AVANTech Lessons Learned from Stored Water PFAS Removal at a US DOD Site – 21410

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ABSTRACT

This presentation describes an AVANTech project in which 113,550 liters (30,000 gallons) of water were treated for per- and polyfluoroalkyl substances (PFAS) on a Department of Defense (DOD) site. One of the latest environmental and health challenges faced by the DOD is the proper disposal of aqueous film forming foams (AFFF) used to extinguish fires, often as part of training exercises. The foams contain high levels of PFAS that are known by the EPA to have adverse health effects on humans. With states beginning to regulate these compounds, DOD sites are tasked with treating and disposing the remnants of the foam, which can exist in soil, groundwater, and highly contaminated water stored in tanks.

At Whiteman Air Force Base in Missouri, two water storage tanks contained between 46 and 56 µg/L of PFOS and PFOA (two common PFAS compounds). These two compounds needed to be removed to below the EPA-mandated Health Advisory Level of 70 ng/L. A modular mobile water treatment system was designed and fabricated to treat approximately 113,550 liters of water over the course of one week. Using an oxy-anion specific ion exchange media, the water was pumped at a very low spatial velocity to ensure maximum PFAS removal and to minimize secondary waste in the form of spent media. A pre-filter removed suspended solids that could inhibit media performance. Effluent water was collected in two frac-type monitor tanks where product quality was confirmed. The used ion exchange media was dispositioned via a hazardous waste incinerator to ensure that the removed PFAS did not re-enter the environment.

The project was successful in that the PFOS/PFOA concentrations were reduced to below 70 ng/L (99.9% removal). Through this operation, insight was gained that will optimize the process and improve results on future processing projects. The ion exchange media reduced concentrations of most PFAS compounds to below 70 ng/L, and most of those to below the detectable limit. One compound, 6:2 FTS, remained in excess of 70 ng/L. Previous data on this type of media has shown that breakthrough for 6:2 FTS occurs earlier than for other PFAS compounds. While not required for this operation, removal of this compound to below the same limit could present a challenge for future treatment projects. Additional considerations will need to be made which could include a change in the type and/or volume of media used.

The size of the treatment operation is also something to consider. Whiteman Air Force Base required treatment of 113,550 liters of water, allowing the convenience of designing around a very conservative spatial velocity. Other DOD or industrial sites could have a much larger volume of water or could require a larger mobile or permanent continuous system. Process optimization would involve balancing a higher flow rate with a reasonable media volume. This project utilized a modular treatment system, which worked well for the application as only one type of a single-use media bed was required. For larger and/or permanent systems, the application of different types of adsorption media, chemical regeneration, and media bed replacement will need to be evaluated. Larger systems would also warrant further evaluation to optimize the treatment and disposal of liquid and solid secondary waste to ensure the PFAS does not re-enter the ecosystem and to minimize overall operating costs. Lessons learned from this project will be presented.

INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) remediation is a topic of growing interest as federal, state, and local regulations on acceptable concentrations in water become more common.

This group of over 2,000 known compounds originates from several sources including consumer products and firefighting foams. They are known as “forever chemicals” because they bioaccumulate and do not readily decompose.

One common source of PFAS in non-drinking water is aqueous film forming foams (AFFF), which are used to extinguish fires involving hydrocarbon-based liquids. Department of Defense (DOD) sites often use AFFF in training exercises. The high levels of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in the foam led to a dramatic reduction in usage, as these compounds can enter groundwater and pose adverse health effects on humans. Most AFFFs manufactured in recent years contain molecules with carbon chains that are not fully fluorinated. These compounds are believed to bioaccumulate less than their fully fluorinated counterparts [1].

The Environmental Protection Agency (EPA) has recognized this concern and set a Lifetime Drinking Water Health Advisory Level (HAL) of 70 ng/L [2]. As state and local authorities have begun to regulate PFAS, DOD sites are tasked with treating and disposing the remnants of AFFF. Contaminated water is often stored in tanks on site while awaiting treatment.

At Whiteman Air Force Base (AFB), approximately 113,550 liters of water containing high levels of PFAS were contained in two underground tanks. To release the water to the ground, the PFOS/PFOA concentration needed to be below the 70 ng/L limit set by the EPA [3]. Though the water was classified as non-drinking, untreated water can eventually enter groundwater and infiltrate drinking water sources. Therefore, the 70 ng/L HAL was used as the limit for this treatment operation as well. Whiteman AFB was looking for a temporary treatment operation and analytical testing to be able to release the water. AVANTech was awarded this opportunity and developed a modular mobile system with a commonly accepted treatment method to address the needs of Whiteman AFB.

CURRENT TECHNOLOGY

Many treatment methods have been studied for PFAS removal and destruction. In terms of cost and effectiveness, two methods stand out from the rest. Granular activated carbon (GAC) has existed for decades and is most often used to remove organics from water streams. It has been heavily studied for removal of PFAS and is generally successful. Granular activated carbon can easily remove longer chain compounds, such as PFOS and PFOA, to below acceptable limits with proper pretreatment. Its proven effectiveness and low initial media cost are appealing to utilities who are looking for a quick solution.

Anion Exchange is a more recent, but still widely accepted treatment method for PFAS. It can capture shorter chain compounds better than GAC, although it cannot remove all of them to the same concentrations as PFOS/PFOA. Since the smaller chain compounds are not as regulated, this is typically not limiting to the treatment goals [2]. Anion exchange media has a higher media cost per unit volume than GAC, but it also has better kinetics, which permits a smaller bed volume.

DESCRIPTION OF WORK

Bench-scale laboratory testing was performed on a simulant containing similar amounts of PFAS as the water at Whiteman AFB. To accurately reflect operation, a packed column of adsorption media was operated at the same linear velocity as that planned for the full-scale system. Analytical results of the effluent showed media removal capacity to below 30 µg/L, a 99.9% removal efficiency.

Over the course of three working days, the 113,550 liters of water were treated with a modular mobile treatment system. As shown in Figure 1, the system included a self-priming centrifugal pump to pull water from the underground tanks, a pre-filter, and two ion exchange columns operated in a lead-lag configuration and loaded with oxy-anion specific ion exchange media. Effluent water was collected in two 79,485-liter (21,000-gallon) frac-type monitor tanks where product quality was confirmed.

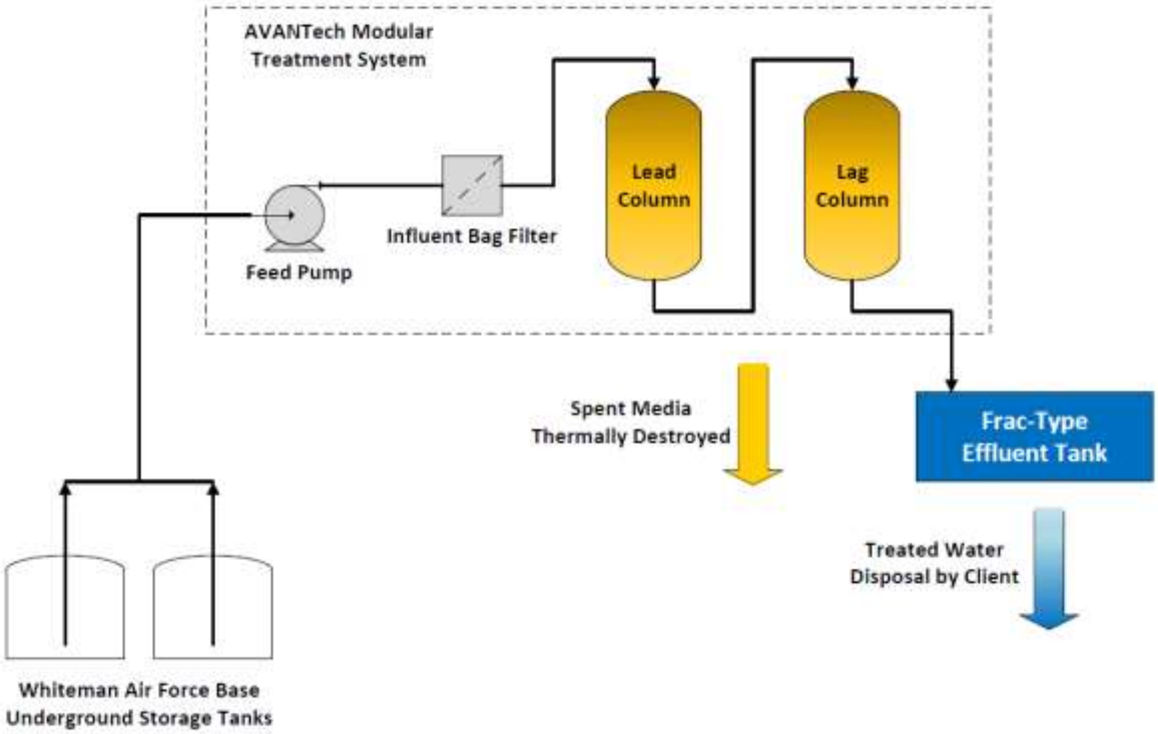

Figure 1. System Flow Diagram

Water was pumped from the underground tanks at approximately 37.9-45.4 LPM (10-12 GPM) throughout the run. This low flow rate meant a long residence time for the water in the ion exchange columns, which maximized PFAS removal and minimized secondary waste in the form of spent ion exchange resin.

Multiple inlet and outlet samples were taken throughout the treatment campaign to verify feed constituents were within the expected range and to confirm that effluent quality requirements were being met. One set of influent and effluent samples was taken each of the three days of operation.

RESULTS

The pre-filter effectively removed approximately 20 mg/L of total suspended solids (TSS) from the influent while producing a clean filtrate as evidenced by the lack of significant differential pressure across the ion exchange columns. As shown in Table 1, the concentrations of PFOS and PFOA were below the limit of 70 ng/L in each effluent sample.

Table 1. PFOS and PFOA Analytical Results

Sample	Inlet PFOS (ng/L)	Inlet PFOA (ng/L)	Outlet PFOS (ng/L)	Outlet PFOA (ng/L)	PFOS/PFOA Removal Successful (< 70 ng/L total)
Day 1	47,000	720	24	< 3.7	Yes
Day 2	39,000	650	7.9	< 4.0	Yes
Day 3	42,000	610	11	< 3.7	Yes

One compound, 6:2 fluorotelomer sulfonate (FTS), was not listed in the influent water quality provided by the client but was present in the water treated. A concentration well above the 70 ng/L limit was present in each effluent sample, as shown in Table 2.

Table 2. 6:2 FTS Analytical Results

Sample	Influent 6:2 FTS (ng/L)	Effluent 6:2 FTS (ng/L)
1	50,000	2,000
2	53,000	210
3	59,000	200

The accepted effluent water was released by Whiteman AFB, and the spent ion exchange media was thermally destroyed at a licensed incineration facility. The incinerator reached 927 °C (1700°F) to comply with Whiteman's specification.

DISCUSSION

6:2 FTS Removal

Analytical results of the treated water were well within the limit of 70 ng/L PFOS and PFOA. Several other compounds in the PFAS family were present in the water, and almost all were reduced to undetectable limits. One compound, 6:2 FTS, stood out from the others, as its effluent level was above the 70 ng/L limit. Since this compound is not included in the PFOS/PFOA requirement, the treatment was successful per the needs of the client. However, if future treatment operations require removal of 6:2 FTS, it will be important to understand why the ion exchange media was less effective as well as how to remove it to similar levels as the other compounds.

Based on currently available data, the short-chain 6:2 FTS is less toxic and less persistent in the environment than the longer chain PFOS [4]. The term "short-chain" means that, while there are still 8 carbon atoms, only six are perfluorinated (Figure 2). This difference reduces its ability to be captured by the ion exchange media to the same levels as PFOS and PFOA. This compound has been used as a replacement for PFOS and PFOA in firefighting foams such as AFFF [1].

For now, short-chain compounds such as 6:2 FTS are less of an environmental and health concern, but as they increasingly replace the more toxic PFAS, they could eventually pose enough of a threat that regulations will include them as well.

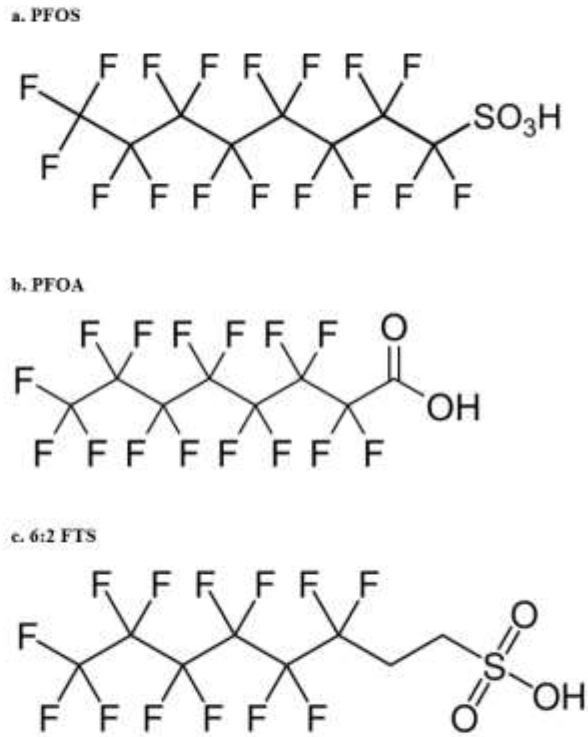

Figure 2. Compounds Present in Effluent

Influent Water Chemistry

Another important aspect to consider is the presence of other compounds in the water to be treated. Influent water quality has an enormous effect on ion exchange capability. Other anions can compete with the PFAS for ion exchange sites and inhibit the performance of the media. In this case, an upstream anion bed may be necessary. Additionally, an upstream carbon bed may be beneficial if other organics are present in the water.

Total suspended solids should also be specified. Solids can accumulate on the media, increasing differential pressure, and making it more difficult to achieve desired flow rates. The TSS concentration was not provided for this treatment operation, but a 5-μm bag filter was used to reduce solids and removed approximately 20 mg/L from the feed water. While this filter worked for the temporary system, a more suitable solution may have been possible if the actual concentration of suspended solids and particle size distribution of the influent water were known. It is crucial that a full water chemistry be provided so the treatment system can be designed to selectively remove PFAS to the largest extent.

Sizing Conservatism

Correct sizing is necessary in any system design to maximize efficiency and minimize cost. For the treatment effort at Whiteman AFB, the volume of water to be treated was small enough that the media volume would be very conservative to ensure PFOS/PFOA removal to 70 ng/L.

There was no concern about media exhaustion. The primary operating parameter in the sizing of this system was the empty bed contact time. A conservative value of 8.02 BV/h (1 gpm/ft^3) was used, and then the resulting quantity of media was doubled. Because of this, the PFAS should have been removed in the lead column, but the lag column was present to capture any breakthrough. A lead-lag scenario may not always be necessary, but a second column can lengthen the time between regenerations or media replacements in a continuous process. For larger batches or permanent systems, a detailed sizing would be to be performed to determine the point of media exhaustion.

Secondary Waste Disposal

The treatment and disposal of secondary waste is vitally important to ensure PFAS does not return to the ecosystem. For ion exchange systems, secondary waste exists in the form of the spent media. There are two primary methods to address this waste. Regeneration is common for traditional ion exchange operations. Performing a regeneration allows the spent resin to be reused instead of replaced, cutting ongoing media costs. Regeneration produces a concentrated aqueous waste stream that needs to be disposed. In the case of media containing PFAS, this waste stream cannot be disposed of by traditional means. Further, for the temporary modular treatment system at Whiteman AFB, regeneration was not necessary as the media was not expected to be exhausted prior to completion of treatment. Therefore, it was not considered for this operation.

Thermal destruction, or incineration, is a widely accepted disposal method. The spent media is removed from the ion exchange columns and sent to an incineration facility, where high temperatures break the carbon-fluorine bonds that characterize the PFAS molecules. Because PFAS are not currently considered hazardous substances, they are not subject to regulations and little is known about emissions or byproducts from incineration [5]. More research is necessary to fully understand these concerns.

CONCLUSION

The need for PFAS treatment at DOD sites is ongoing. The use of anion exchange and incineration of the spent media is a common treatment technique, but improvements can be made on both the client and vendor ends to maximize removal of all compounds in the PFAS family and minimize secondary wastes and the associated costs.

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