Removal of Per- and Polyfluoroalkyl Substances with S-PAC and Ceramic Membranes

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Background: Per- and polyfluoroalkyl substances (PFAS) have become high-profile contaminants in ground water. Over 2000 molecules are classified as PFAS, and the EPA has a health advisory for two of them, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate acid (PFOS) (Figure 1) (EPA, 2016). This study places an emphasis on these two molecules.

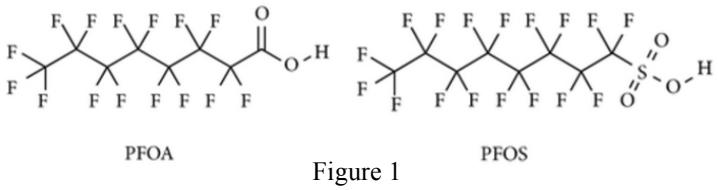


Figure 1

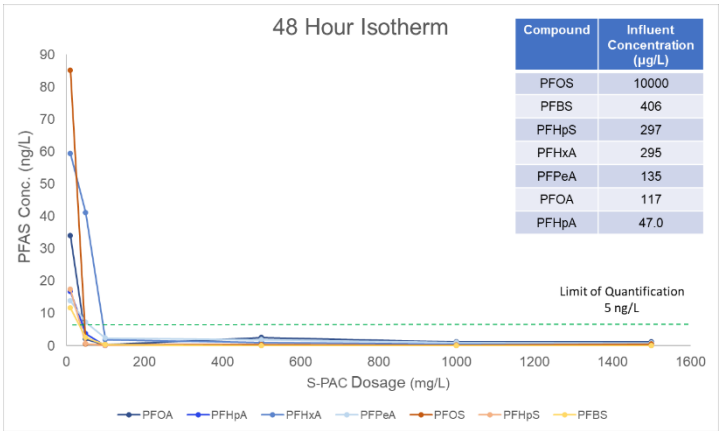
PFAS are used in the manufacturing of many products such as textiles and water-repelling coatings as well as in firefighting foams. They are resistant to breakdown due to their strong carbon-fluorine bonds, and they accumulate in biological systems. Water treatment is needed to remove the contaminant. Superfine powdered activated carbon (S-PAC) removes PFAS through adsorption. S-PAC has a much smaller average diameter, 0.88 µm, than granular activated carbon (GAC), a widely used adsorbent. The smaller particle size is thought to improve adsorption kinetics and reduce waste generation (Partlan et al, 2016). The small size of S-PAC requires membrane filtration to remove it from water. Ceramic membranes show promise due to their ability to withstand backpulsing, a high-pressure stream of water to remove membrane foulants.

Objectives: This study compares the adsorption capacity of S-PAC to the capacity of GAC through isotherm tests. A filtration system that utilizes S-PAC adsorption and ceramic membrane filtration is used to determine optimal system parameters. This study determines the efficiency of the treatment for reducing PFAS concentration, the ability of a ceramic membrane to remove S-PAC, and backpulsing's ability to prevent high levels of irreversible fouling.

Methodology: Isotherm batch tests were conducted to determine the adsorption capacity of S-PAC. Six jars were dosed with S-PAC ranging from 10 mg/L to 1500 mg/L. The jars also contained dechlorinated tap water spiked with aqueous firefighting foam (AFFF) to obtain 10 µg/L of PFOS. The jars were shaken for 94 hours with periodic sampling. The tests were repeated with GAC over a longer time period to determine whether S-PAC has improved adsorption. Steady-state tests were conducted to determine the efficiency of S-PAC combined with a ceramic membrane in a microfiltration (MF) system. Multiple trials, all with an AFFF dose that resulted in 10 µg/L of PFOS in dechlorinated tap water for the influent water, tested various system parameters. Trial 1 ran for six hours with the following parameters: 1500 mg/L S-PAC, 2 L/min effluent, and 150 LMH flux. The trial was ended due to significant membrane fouling and rapidly increasing pressure. Trial 2 ran for 24 hours with the following parameters:

500 mg/L S-PAC, 3 L/min effluent, and 50 LMH flux. Lowering the S-PAC dosage while increasing the crossflow within the membrane reduced fouling and prevented a pressure increase. Trial 3 was very similar, but ran at a higher flux of 60 LMH to give the system more control. Trial 4 ran for about 24 hours with the following parameters: 100 mg/L S-PAC, 3 L/min effluent, and 60 LMH flux. Permeate samples were taken throughout the trials to test the water quality.

Results and Discussion:



Compound	Influent Concentration (µg/L)
PFOS	10000
PFBS	406
PFHpS	297
PFHxA	295
PFPeA	135
PFOA	117
PFHpA	47.0

Figure 1. PFAS Concentrations vs S-PAC Dosage after 48 hours.

The S-PAC dosages of 100, 500, 1000, and 1500 mg/L removed all PFASs to below the LC-MS limit of quantification. Based on this data, 100 mg/L was chosen as the optimal dosage for the MF system because it has a high removal rate while still being a low enough dosage to prevent major membrane fouling.

Trial	S-PAC Dose (mg/L)	Flux (LMH)	Permeate Flow (mL/min)	Water Treated (L)	Break-through	Fouling
1	1500	150	100	35.00	No	Major
2	500	50	35	48.59	No	Minor
3	500	60	40	58.17	No	Minor
4	100	60	40	43.20	Expected	Minor

Figure 2. MF System trial parameters and data

Trial 1 was the recommended dosage and trial 4 had optimized parameters. Fouling was mitigated by backpulsing the membrane every 5 minutes. Major fouling took place in trial 1, after which the membrane was removed and physically cleaned. Operating conditions were updated to minimize fouling during subsequent filtration experiments. Trial 2 had PFOS log removal >3.18 with 20 minutes of contact time between the S-PAC and the contaminated water. The permeate samples from trial 4 were not run during the summer research session due to machine complications, however, PFASs are expected to appear in the permeate.

Conclusions: S-PAC dosages at or above 100 mg/L can remove high PFAS concentrations, several orders of magnitude above what is normally found in contaminated groundwater, from tap water. When the tests were extended to the microfiltration system, S-PAC dosages of 500

mg/L removed high concentrations of PFASs to below 70 ng/L within a 20 minute contact time over a 24 hour period without fouling the membrane.

References

Environmental Protection Agency. Drinking Water Health Advisories for PFOA and PFOS. **2016**. https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

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