Task 3: Request for Proposals:

2027

Resilient Water Supplies: PFAS Removal using Biological Materials

Task Sponsored by: Freeport-McMoRan (Platinum) and Los Alamos Technical Associates (LATA) (Iron)

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

Introduction

Freeport-McMoRan (FMI) is inviting your team to develop an innovative, sustainable PFAS removal system using biological materials. While PFAS contamination is not associated with FMI's operations, the company recognizes the importance of advancing solutions to emerging water challenges. Through its sponsorship of this task, FMI is supporting research and innovation that can improve environmental sustainability and benefit communities affected by PFAS contamination, particularly small and under-resourced communities.

Teams will explore practical, affordable approaches for removing PFAS from contaminated groundwater obtained from wells 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 exploring biological materials as a promising approach to PFAS removal, with the potential to provide sustainable, cost-effective treatment, particularly for short-chain PFAS molecules.

Problem Statement

Design an innovative, full-scale treatment system using biologically derived materials to remove PFAS from contaminated water. Test the system using WERC-provided contaminated well water from Well 2 at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM. The wells' composition will be similar to that shown in Table 2 and on the BGNDRF website [28]. Assume the groundwater wells operate at flow rates averaging 700 gpm (1 MGD equivalent under continuous 24-hour operation).

Evaluate the proposed solution using both raw and concentrated BGNDRF well water. The concentrated well water provides higher PFAS concentrations, allowing treatment effectiveness to be more easily measured, particularly for short-chain PFAS that are present in very small amounts in the raw water.

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; and 3) used individually or in combination.

Your design should develop a biologically based PFAS-removal system that:

- Prioritizes the removal of short-chain PFAS compounds, such as PFBA and PFBS. Effective removal of long-chain PFAS compounds will be considered an additional benefit.
- Proposes system conditions and operating variables that optimize PFAS removal
- 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:

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

Background

PFAS Overview

Per- and **P**oly**F**luoro**A**lkyl **S**ubstances (**PFAS**), commonly known as "forever chemicals," comprise a large family of fluorinated chemicals characterized by carbon chains in which some or all of the hydrogen atoms have been replaced by fluorine. The family includes thousands of compounds that vary in molecular size, structure, and functional groups.

PFAS have been used in or associated with the manufacture of products such as firefighting foams, water- and stain-resistant fabrics, non-stick coatings, polishes, waxes, and paints. A defining feature of the general PFAS chemistry is the carbon-fluorine (C–F) bond, one of the strongest bonds in organic chemistry. The strength and stability of these bonds contribute to many useful properties of PFAS-containing materials, including resistance to heat, water, oils, stains, and chemical degradation. However, this same chemical stability makes many PFAS extremely resistant to degradation and allows them to persist in the environment for long periods.

PFAS contamination is often found near 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, where fine particles have traveled 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.

The removal and destruction of PFAS has become a growing global concern because many of these compounds are highly persistent in the environment, and exposure to certain PFAS has been associated with adverse human health effects. These include decreased fertility and high blood pressure in pregnant women; developmental effects in children; increased risk of certain cancers; reduced immune response; hormone interference; and increased risk of obesity and elevated cholesterol levels [1].

While larger municipalities often have the resources to install advanced PFAS remediation systems, many small, rural communities, often sited near industrial areas, 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 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 upstream removal stage of the treatment process, and focuses on relatively small, water-mobile PFAS compounds, including PFOA, PFOS, PFBA, and PFBS.

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.

Effect of PFAS Chain Length on PFAS Characteristics

PFAS properties are strongly influenced by 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, while the head consists of a hydrophilic functional group, therefore, the longer the PFAS chain, the higher the hydrophobicity of the molecule.

Thus, long-chain PFAS such as PFOA and PFOS tend to be more hydrophobic, while shorter-chain PFAS such as PFBA and PFBS are more hydrophilic, making them more water-soluble. These differences strongly influence how PFAS move through the environment and how effectively they can be removed from water.

Long-chain PFAS Molecules

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

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

Both are long-chain, 8-carbon (C-8) molecules, reflected by the root "octa" in their names, but they differ in their functional groups (Fig. 1).

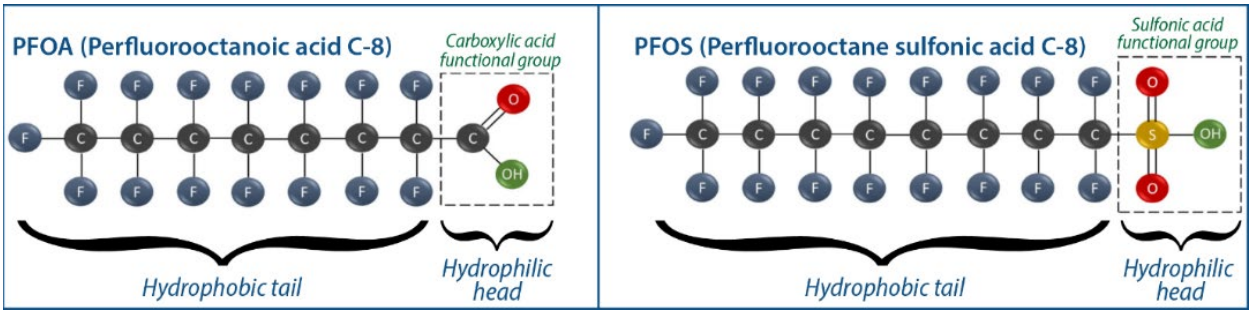

Fig. 1. Hydrophobic and hydrophilic regions of long-chain PFOA and PFOS compounds. In both molecules, the hydrophobic tail is comprised of 8 fully fluorinated carbon atoms (C-8). *Modified from Panieri et al. 2022* [2].

Short-chain PFAS

Short-chain molecules were introduced as replacements for longer-chain compounds, with the expectation that, being more hydrophilic, they would be eliminated from the body more readily, thereby reducing bioaccumulation. However, their greater water solubility allows them to travel more readily through groundwater and surface water and can make them more difficult to remove using conventional treatment technologies.

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:

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

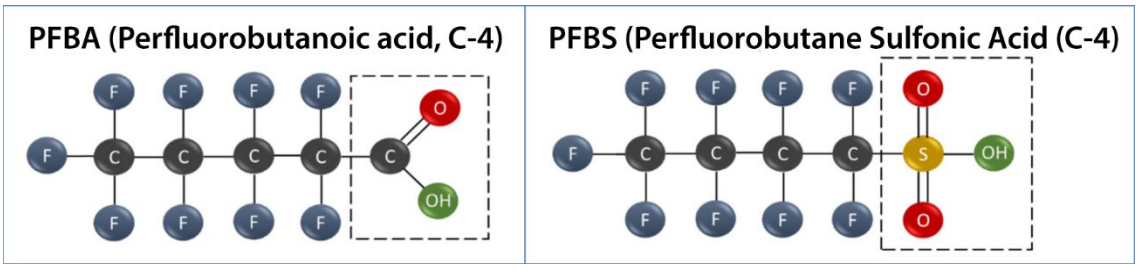

Fig. 2. Molecular structures of two short-chain PFAS compounds, PFBA and PFBS. PFBA has a carboxylic acid functional side group, similar to PFOA, and PFBS has a sulfonic side group, similar to PFOS. *Adapted from Panieri et al. 2022* [2].

Effect of Functional Groups on PFAS Removal: Sulfonates vs. Carboxylates

The functional group also influences PFAS behavior. PFOA and PFBA contain carboxylic acid functional groups, while PFOS and PFBS contain sulfonic acid functional groups. In typical environmental pH ranges, both functional 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. These differences can affect PFAS adsorption, mobility, and treatment effectiveness and are discussed below.

Sulfonates generally exhibit stronger sorption to removal media than 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.

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 water treatment 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 treatments.

PFAS Contamination Across the US

The *Environmental Working Group* (EWG) posts an online interactive map of PFAS contamination across the U.S. and around the world [5]. The map shows higher PFAS levels in areas with greater population densities and extensive agricultural activity, although this pattern may partly reflect sampling bias because monitoring is often focused where higher PFAS concentrations are expected. The EWG map, current as of March 2026, is shown in Fig. 3, with labels added to identify sites discussed in this document: *Songbird Farm*, *Stoneridge Farm*, and BGNDRF[1]. BGNDRF will be the source of PFAS-contaminated water used in this design challenge.

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

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

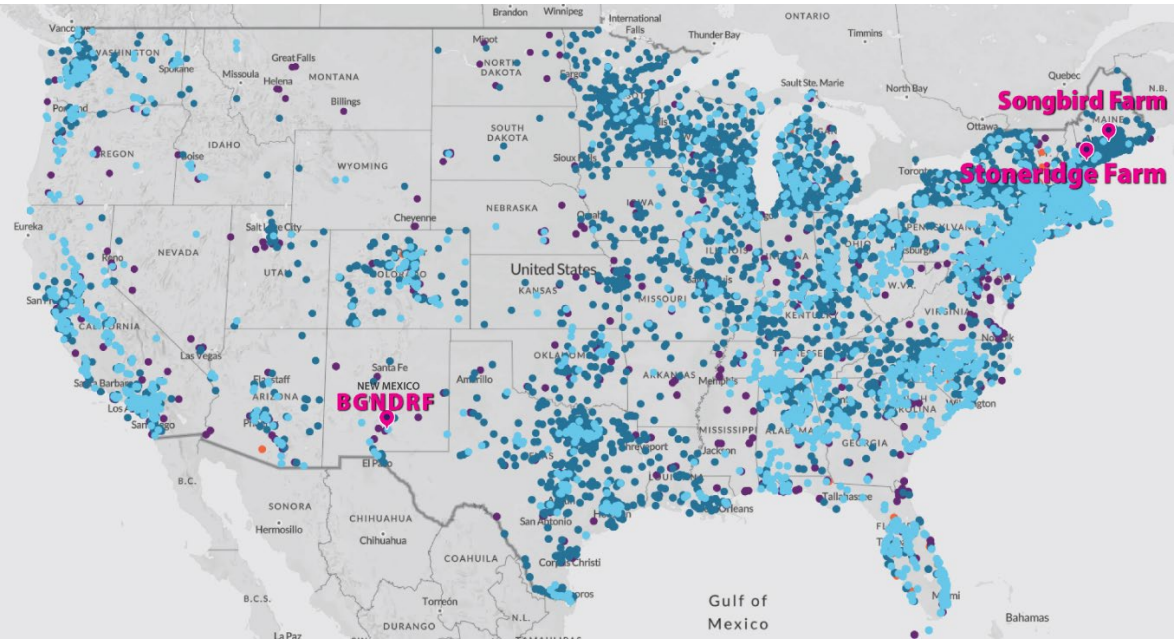

Fig. 3. EWG Interactive map of US PFAS data compared with the EPA MCL [5]. Key to locators: *1) Light blue* – above EPA MCL; *2) Dark blue* – below EPA MCL; *3) Purple* – Military sites; *4) Red* – other known sites where PFAS was found but not measured against drinking water standards (such as industrial 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.*

For example, extremely high levels of PFAS were discovered in the water, soil, and cows' milk at *Stoneridge Farm* in Arundel, Maine (labeled in Fig. 3). The contamination dates to 1983, when owner Fred Stone, a third-generation dairy farmer, and other farmers across the state were encouraged to improve their soils with sludge from paper mills and wastewater treatment plants. The sludge, later found to contain PFAS, was spread on the farm for more than 20 years, resulting in PFAS accumulation in the soil, forage, and ultimately the cows' milk. Stone was forced to stop commercial milk production and eliminate most of his dairy herd—130 head—a substantial economic loss, as a producing dairy cow can be valued at more than $3,000. Although he continues to keep a small number of cattle, PFAS contamination ended the farm's commercial dairy operation [6, 7].

About 100 miles northeast of Arundel is *Songbird Farm* in Unity, Maine (labeled in Fig. 3). It is a small family-owned organic farm whose owners purchased the property in 2014. In 2021, testing revealed elevated PFAS levels in the farm's soil, groundwater, and produce, as well as in the farmers themselves. Groundwater concentrations reached approximately 8,000 ppt, while soil concentrations reached 390 ppb PFOS. The contamination was traced to municipal sludge, or biosolids, applied to the land decades earlier by a previous owner. At these levels, the farmers stopped selling their crops and shut down farm production [8, 9].

By 2025, PFAS contamination had affected 90 of Maine's more than 7,000 farms to varying degrees, prompting the state to award $3 million in grants for research to help farmers manage PFAS-contaminated agricultural land [10].

These two examples of PFAS contamination resulted from the use of biosolids to enrich agricultural soils, but other contamination sources have also devastated farmers' livelihoods. At *Highland Dairy* near Clovis, NM, PFAS-contaminated groundwater migrated from nearby Cannon Air Force Base, where PFAS-containing firefighting foams had been used. The dairy's owner, Art Schaap, was ultimately forced to euthanize his entire herd of 3,665 cows, resulting in an estimated $5,946,462 in lost revenue and increased expenses [11]. In 2018, two wells on the property contained PFAS concentrations of 671 ppt and 1,649 ppt, while concentrations in the cows' milk reached 1,620 ppt [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 1 [13, 14].

As shown in the table, 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, when organic matter is present, GAC's adsorption efficiencies significantly decline.
- 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 they are often cost-prohibitive due to high capital costs, energy requirements, and membrane fouling [13].

Table 1. 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 due to expense	• Regeneration requires a large amount of regenerant and produces PFAS-contaminated wastewater. • Disposal: landfills or incineration, risking PFAS contamination in groundwater and air, respectively.
Membranes: Reverse Osmosis (RO); Nanofiltration	• Up to 99%; • Removes both long and short chains with comparable effectiveness.	Periodically cleaned; eventually disposed	• High capital costs. • High energy consumption. • Susceptible to scaling and organic fouling. • Spent cleaning solution is contaminated. • PFAS-laden wastewater concentrate

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

- ***Electrooxidation.*** Drawbacks: challenges with scale-up, long residence times, high energy consumption, electrode maintenance, reduced effectiveness for short-chain PFAS. Additionally, incomplete defluorination may produce shorter-chain PFAS.
- ***Photocatalysis.*** Drawbacks: long residence times, high energy consumption, reliance on highly efficient catalysts, inconsistent UV light penetration, and potential catalyst fouling.
- ***Other advanced oxidation and reduction processes.*** Drawbacks: long residence times, high energy and/or chemical requirements, and some processes require specific conditions such as high pH and low-oxygen environments.

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].

Baseline Comparison with Established PFAS Treatments

A key goal of this design challenge is to remove PFAS in the presence of other constituents found in real-world water, hence the reason WERC selected BGNDRF well water for demonstrating your team's solution. Once treatment performance has been measured, your team's results should be evaluated in the context of established PFAS-removal research. However, exercise caution when making these comparisons, as some published removal efficiencies were measured using only PFAS and deionized water and may not reflect treatment performance or media life in more complex water sources.

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.

Pre-treatments: Pre-treatment of the source water or conditioning of the biological treatment materials may improve PFAS removal. Depending on the selected media and water chemistry, teams may investigate pretreatment methods that reduce interfering constituents, modify water chemistry, increase accessible surface area, or alter the surface characteristics of the treatment material. Any pretreatment should be considered as part of the overall treatment system and evaluated for its effects on treatment performance, material and energy requirements, waste generation, operational complexity, and cost.

Replacement effects: Research suggests that long-chain PFAS tend to displace previously adsorbed short-chain molecules from their adsorption sites. Long-chain molecules also have a greater tendency to form micelles (clusters with hydrophobic tails grouped inward and hydrophilic heads facing the surrounding water), 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 (SO_4^{2-}) 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

PFAS removal effectiveness can be evaluated through:

- ***Removal Efficiency (%)***: Determined relative to the initial PFAS concentration: [(Initial - Final)/Initial] *100.
- ***Hydraulic Retention Times (HRT):*** 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 Quantification: **EPA Method 537 Modified Isotope Dilution.**

PFAS detection and quantification are guided by various EPA methods. They are analyzed using mass spectrometry (MS) to conduct targeted analysis, meaning that the analysis measures only a predefined list of PFAS analytes. 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.

Through WERC, *The Environmental Exposomics and Trace Analysis Laboratory* (EETA Lab) in El Paso, TX, has offered to provide analytical testing for all teams on two occasions: once in late February 2027 and again during the contest in April 2027. (See *Bench-Scale Demonstration*, below, for additional details.)

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* and *Bench-scale Demonstration*)

Indirect PFAS Estimation: EPA Method 1621, Absorbable Organic Fluorine (AOF)

As an inexpensive and more accessible screening method, 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 can be 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, is not recommended for PFAS destruction, as it 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].

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 (Fig. 3, Fig. 4). 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—typically ranging between 1,000 and 10,000 mg/L of total dissolved solids (TDS)*.)

Research at BGNDRF is particularly important to water security in arid regions, where decades of groundwater pumping have resulted in increasingly saline water being extracted from deeper aquifers [26]. Alamogordo was selected as the facility's location because of the area's abundant brackish groundwater resources. BGNDRF now operates four brackish groundwater wells and maintains onsite evaporation ponds for research activities and concentrate disposal [27]. The region's abundant sunshine also 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 mostly on Wells 1 and 3 for research, significantly limiting their operations. The facility does have a small GAC system to remove PFAS and can send water to its ponds based on capacity. Although the source of PFAS at BGNDRF has not been pinpointed, two nearby potential sources of PFAS have been identified: A former municipal landfill and a former factory that produced Teflon-coated cookware (Fig. 4).

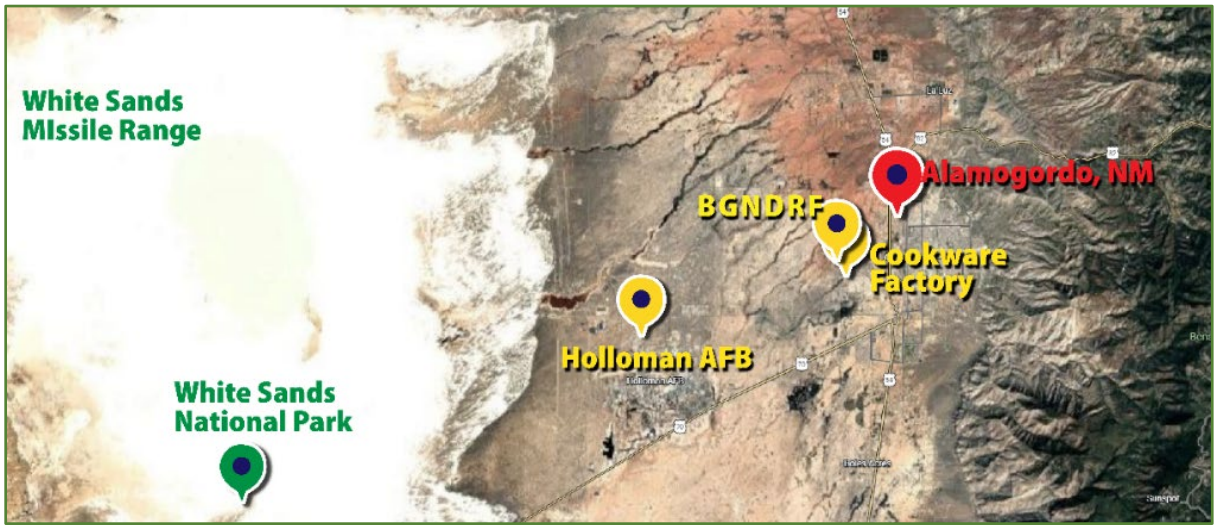

Fig. 4. Google Earth Map of Alamogordo, NM area, showing locations of BGNDRF, the former cookware manufacturing facility, and Holloman Air Force Base. Although both the manufacturing facility have the potential to have released PFAS compounds into the groundwater, neither has been definitively identified 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.

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]. Teams developing viable biologically based solutions have an opportunity to contribute new approaches to this ongoing area of research.

BGNDRF Water Source and Bench-Scale Testing

PFAS-contaminated water from BGNDRF Well 2 was selected for this design challenge because it allows teams to evaluate their solutions using actual groundwater with a complex water matrix. BGNDRF will provide both raw well water and concentrated water for WERC's bench-scale demonstrations, allowing teams to evaluate treatment at both ambient and elevated PFAS concentrations. The facility's proximity to the contest venue in Las Cruces, approximately 60 miles away, also makes it practical to provide fresh samples for testing.

BGNDRF has identified approximately 40 PFAS analytes in Wells 2 and 4, including PFBA, PFBS, PFOA, and PFOS. Typical concentrations for the four target compounds are listed in Table 2. However, understanding the overall water matrix is also important because electrical conductivity, total dissolved solids (TDS), mineral concentrations, and other water-quality parameters may affect PFAS treatment. For these data and a complete list of PFAS analytes, refer to the *Water Quality Monitoring Data from Well Water Analysis* on the BGNDRF website [28].

WERC will collect fresh samples from BGNDRF Well 2 and ship them to each registered team in January 2027. A second set of samples will be provided at the April contest. Both sets will be analyzed, and constituent concentrations will be provided to teams when the water is distributed. Based on historical water-quality data, BGNDRF expects the PFAS concentrations in these samples to be similar to those shown in Table 2.

Table 2. Typical concentrations of PFBA, PFBS, PFOA, and PFOS in BGNDRF Well 2 water. Concentrations were measured using EPA Method 537.
Entries in blue updated 10/8/2026. The BGNDRF Director added PFHxS to the table.

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	9.6	*17*
Perfluorobutanesulfonic acid	PFBS	2.7	*5*
Perfluorooctanoic acid	PFOA	270	*480*
Perfluorooctanesulfonic acid	PFOS	22	*40*
Perfluorohexanesulfonic acid (PFHxS)	PFHxS	9.6	*17*

***Estimating PFAS Concentration in Raw Well-water Concentrate:** WERC is awaiting PFAS concentration data for the concentrated well water; these values are therefore not included in Table 2. Data will be provided to registered teams when available, and will also be posted in the Task 3 FAQs on the WERC website.

In the meantime, teams may estimate PFAS concentrations in the concentrated effluent by assuming the concentrate is produced by a single-stage RO system operating at 75% recovery. Under this assumption, 25% of the feed is released as concentrate, yielding a PFAS concentration approximately 4x that of the raw well water. Actual values may vary from this estimate.

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, in the presence of co-contaminants such as saline water, dissolved solids, minerals, etc.

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 Well 2 [28] while maximizing media capacity, delaying breakthrough, and extending system life. Optionally, teams may investigate regeneration and reuse of the treatment media.

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). To compare your CAPEX and OPEX with existing technologies, use the 2025 *American Water Works Association* (AWWA) data, which report capital and operating costs for GAC treatment of PFAS-contaminated drinking water of $2.99 to $8.89/gallon and $0.06 to $0.28/gallon, respectively [29].

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 these outcomes:

- ***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 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.).
- ***Use the following units of measure in all reports.*** These adhere to customary engineering practice that, at times, mixes 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, residuals, 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 this full-scale operation as the cost per gallon of treated water ($/gal), and on an annual basis ($/yr), based on 1 MGD treatment.

  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.
    - Compare the CAPEX to that of a GAC system of the same capacity, using data from AWWA [29].
  - *Operating expenses* 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 costs:
    - Labor rates: Professional engineer ($150/hr), operator ($70/hour). Rates include fringe benefits.
    - Disposal costs: Refer to EPA Interim Guidance [30] for estimated incineration, landfill, and injection-well disposal costs. Include the cost of hauling the residuals to BGNDRF's nearest disposal site.
    - Energy costs: Use an electricity rate of $0.09/kWh, and research an industrial natural gas rate and state in $/MM BTU.
    - Include additional operating costs your team identifies.
    - Compare the OPEX on an annual basis ($/yr) and $/gal to that of GAC for a comparable water chemistry. Assume the OPEX for GAC to be $0.25/gal.
  - *Visualization tools:* Use sensitivity analyses, graphs, and other visuals to illustrate how key parameters impact system performance and economics.
- ***Develop a Community Relations Plan and/or a Public Involvement Plan*** (see *Team Manual*), as applicable.
- ***Report any 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 situations in which those designs might be more viable than your chosen design, depending on the given region and factors that may change over time.
- ***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.
- All bench-scale prototypes may run from 10 am on Monday to 2 pm on Tuesday. Any overnight operations must be approved in the ESP.
- WERC will collect your team's final effluent samples on Tuesday, 6 April, no later than 2:00 pm.
- The samples will be delivered to the EETA Lab in El Paso, TX, where they will be analyzed using EPA Method 537. The results will be delivered to the judges on the morning of Wednesday, 7 April. Teams will learn their results after the contest.

Before the contest:

- Your team will submit the 30% Project Review, build and test the bench-scale prototype, and obtain ESP approval. In the 30% Project Review, specify the amount of raw and concentrated water needed at the contest to demonstrate your treatment system.
- ***In January 2027***, WERC will ship to each registered team up to 18 L (5 gal) each of raw and concentrated water from BGNDRF Well 2. Prior to shipment, EETA will analyze the water for PFAS, and the resulting concentrations will be provided to teams.

  Once the samples are in your possession, your team is responsible for properly disposing of PFAS-contaminated water or at your home institution. If needed, you may ship any excess water to WERC for disposal, or bring it to the contest in April.
- ***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:
  - Each team may ship up to 3 sets of samples to WERC for analysis in February.
  - Each set consists of two samples:
    - One pre-treatment sample
    - One post-treatment sample
  - Therefore, each team may ship a maximum of six samples to WERC for early analysis.
  - The cost is $45 per sample, so the maximum cost is $270 for six samples. You are being charged only for EETA's cost for the laboratory supplies needed to analyze your samples.
  - Your team is not required to submit all three sets of samples. You may submit fewer samples and will be charged only for the samples you submit.
  - Detailed 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 (excepting BGNDRF water samples) needed to demonstrate the system.

At the contest WERC will provide:

- Basic booth setup, as described in the *Team Manual*
- Up to 18 L (5 gal) each of raw and concentrated water from Well 2, from the same source provided in January. Teams are not required to use the full volume of either sample.
- Sample-collection bottles, nitrile gloves, safety glasses, and any other items requested by your team in the 30% Project Review.

Contest Analytical Testing Techniques

At the contest, WERC will collect fresh samples from BGNDRF and analyze the untreated raw and concentrated water to establish baseline PFAS concentrations that will be applied to all teams. WERC will then collect two post-treatment samples from each team for PFAS analysis:

- Raw water after treatment
- Concentrated water after treatment

WERC will cover all costs of analyzing samples collected during the contest and sent to EETA for analysis.

Method 537 Testing. WERC and EETA will provide each registered team EPA Method 537 LC/MS/MS (Orbitrap) testing for the 40 analytes listed in BGNDRF's tables [28] for the following samples:

1. ***January 2027:*** Raw and concentrate waters from BGNDRF Well 2 before they are shipped to your team
2. ***February 2027:*** Team-provided effluent from your team's bench-scale testing that you ship to us.
3. ***April 4, 2027:*** Raw and concentrate waters from BGNDRF Well 2 provided at the contest.
4. ***April 6, 2027:*** Team-provided effluent from your team's bench-scale demonstration.

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 the Appendix. 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 repellent, 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.

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 the Appendix, its references, and any instructions provided by WERC. Note that, for analytical testing, the EETA Lab will also run blanks as a part of their in-lab quality control procedures. Blanks are samples submitted for quality control to assess potential background contamination. More details for preparing samples will be provided in January 2027 before you ship any samples to us in February.

30% Project Review

Submission date: Dec. 31, 2026

Early submission: You may submit earlier if you wish to receive feedback sooner.

Submission Form: Use the submission form provided on the Team Site (*URL TBD*)

The 30% Project Review 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. Pay particular attention to preparing a complete Process Flow Diagram (PFD); it should be a complete representation of your design.

Submit the 30% Project Review as early as possible. Although the review is not scored, your team will receive early feedback from the judges. You are allowed to change your plans after submitting this report. Include as many items listed below as possible. The more detail provided in your review, the better direction you will get from the judges. (See *Team Manual* for more information.)

Include the following project-specific details in the 30% Project Review:

Technical:

- *Top 2-3 design requirements for Task 3*, and how your design maps to each goal.
- *Pre-contest Effluent Analysis Plan.* Let us know the number of preliminary samples your team plans to ship to WERC in February 2027 for analysis by EETA.
- *Complete Process Flow Diagram (PFD).* The PFD serves as a robust outline of all processes in your treatment system, showing balanced inputs and outputs.
- *Preliminary data and/or calculations that support the proposed design, if available.* This might include expected chemical reactions (reactants, reaction times, etc.), flow volumes, rates, etc.
- *Rough cost estimates for the full-scale design to demonstrate project feasibility.* This will help your team and the judges consider modifications that might improve the project's outcomes.

Bench-scale setup:

- *A 3D diagram, to scale, of your bench-scale setup.* Include outer dimensions.
- *All bench-scale setup requests:*
    a. Volume of well water needed;
    b. Potential need to run the process overnight (justify the needs and describe continuous monitoring, power needs, safety measures).
- *Auxiliary equipment and supplies requests,* if any, such as pressurized gas cylinders, bulky items, etc. Provide justifications for each requested item.
- *Potential safety protocols needed to operate your prototype.*

Deliverables (See *Team Manual*)

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

- 30% Project Review – use submission form provided on the WERC Website *Forms* page.
- Experimental Safety Plan (ESP) and Required Short Course.
- Equipment Transport Form (if shipping equipment to Las Cruces)
- Technical Report—System design, data analysis, full-scale proposal, and 3 independent audits
- Flash Pitch—Pitch your design 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 join 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	Email ESP to Juanita Miller (miljgh@nmsu.edu). Include requests for chemicals, materials, etc.
March 22, 2027	Submit Equipment Transport form (if shipping items to Las Cruces)
March 26, 2027	Technical Report due
March 29, 2027	Submit Flash Pitch Slides and Summary
April 4 – 7, 2027	Contest in Las Cruces

Contacts:

Safety Officer ● ESP Approval: Juanita Miller, miljgh@nmsu.edu

Task and Contest Questions: Ginger Scarbrough, gscarbro@nmsu.edu, 575 312-7623 (cell)

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Appendix – 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 [31 - 33], and each reference adds unique insights.

WERC recommends first studying the chart below from the Massachusetts Department of Environmental Protection (MassDEP) [31]. It summarizes most prohibited and allowable items for laboratory PFAS studies, but note that this is not an all-inclusive guide.

Two references [32, 33] 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 (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.

Guidelines for material/supply use during PFAS research and sampling activities. This is not an all-inclusive list. Refer to [30, 21, 33, and 34] for additional details. *Table reproduced from MassDEP* [31].