photocatalysis.*** Drawbacks: long residence times, high-energy consumption, the need for highly efficient catalysts, challenges maintaining consistent UV light penetration, and the risk of catalyst fouling.
- ***Advanced oxidation and reduction processes.*** Drawbacks: may require long residence times, an anoxic environment, and high pH.

Sulfonates vs. Carboxylates: Factors Affecting PFAS Removal

This design challenge requires teams to investigate key variables that influence PFAS removal using biological materials. Most PFAS compounds have either a sulfonate or a carboxylate head group. In typical environmental pH ranges, both groups lose a hydrogen ion and carry a negative charge. However, their structural and chemical differences significantly alter how they might interact with biological filters.

Sulfonates generally exhibit stronger sorption to removal media than the comparable carboxylates. Their exceptionally low pK_a values (acid dissociation constant—a measure of how readily a compound will release a hydrogen ion, H+) indicate extreme acidity, meaning they remain almost completely deprotonated in water and carry a persistent negative charge. As a result, electrostatic interactions play a primary role in their removal. Hydrophobic interactions (due to the fluorinated tail) can further enhance sorption. Together, these mechanisms often result in stronger binding and longer retention on treatment media than for carboxylates. Sulfonates tend to dominate the adsorption sites and require more aggressive regeneration techniques (carefully selected chemical flush chemistry and processes).

Carboxylates are less acidic than sulfonates, due to their higher pK_a values. Thus, they tend to exhibit weaker interactions with PFAS removal media and may break through more quickly. While electrostatic interactions are important in carboxylates, hydrophobic interactions tend to have more influence on their adsorption. In addition, their charged functional group attracts surrounding water molecules, forming a water barrier (often called a hydration shell) around the molecule. This hydration shell can reduce direct contact between the molecule and the adsorption media and may affect filter bed size, media regeneration, and/or replacement frequency.

Optimizing PFAS Removal Using Biological Materials: Variables to Consider

To optimize the removal of PFAS compounds, teams will experiment with variables that can significantly affect a system's success. As it is not possible to test every variable and media type, teams may wish to implement predictive methods or other advanced decision-support tools for screening PFAS-removal technologies [16].

Potential variables, based on observations across established PFAS treatment technologies, are listed below. While not a comprehensive list, they highlight basic principles that may affect biologically based treatments.

Replacement effects: Research suggests that long-chain PFAS may displace previously adsorbed short-chain molecules from their adsorption sites. Long-chain molecules also have a greater tendency to form micelles which can enhance their sorption behavior [17].

Competing-ion effects: Dissolved ions can influence PFAS adsorption by either enhancing or inhibiting their removal. For example, PFOA and PFOS typically exist as negatively charged anions in water. As a result, other anions, including sulfate (SO42-) and chloride (Cl-) may compete for adsorption sites and reduce PFAS uptake [17]. On the other hand, cations such as Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} can promote PFAS adsorption onto some sorbent materials by reducing the electrostatic repulsion between the PFAS molecules and the media [18].

Organic Matter: Organic matter may reduce PFAS removal by competing for adsorption sites. In addition, larger organic molecules can physically block pores and adsorption sites within the removal media; this also reduces treatment efficiencies.

pH: Solution pH can significantly affect PFAS removal because changes in pH alter the surface charge of the treatment media, the ionization of functional groups, and the interactions between PFAS and adsorption sites. Studies have shown that both acidic and alkaline conditions can influence removal performance, depending on the treatment technology and water chemistry.

Evaluating PFAS Removal

When building, testing, or sampling from the bench-scale prototype, take care to avoid background PFAS contamination that could negatively affect your removal results. (See Appendix B and *Bench-scale Demonstration*)

PFAS removal effectiveness can be evaluated through:

- ***Removal Efficiency (%)***: Determined relative to the initial PFAS concentration:
  [(Initial - Final)/Initial] *100
- ***Hydraulic Retention Times:*** The average time water remains in the treatment system. Longer HRT increases contact between PFAS and the treatment media. A balance must be struck between removal efficiency and required flow rates of the overall system.
- ***Breakthrough Curves:*** Breakthrough indicates the point at which the influent bypasses the removal media and "breaks through" to the effluent. This occurs when a large majority of the binding sites are already occupied, and the media can no longer remove more PFAS. To extend media life, breakthrough should be minimized. Breakthrough curves plot the transition from complete removal through the point at which the solute first appears in the effluent solution (breakthrough).
- ***Treatment Residuals:*** Describe and quantify PFAS-enriched waste, spent media, biomass disposal, regeneration solutions, or other residuals as applicable to your project.
- ***Mass-loading Capacity:*** Total mass of PFAS removed per unit volume (or mass) of the treatment media.
- ***Regeneration Processes*** (*optional*): Your team may propose steps for regenerating the treatment media.

PFAS detection and quantification are guided by various EPA methods. They are analyzed using mass spectrometry (MS) to conduct targeted analysis, meaning that only analytes on the targeted list are measured. At the contest, WERC will employ EPA Method 537 Modified Isotope Dilution [19]—an LC/MS/MS process— to measure PFAS concentrations before and after your system's treatment process. This method requires specialized equipment that may be available on your campus. Due to analytical costs, teams may wish to limit the number of samples analyzed through this method. WERC and the *XXX* lab in El Paso, TX will offer analytical testing once in late February 2027, and again at the contest in April 2027. (See Bench-Scale Demonstration, below.)

As an inexpensive and more accessible screening method, EPA Method 1621, Absorbable Organic Fluorine (AOF) was developed to identify potential PFAS contaminants. AOF implements combustible ion chromatography to detect PFAS-related fluorine. It can be used to estimate removal efficiencies by comparing samples before and after PFAS removal. It is not as comprehensive as LC/MS/MS because it only estimates the amount of organic fluorine in a sample that is adsorbable, rather than quantifying specific targeted analytes [20, 21]. However, if this equipment is available on your campus, it is an effective screening tool.

PFAS Disposal

Once removed from water, soil, air, or other environmental media, PFAS-containing residuals are typically managed through one of three approaches: injection into permitted Class I industrial or hazardous waste injection wells, disposal in permitted RCRA Subtitle C hazardous waste landfills, or destruction in permitted hazardous waste incinerators. Although these methods are currently being implemented, each remains an active area of research due to concerns about the potential release of PFAS [22, 23]. In particular, incineration, a standard method for disposing of various waste streams, has been found to result in incomplete destruction, at times transforming long-chain PFAS into short-chain PFAS and other fluorinated byproducts. These compounds are sometimes released to the atmosphere, where they can travel long distances [24].

Biological Materials: Emerging Opportunities in PFAS Remediation

Despite advances in PFAS treatment, current technologies still face challenges with energy consumption, selectivity, regeneration, scalability, and waste management. As a result, researchers are investigating biologically derived materials as a more sustainable "green chemistry" approach to PFAS remediation. Natural polymers such as aquatic plants, cellulose, starches, dextrin, biochar, and other biomaterials have demonstrated potential for PFAS removal, while offering opportunities to reduce treatment costs and environmental impacts [13, 25].

Task 3 PFAS Sampling Site: BGNDRF Facility

To address this challenge, teams will be provided with PFAS-contaminated groundwater from the US Bureau of Reclamation's Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM (labeled in Fig. 3). As the nation's only major US research facility dedicated to brackish water desalination, BGNDRF hosts researchers investigating the treatment of saline groundwater, water produced by oil and gas operations, and post-treatment reject concentrates. (Brackish water is moderately saline water having a salt concentration between that of freshwater and seawater—between 1,000 and 10,000 mg/L of total dissolved solids (TDS)).

The research conducted at the facility is crucial to water security in arid regions, where decades of groundwater pumping have led to increasingly saline water being extracted from deeper aquifers [26].

The facility was established in Alamogordo because of the area's abundant brackish groundwater resources. BGNDRF now has four brackish groundwater wells and maintains onsite evaporation ponds for research activities and concentrate disposal [27]. In addition to its groundwater resources, the site's abundant sunshine supports solar-powered research operations.

PFAS was first detected in one of BGNDRF's evaporation ponds in 2017. In 2019, it was identified in Wells 2 and 4, with Well 2 exhibiting the highest concentrations. As a result, the facility has relied solely on Wells 1 and 3 for research, significantly limiting their operations. Although the source of PFAS at BGNDRF has not been pinpointed, two nearby potential sources of PFAS have been identified: Holloman Air Force Base (firefighting foams) and a former factory that produced Teflon-coated cookware (Fig. 4).

Because many researchers at BGNDRF develop water treatment technologies for rural and Tribal communities in arid regions, restoring the facility's full research capacity will strengthen efforts to advance desalination and water reuse technologies for water-stressed regions. However, PFAS remediation is costly. In 2023, the US President's *Investing in America* agenda announced a $12.6 million project to construct an advanced PFAS treatment facility to restore access to Wells 2 and 4 and reduce the load on Wells 1 and 3 [26].

BGNDRF will provide water from the two wells, along with RO concentrate generated from them, for use in WERC's bench-scale demonstrations. The concentrate allows teams to evaluate their designs at higher PFAS concentrations than those found in the raw groundwater. (Table A-1 compares PFAS levels for raw and concentrated water.) BGNDRF is an ideal location for this task because PFAS levels in Wells 2 and 4 remain elevated, and the facility is located only 60 miles from the contest venue in Las Cruces, NM.

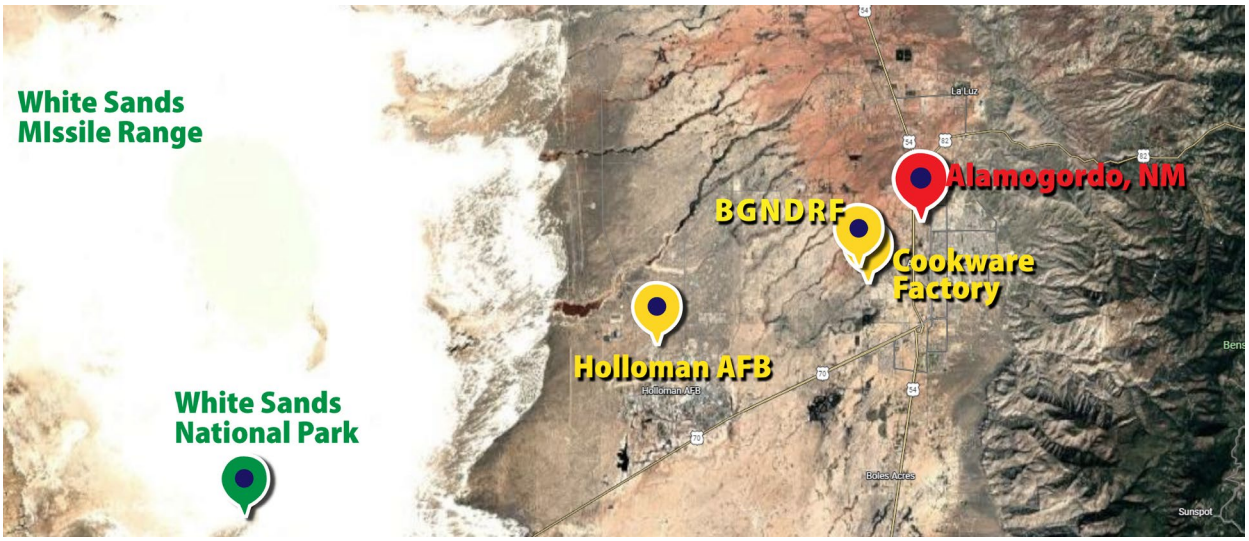

Fig. 4. Google Earth Map of Alamogordo, NM area, showing locations of BGNDRF, the former cookware manufacturing facility, and Holloman Air Force Base. Although both the manufacturing facility and the air force base have the potential to have released PFAS compounds into the groundwater, neither has been definitively identified as the source of the contamination. As a side note, WERC teams enjoy visiting White Sands National Monument. This figure illustrates BGNDRF's proximity to White Sands, and the vast extent of the gypsum dune fields.

BGNDRF has identified approximately 40 analytes from Wells 2 and 4, including PFBA, PFBS, PFOA, and PFOS. Typical concentrations for the four target compounds are listed in Table 1, and the complete analyte list is provided in Table A-1. WERC will collect and ship fresh samples from Well 2 and/or 4 to each registered team in Spring 2027 and will provide new fresh samples at the April contest. Both sample sets will be analyzed; constituent concentrations will be reported to your team when the water is distributed. Based on years of data, BGNDRF expects the fresh samples to be very similar to those in Tables 1 and A-1.

Table 1. Typical PFAS concentrations of PFBA, PFBS, PFOA, and PFOS found in BGNDRF Well #2. Concentrations of each analyte were measured using EPA Method 537. See Table A-1 for complete list of analytes. *Concentrate information TBD*

Analyte	Acronym	PFAS Concentration of Raw Well Water Using EPA Method 537 (ng/mL)	PFAS Concentration of RO Concentrate Using EPA Method 537 (ng/mL)
Perfluorobutanoic acid	PFBA	9.8	*TBD*
Perfluorobutanesulfonic acid	PFBS	3.5	*TBD*
Perfluorooctanoic acid	PFOA	270	*TBD*
Perfluorooctanesulfonic acid	PFOS	22	*TBD*

Task 3 Goals

The primary goal of this challenge is to develop a biologically based treatment system that effectively removes short-chain PFAS compounds, specifically PFBA and PFBS. The system should achieve high removal efficiency while accommodating expected flow rates and minimizing PFAS residuals, maintenance, operational complexity, and capital and operating costs (CAPEX and OPEX). Ideally, the design will also demonstrate effective removal of long-chain molecules (PFOS and PFOA), but this is a secondary consideration, because GAC is already an established, simple, and cost-effective technology for removing long-chain PFAS.

To optimize PFAS removal, evaluate factors such as biomaterials selection, competing-ion effects, pH, pre-treatments, and other relevant conditions. The system should perform effectively in the presence of the co-contaminants found in Wells 2 and 4 (Appendix A) while maximizing media capacity, delaying breakthrough, and extending system life. Optionally, teams may investigate regeneration and reuse of the treatment media.

Teams may implement real-time monitoring, predictive modelling, artificial intelligence, machine learning, automation, or other advanced decision-support tools to screen for operating conditions that maximize PFAS removal.

Design Requirements

Your proposed design should answer the Problem Statement given on page 1 and provide specific details and outcomes as follows:

- Develop an innovative and cost-effective PFAS removal system implementing biological materials to reduce concentrations of PFBA, PFBS, PFOA, and PFOS found in groundwater extracted from Well 2 (and/or Well 4) at the BGNDRF facility. Prioritize short-chain removal (PFBA and PFBS), with a secondary focus on removing long-chain compounds (PFOA and PFOS). The ideal solution will be successful for all four compounds.
- Review the literature for previous PFAS mitigation efforts and develop your own innovative solution.
- Focus on treatments that maximize PFAS removal efficiency and flow rates, optimize hydraulic retention times, and minimize breakthrough, PFAS residuals, cost, maintenance, and operational complexity.
- Consider key variables that will influence your system's effectiveness, including, but not limited to, type of biomaterial(s) used, competing-ion effects (anion interference), pH, pre-treatment methods, etc.
- Include Process Flow Diagrams (PFDs) for the selected PFAS removal process. The PFDs must include mass and energy balances (input and output rates, including waste streams, reactants, reaction rates, etc.).
- Units of measure used in the team's report shall adhere to customary engineering practice (yes, there is some mixing of units, according to the entity that sets the standards):

  - PFAS concentrations shall be reported in EPA's established units (ppt, ppb, within the text and as ng/mL in tables).
  - Flow rates shall be expressed in gallons per minute (gpm), gallons per day (gpd), or million gallons per day (MGD).
  - Breakthrough behavior shall be expressed in ppt/gram (ppt/g) of material in the media.
  - Costs shall be expressed on a cost per year ($/yr) or cost per gallon ($/gal) basis.

- Develop a bench-scale prototype to demonstrate the capabilities of your design. The PFAS removal solution should support long-term operation with minimal maintenance. Validate the prototype's operational feasibility and sustainability through extended bench-scale studies conducted at your institution, and report these in your deliverables. (See *Bench-scale Demonstration*, below).

- Report your system's bench-scale removal characteristics, to include:
  - Flow rates (gpm)
  - Hydraulic retention time (minutes).
  - Influent and effluent concentrations (ppt)
  - Removal efficiency (%)
  - Breakthrough behavior (ppt/g)
  - Waste generated and associated management methods
  - Desorption/regeneration efficiency and reuse ability, if applicable to your project.

- Present a Techno-Economic Analysis (TEA) for implementing your full-scale PFAS mitigation system using water from a groundwater well that operates at flow rates averaging 700 gpm (equivalent to 1 MGD under continuous 24-hour operation). Report all costs for a full-scale operation on an annual basis ($/yr) and the cost per gallon of treated water ($/gal).

  Include your estimate of capital costs (CAPEX) and operational costs (OPEX) for a full-scale solution and appropriate graphical representation of your cost data.

  - Capital expenses typically include, but are not limited to, equipment, pipes, pumps, etc. Do not include costs of buildings, site improvements, or other infrastructure not directly associated with the treatment process.
  - Operating expenses (OPEX) should include, but not be limited to, materials needed, including consumables (chemicals, sacrificial components, liner repair, etc.) In addition to other operating costs your team identifies, include these operating costs:
    - Labor rates: Professional engineer ($150/hr), operator ($70/hour).
    - Disposal costs: Refer to EPA Interim Guidance [28] for estimated incineration, landfill, and injection-well disposal costs. Include the cost of hauling the residuals to BGNDRF's nearest disposal site.
    - Energy costs: research an industrial natural gas rate and state in $/MM BTU; an electricity rate of $0.09/kWh. Include additional operating costs your team identifies.
    - Compare the OPEX on annual basis ($/yr) and $/gal to that of GAC for a comparable water chemistry (*this data may be provided by BGNDRF – Watch FAQs for details*).
  - Visualization tools: Use sensitivity analyses, graphs, and other visuals to illustrate how key parameters impact system performance and economics.

- Include a public involvement plan, as applicable (see *Team Manual*).
- Report the use of AI, machine learning, predictive modeling, automation, or other decision-support tools, and describe how the tools were used. These resources may be used only to support the team's independent engineering research, analysis, calculations, assumptions, and conclusions. Teams remain fully responsible for verifying all information, performing the underlying engineering analysis, and defending their design decisions based on their own work.
- Reflect on alternative designs and the conditions under which they may be preferable to your design, recognizing that the optimal solution may vary by region, application, and changing circumstances.

- Address any intangible benefits of the selected treatment process.
- Address safety aspects of handling the water, volatiles, waste streams, and any final products at all relevant points in your treatment system. These issues should be addressed:
  - for both the full-scale design and the bench-scale demonstration
  - In both the written report and the Experimental Safety Plan (ESP)
- To qualify for the P2 (Pollution Prevention) Award, document your project's success in improving energy efficiency, pollution prevention, and/or waste minimization. Place this in a separate "Pollution Prevention" section of the report.

Bench Scale Demonstration

Teams shall design and construct a working bench-scale system to illustrate the requirements of the Problem Statement (p. 1) and the Design Requirements listed above. When designing the prototype, keep in mind that the contest is held at a banquet facility. You will have access to 120V power, but no typical lab resources (e.g., no fume hoods, ovens, etc.).

At the contest, WERC will manage water distribution and post-treatment sample collection. Due to contest constraints, your bench-scale prototype can run from 10 am on Monday to 2 pm on Tuesday, but any overnight operations must be approved in the ESP. On Tuesday, 6 April, WERC will collect your team's final effluent samples and blanks and submit them to the analytical testing lab for EPA Method 537 analysis.

Teams will be provided with both raw and concentrated samples from BGNDRF's Well 2 (and/or Well 4, as available). 18 liters (5 gallons) of each (raw and concentrate) will be shipped to each team in Spring 2027, and up to 18 liters of each will be provided at the contest in Las Cruces. (You don't need to use a full 18 L. In your 30% Project Review, let us know how much you will need to demonstrate your system at the contest.)

PFAS Handling Considerations

The samples must be handled in accordance with all applicable regulatory and laboratory safety procedures.

In addition, to obtain accurate results from your bench-top prototype, it is imperative that you avoid contaminating your sample with PFAS from outside sources. To minimize sample contamination, follow the PFAS laboratory handling protocols detailed in Appendix B. As a brief overview:

a) ***Do:*** Use stainless steel, silicone, high-density polyethylene (HDPE), and polypropylene in your prototype, sampling equipment, field supplies, and containers. Use new powder-free nitrile gloves each time you handle equipment or samples. Wash your hands frequently, and wear cotton or synthetic fabrics that have been washed at least 6x since new (no fabric softeners or dryer sheets). Follow effluent shipping protocols (e.g., pack in cooler on ice; no "blue ice" packs).

b) ***Don't:*** Use any PFTE (teflon) products, including Teflon tape. Use caution with hoses, as some rubber products contain PFAS. Don't use glass in your system or sample collection, as PFAS tends to adhere to it. Don't use cosmetics, hair care products, insect repellant, or sunscreen (unless PFAS-free) when building, testing, or sampling. Don't wear water-resistant fabrics, such as GoreTex. Don't bring packaged foods into the laboratory, particularly those that have oil- or water-resistant coatings.

c) See Appendix B for additional information.

These are not all-inclusive lists of permitted and prohibited protocols. To ensure that your design is fully credited for its success in removing PFAS compounds, follow all guidelines in Appendix B, its references, and any instructions provided by WERC. Note that, for analytical testing, WERC will require "blanks" along with your treated samples. Blanks are samples submitted for quality control to assess potential background contamination. More details for preparing samples will be provided in Spring 2027 before you ship samples to us in February.

Before the contest:

- Your team will submit the 30% Project Review, build and test the bench-scale prototype, and obtain ESP approval.
- In January 2027, WERC will ship each team 18 L (5 gal) of each: raw water and concentrate from Well 2 (or 4). The water will be tested for PFAS analytes prior to being shipped, and these will be reported to you.
- Your team is responsible for properly disposing of PFAS-contaminated water or materials. If needed, you may ship (or bring in April) these to WERC for disposal.
- In February 2027, your team may opt to ship samples of your effluent (250 mL samples) to WERC for preliminary testing under EPA Method 537. Sample preparation instructions will be provided in Spring 2027.

At the contest your team will provide:

- A working bench-scale prototype that demonstrates your team's full-scale PFAS mitigation system, including all materials and supplies needed to demonstrate the system. Exception: the water will be provided by BGNDRF and WERC will deliver it to the contest venue.

At the contest WERC will provide:

- Basic booth setup, as described in the *Team Manual*
- BGNDRF raw and concentrate water from Well 2 and/or 4, sample-collection bottles, nitrile gloves, safety glasses, and any other items requested by your team in the 30% Project Review.

Contest Analytical Testing Techniques (Guided by WERC and provided free of charge to teams)

WERC will provide each registered team EPA Method 537 LC/MS/MS (Orbitrap) testing for the 40 analytes listed in Table A-1 for the following samples:

1. ***January 2027:*** Raw and concentrate waters from BGNDRF Wells 2 and/or 4 that are shipped to your team.
2. ***February 2027:*** Team-provided effluent and blanks from your team's bench-scale testing.
3. ***April 4, 2027:*** Raw and concentrate waters from BGNDRF Wells 2 and/or 4 provided at the contest.
4. ***April 6, 2027:*** Team-provided effluent and blanks from your team's bench-scale demonstration.

30% Project Review

An important part of preparing your bench-scale demonstration is completing the 30% Project Review. Due in late December, it outlines the general design and functionality of your PFAS removal system, as well as the details for demonstrating and testing your system during the contest in Las Cruces. The 2027 *Team Manual* gives general guidelines for the 30% review. Pay particular attention to preparing a complete Process Flow Diagram (PFD).

Include the following project-specific details:

1. Complete Process Flow Diagram (PFD). The PFD serves as a robust outline of all processes in your treatment system, showing balanced inputs and outputs.
2. Drawing of your bench-scale demonstration setup. The draft should be a 3-D view, drawn to-scale, with dimensions labeled. Drawings that WERC cannot easily interpret will be returned to the team for revisions – help us understand your plans so we can support you!
3. Request the volume of synthetic solution needed at the contest to run your bench-scale demonstration.
4. Pre-contest Testing Plan. Let us know if your team plans to have a preliminary sample analyzed at WERC's analytical testing lab in February 2027.
5. Include any safety considerations for running the demonstration.

Deliverables (See *Team Manual*)

Each team must submit (*in order of submission*):

- 30% Project Review
- Experimental Safety Plan (ESP) and Required Short Course.
- Technical Report—System design, data analysis, full-scale recommendation, and 3 independent audits.
- Flash Pitch—Pitch a product or process to investors, community leaders, or potential funding agencies.
- Oral Presentation—Summary of design and key findings
- Poster Presentation—Visual summary of system and results
- Bench-Scale Demonstration—Working model with measurable performance

Evaluation Criteria

Each year, the WERC Environmental Design Contest and its sponsors award more than $35,000 in cash prizes. Awards include task-specific prizes and overall contest awards. See the Team Manual for details. Read the 2027 Team Manual, as a team, for a comprehensive understanding of the contest evaluation criteria: https://werc.nmsu.edu/team-info/guidelines.html

Judges' evaluation of your entry will include consideration of the following points specific to this task.

- Quality Process Flow Diagram
- Reasonable flow rates and hydraulic retention time
- Removal efficiency
- Breakthrough behavior
- Waste generation and management
- Potential for real-life implementation in an operating well, including effectiveness, expected reliability, and maintainability.
- Cost effectiveness of your solution, compared with other options your team identifies.
- Thoroughness and quality of the economic analysis.
- Originality and innovation represented by the proposed technology.
- Other specific evaluation criteria that may be provided at a later date (watch the FAQs).

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

Today	Email us to reserve a spot for your team and get on the email list for this task. Registration is limited to the first 34 teams.
Weekly	Check FAQs weekly for updates: Task-specific FAQs: 2027 Tasks/Task FAQs General FAQs: WERC General FAQs
Nov. 1 – Dec. 31, 2026	Early Bird Registration (discount applies)
Dec. 31, 2026	30% Project Review Due
Dec. 1, 2026 – March 1, 2027	Mandatory On-demand Course: *Preparing the Experimental Safety Plan*. See WERC's website and Team Manual for information.
February 15, 2027	Final date to register a team.
March 1 – 5, 2027	ESP due to Juanita Miller. Include requests for chemicals, materials, etc.
March 26, 2027	Technical Report due
April 4 – 7, 2027	Contest in Las Cruces

Contacts:

ESP and Safety Officer: Juanita Miller, miljgh@nmsu.edu
All other questions and concerns: Ginger Scarbrough, werc@nmsu.edu

References

[1] U.S. Environmental Protection Agency. Our Current Understanding of the Human Health and Environmental Risks of PFAS. https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas (Accessed 7/4/2026).

[2] Panieri E, Baralic K, Djukic-Cosic D, Buha Djordjevic A, Saso L. PFAS Molecules: A Major Concern for the Human Health and the Environment. *Toxics* 2022. 10(2). 44. https://doi.org/10.3390/toxics10020044 (Accessed 7/21/2026).

[3] U.S. Environmental Protection Agency. Per- and Polyfluoroalkyl Substances (PFAS). Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas (Accessed 7/4/2026).

[4] U.S. Environmental Protection Agency. Proposed PFOA and PFOS Compliance Extension Rule. https://www.epa.gov/sdwa/proposed-pfoa-and-pfos-compliance-extension-rule (Accessed 7/21/2026).

[5] Environmental Working Group. 2026. Mapping the PFAS contamination crisis: New data show 9,728 sites with PFAS in 50 states, the District of Columbia and four territories. https://www.ewg.org/interactive-maps/pfas_contamination/map/ (Accessed 7/21/2026).

[6] Valigra, Lori. Maine was warned about toxins in sludge decades before PFAS crisis began. *The Maine Monitor 2026*. https://themainemonitor.org/maine-warned-toxins-sludge-decades-before-pfas-crisis/ (Accessed 7/21/2026).

[7] The University of Maine: Senator George J. Mitchell Center for Sustainability Solutions. More Information About PFAS. https://umaine.edu/mitchellcenter/pfas-research-initiative/more-information-about-pfas/ (Accessed 7/21/2026).

[8] Defend Our Health. Testimony of Adam Nordell – Defend Our Health / Songbird Farm in Support of LD 132 "An Act to Require Health Insurance Carriers to Provide Coverage for Blood testing for Perfluoroalkyl and Polyfluoroalkyl Substances" https://legislature.maine.gov/testimony/resources/HCIFS20230328Nordell133240769978376596.pdf (Accessed 7/21/2026).

[9] Maine Department of Agriculture, Conservation and Forestry. Maine PFAS Fund Closes on Acquisition of Second Impacted Farm Property. https://www.maine.gov/dacf/about/news/news.shtml?id=13350672 (Accessed 7/21/2026).

[10] Maine Department of Agriculture, Conservation and Forestry. Maine Awards $3 Million to Advance PFAS Solutions for Farmers. May 2026. https://www.maine.gov/dacf/about/news/news.shtml?id=13350581 (Accessed 7/14/2026).

[11] State of New Mexico Environment Department. New Mexico assists Clovis family dairy farm with PFAS contamination: State seeking information to guide next steps on hazardous waste disposal of PFAS-laden carcasses. https://www.env.nm.gov/wp-content/uploads/2022/05/2022-05-19-COMMS-New-Mexico-assists-Clovis-family-dairy-farm-with-PFAS-contamination-Final.pdf (Accessed 7/14/2026).

[12] The National Agricultural Law Center. Spilled Milk: Dairy operation sues over alleged chemical damages. https://nationalaglawcenter.org/spilled-milk-dairy-operation-sues-over-alleged-chemical-damages/ (Accessed 7/14/2026).

[13] Davyd Urbanas, Edita Baltrėnaitė-Gedienė. A critical review of the methods being proposed to solve the PFAS problem in drinking water: Are they practically applicable in the real world? *Emerging Contaminants* 2025. 11(4). 100563. https://doi.org/10.1016/j.emcon.2025.100563 (Accessed 7/4/2026).

[14] Gill, D., & El Hanandeh, A. Review of the Effectiveness of Current Water Treatment Technologies for PFAS Removal. *Water* 2026. 18(13). 1653. https://doi.org/10.3390/w18131653 (Accessed 7/21/2026).

[15] Fuhar Dixit, Rahul Dutta, Benoit Barbeau, Pierre Berube, Madjid Mohseni. PFAS removal by ion exchange resins: A review. *Chemosphere* 2021. Volume 272. 129777. https://doi.org/10.1016/j.chemosphere.2021.129777.

[16] U.S. Environmental Protection Agency. Predicting How Effective Water Filters are at Removing a Variety of PFAS. https://www.epa.gov/sciencematters/predicting-how-effective-water-filters-are-removing-variety-pfas (Accessed 7/21/2026)

[17] Yi Zhang, Amanda Thomas, Onur Apul, Arjun K. Venkatesan. Coexisting ions and long-chain per- and polyfluoroalkyl substances (PFAS) inhibit the adsorption of short-chain PFAS by granular activated carbon. *Journal of Hazardous Materials* 2023. Volume 460. https://doi.org/10.1016/j.jhazmat.2023.132378.

[18] Caihong Liu, Xinyi Cheng, Jingjun Bo, Rui Gao, Ye Shen, Yue Zhi, Dan Song, Qiang He. Unraveling the synergistic impact of calcium ions and pH on the rejection of per- and perfluoroalkyl substances by nanofiltration in complex water matrices. *Journal of Hazardous Materials* 2026. Volume 501. https://doi.org/10.1016/j.jhazmat.2025.140666. (Accessed 7/18/2026).

[19] U.S. Environmental Protection Agency. EPA PFAS Drinking Water Laboratory Methods. https://www.epa.gov/pfas/epa-pfas-drinking-water-laboratory-methods (Accessed 7/18/2026).

[20] U.S. Environmental Protection Agency. Method 1621 Determination of Adsorbable Organic Fluorine (AOF) in Aqueous Matrices by Combustion Ion Chromatography (CIC). https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf (Accessed 7/18/2026).

[21] Shoemaker, JA and JL Jones. Development of Adsorbable Organic Fluorine (AOF) Screening Method with Detection by Combustion Ion Chromatography (CIC). https://www.epa.gov/system/files/documents/2021-09/cq1_br1_shoemaker.pdf (Accessed 7/18/2026).

[22] U.S. Environmental Protection Agency. Fact Sheet for the 2026 Interim Guidance on the Destruction and Disposal of PFAS. https://www.epa.gov/pfas/fact-sheet-2026-interim-guidance-destruction-and-disposal-pfas (Accessed 7/18/2026).

[23] Jason Kovacs, Richard Higgins, Nathalie Ionesco, Young Cho. Environmental impact of PFAS incineration. *Waste Management Bulletin* 2025. 3(3). 100202. https://doi.org/10.1016/j.wmb.2025.100202. (Accessed 7/18/2026).

[24] L.J. Winchell, J.J. Ross, M.JM. Wells, X. Fonoll, J.W. Norton Jr, K.Y. Bell. Per-and polyfluoroalkyl substances thermal destruction at water resource recovery facilities: A state of the science review. *Water Environment Research* 2021. 93:826-843. https://pubmed.ncbi.nlm.nih.gov/33190313/ (Accessed 7/24/2026).

[25] Hassan Karimi-Maleh, Zahra Biglari, Hasan Sadeghifar, Maryam Najafi, Saravanan Rajendran, Ali Ayati, Arunachalam Chinnathambi, Elena Niculina Dragoi, Shankramma Kalikeri. Shifting paradigms in PFAS resin removal with biomaterial alternatives. *Journal of the Taiwan Institute of Chemical Engineers* 2025. Volume 166, Part 1. 105300. https://doi.org/10.1016/j.jtice.2023.105300 (Accessed 7/24/2026).

[26] U.S. Department of the Interior. Secretary Haaland Announces $12.6 Million from Bipartisan Infrastructure Law for Desalination Research Facility in Southern New Mexico. https://www.doi.gov/pressreleases/secretary-haaland-announces-126-million-bipartisan-infrastructure-law-desalination (Accessed 7/21/2026).

[27] US Bureau of Reclamation Brackish Groundwater National Desalination Research Facility. About. https://www.usbr.gov/research/bgndrf/water.html (Accessed 7/14/2026).

[28] U.S. Environmental Protection Agency. Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances— 2026 Version. https://www.epa.gov/system/files/documents/2026-04/2026-interim-guidance-on-pfas-destruction-and-disposal.pdf (Accessed 7/24/2026).

[29] Massachusetts Department of Environmental Protection (MassDEP). Field Sampling Guidelines for PFAS Using EPA Method 537 or 537.1 June 2021. https://www.mass.gov/doc/field-sampling-guide-for-pfas/download (Accessed 7/18/2026).

[30] U.S. Environmental Protection Agency. Requirements and Best Practices for the Collection and Analysis of Samples for the PFAS National Primary Drinking Water Regulation. https://www.epa.gov/system/files/documents/2025-06/sampling-for-pfas-npdwr-june25.pdf

[31] EPA Pacific Southwest Region. Directions for PFAS Sample Collection. https://www.epa.gov/system/files/documents/2022-06/r9-tribal-drinking-water-sampling-project-directions-for-pfas-sample-collection.pdf (Accessed 7/24/2026).

[32] Interstate Technology Regulatory Council (ITRC). Sampling Precautions and Laboratory Analytical Methods for Per- and Polyfluoroalkyl Substances (PFAS). https://pfas-1.itrcweb.org/wp-content/uploads/2022/09/Sampling_and_Lab_PFAS_Fact-Sheet_082522_508.pdf (Accessed 7/24/2026).

Appendix A – Preliminary BGNDRF Analytes from BGNDRF Well 2

Official list provided with the Final Task Problem Statement

Note that some PFAS analytes were not present in this sample, and therefore are left blank.
WERC will only be testing for PFBA, PFBS, PFOA, PFOS. Based on the relatively low concentrations of PFBA and PFBS, WERC is also providing RO concentrate from Wells 2 and/or 4.

Taqble A-1 (Preliminary)

Analyte	Acronym	BGNDRF [537]
Perfluorobutanoic acid	**PFBA**	**9.8**
Perfluorobutanesulfonic acid	**PFBS**	**3.5**
Perfluorodecanoic acid	PFDA	0.48
Perfluorododecanoic acid	PFDoA	
Perfluorodecanesulfonic acid	PFDS	
Perfluoro(2-ethoxyethane)sulfonic acid	PFEESA	
Perfluoroheptanoic acid	PFHpA	4.8
Perfluoroheptanesulfonic acid	PFHpS	0.74
Perfluorohexanoic acid	PFHxA	4.2
Perfluorohexanesulfonic acid	PFHxS	9.6
Perfluoro-3-methoxypropanoic acid	PFMPA	
Perfluoro-4-methoxybutanoic acid	PFMBA	
Perfluorononanoic acid	PFNA	1.4
Perfluorononanesulfonic acid	PFNS	
Perfluorooctanoic acid	**PFOA**	**270**
Perfluorooctanesulfonic acid	**PFOS**	**22**
Perfluorooctanesulfonamide	PFOSA	
Perfluoropentanoic acid	PFPeA	3.8
Perfluoropentanesulfonic acid	PFPeS	1.8
Perfluorotetradecanoic acid	PFTA	
Perfluorotridecanoic acid	PFTrDA	
Perfluoroundecanoic acid	PFUnA	

Appendix B – Don't Contaminate Your Samples! Handling PFAS to Minimize Laboratory Contamination

To ensure that the analysis of your PFAS removal system is not contaminated with PFAS during removal treatments or sample collection, stringent protocols must be followed. Four references are recommended as guides [28 - 32], and each reference adds unique insights.

WERC recommends first studying the straightforward chart below from the Massachusetts Department of Environmental Protection (MassDEP) [29]. It summarizes most prohibited and allowable items for laboratory PFAS studies, but note that this is not an all-inclusive guide.

Two references [30, 31] specifically refer to collecting drinking water samples from a faucet or taking field samples. Your team will adapt these guidelines for use in your laboratory.

Category	Prohibited Items	Allowable Items
Pumps and Tubing	Teflon®, polytetrafluoroethylene (PTFE) and other fluoropolymer containing materials	High-density polyethylene (HDPE), low density polyethylene (LDPE) bladders , silicone tubing, or peristaltic pump or stainless steel submersible pump
Decontamination	Decon 90	Alconox® or Liquinox®, potable water followed by deionized rinse
Sample Storage and Preservation	LDPE or glass bottles, PTFE-or Teflon®-lined caps, chemical ice packs, and waterproof labels	Laboratory-provided sample container -preferred; or, polypropylene bottles, regular "wet" ice, bubble wrap, passive diffusion bags, and hydrasleeves
Field Documentation	Waterproof/treated paper or field books, plastic clipboards, spiral bound notebook, Sharpie® and permanent markers	Plain paper, metal clipboard, pens, ZipLoc® resealable plastic storage bags, aluminum foil, Post-It® and other adhesive paper products, water-level tape
Clothing	Clothing or boots made of or with Gore-Tex™ or other synthetic water resistant and/or stain resistant materials including polyethylene fiber suits, Tyvek® material, waterproof boots	Synthetic or cotton material, previously laundered clothing (preferably previously washed greater than six times) without the use of fabric softeners
Personal Care Products (on day of sample collection)	Cosmetics, moisturizers, hand cream, sunscreen, insect repellants and other related products	Sunscreens: Alba Organics Natural, Yes to Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss My Face, Baby-safe sunscreens ('free' or 'natural') Insect Repellents: Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus, Herbal Armor, California Baby Natural Bug Spray, BabyGanics Sunscreen and Insect Repellents: Avon Skin So Soft Bug Guard-SPF 30
Food and Beverage	Pre-packaged food, chemical ice packs, fast food wrappers or containers	Resealable plastic storage bags, aluminum foil, bottled water or hydration drinks

NOTE: Brand names are included for illustration only, and do not imply endorsement of the product.

Fig. B-1. Table of some items that are prohibited and allowed for use during PFAS research and sampling activities. This is not an all-inclusive list. Refer to [28, 30, 31, and 32] for additional details. *Table reproduced from MassDEP* [29].