Treatment of Per- and Polyfluoroalkyl Substances With S-PAC and Ceramic Membranes

Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)

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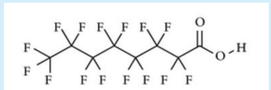
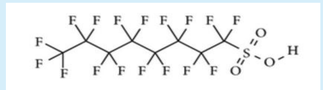
Background

Per- and polyfluoroalkyl substances (PFASs) are a contaminant of major concern. The US EPA issued a health advisory limit of 70 ng/L for the two most widely known compounds, PFOS and PFOA, individually or combined. Many communities are struggling to deal with the removal of these contaminants.



Perfluorooctanoic Acid (PFOA)



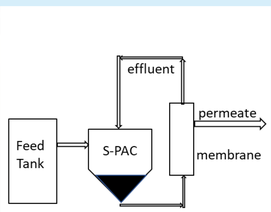
Perfluorooctane Sulfonate Acid (PFOS)

Superfine powdered activated carbon (S-PAC) removes PFASs through adsorption and is followed by membrane filtration which can subsequently remove the S-PAC particles. Granular activated carbon (GAC) is already an accepted technology for PFAS removal. S-PAC particles differ from the traditional treatment train involving GAC in that they have a particle diameter several orders of magnitude smaller than GAC. Therefore, S-PAC should remove PFASs more efficiently from water. Ceramic membranes are a promising option for filtering S-PAC from water due to their ability to resist abrasions, and withstand high pressure and wide pH ranges.

Research Questions

What are the adsorption capacity and kinetics of S-PAC?

What are the optimal operating conditions for the microfiltration system?

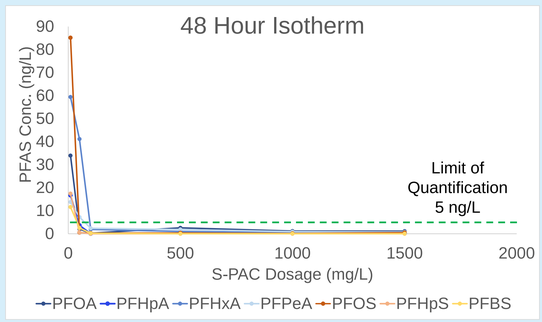


Microfiltration System

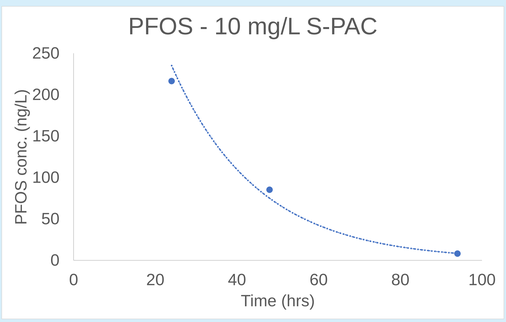
Isotherm Methods & Results

Isotherm jar experiments were run with 6 dosages of S-PAC ranging from 10 to 1500 mg/L. The jars also contained dechlorinated tap water spiked with PFASs (10 to 0.018 µg/L). All PFAS concentrations for the 3 highest S-PAC dosages in the 24 hour samples were below the liquid chromatography tandem mass spectrometry (LC-MS/MS) limit of quantification at 5 ng/L.

The same experiment was replicated with GAC. Results from the GAC isotherms are still being processed. Equilibrium is expected to be reached after longer time spans and at higher concentrations for all dosages.



The S-PAC dosages of 100, 500, 1000, and 1500 mg/L removed all PFASs to below the limit of quantification.



PFOS is the PFAS with the highest concentration in the contaminant suite and 10 mg/L is the lowest S-PAC dosage. These factors combine to give the clearest isotherm due to S-PAC's high adsorption capacity.

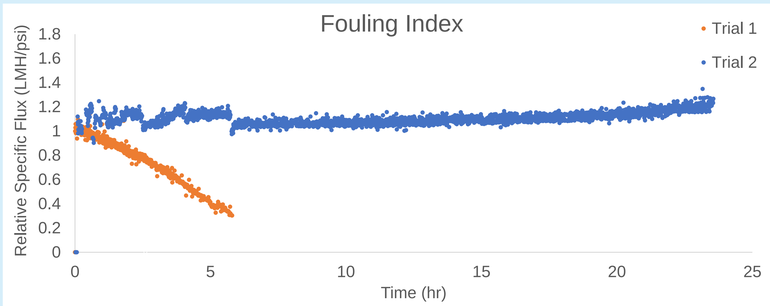
Microfiltration System Methods & Results

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

The S-PAC's adsorption capacity was underestimated for the first 3 trials. Isotherm data influenced the S-PAC dosage for trial 4. Breakthrough is expected to be observed once the samples are analyzed.

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.

Fouled ceramic membrane from the microfiltration system. S-PAC clogs the channels which increases the pressure.



Relative specific flux is a measure of fouling. A value under 1 indicates that fouling has occurred.

Factors that caused trial 1 to foul include a high S-PAC dosage and a high operational flux.

Data Source	Time (min)	Water Source	Water Treated (L)	Adsorption Rate (µg PFAS/g S-PAC)	Break-through
Trial 2 A	600	Tap	20.70	15.66	No
Manufacturer	200	Well	20.00	14.20	No
Trial 2 B	1411	Tap	48.59	40.71	No
Manufacturer	200	Tap	20.00	390.0	Yes

The experimental adsorption rate is believed to be higher than the manufacturer's well water sample due to other organic contaminants present in the water. Trial 4's data is still being processed and is expected to show an adsorption rate similar to the manufacturer's tap water sample if breakthrough occurred.

Microfiltration System Cont.

S-PAC Dosage (mg/L)	Time (hr)	PFOS Conc. (ng/L)	PFOS Log Removal
10	24	216.34	1.66
10	48	85.13	2.07
10	94	8.02	3.10
500	1.67	<5.00	>3.18

Based on an initial PFOS concentration of 10 µg/L.

Both the isotherm and microfiltration samples reached over 3 log removal of PFOS, the most concentrated contaminant. This equates to >99.9% removal which well under the health advisory limit.

Conclusions

- Isotherms
  - S-PAC dosages at or above 100 mg/L can effectively remove high PFAS levels from tap water.
- Microfiltration System
  - Membrane fouling occurs with a combination of a high S-PAC dosage and a high flux. Fouling ceases to be a problem within 24 hours of continuous filtration when both factors decrease.
  - S-PAC dosages of 500 mg/L can remove high concentration of PFASs to below 70 ng/L within a 20 minute contact time.

Future Work

The microfiltration system should be run with natural groundwater to more accurately simulate field application integration. Water from Fountain, CO has been obtained for this purpose.

Further side by side comparisons will be done for S-PAC and GAC looking at adsorption capabilities.

Acknowledgements

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