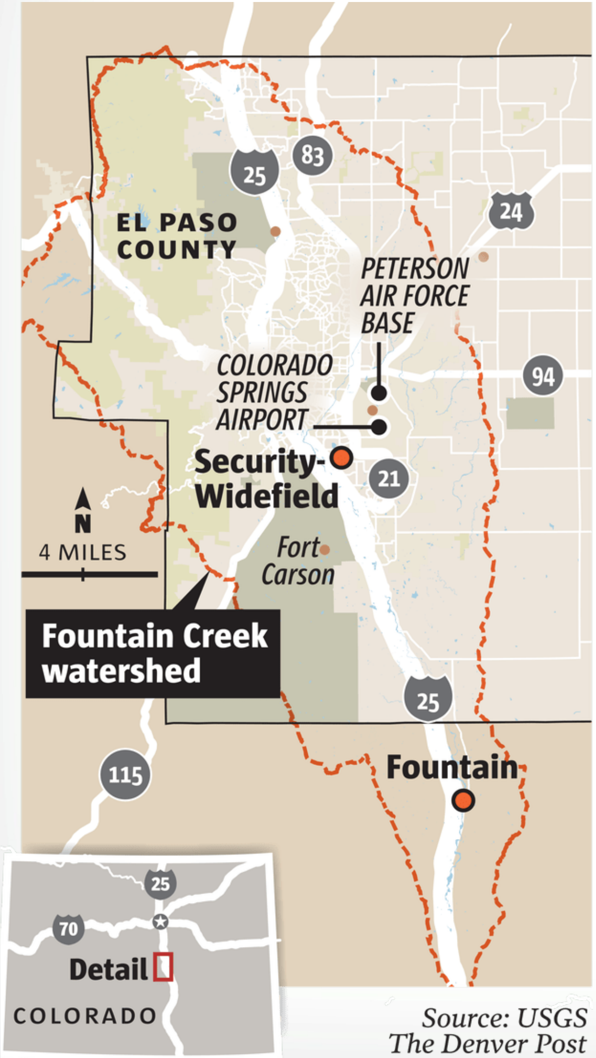
Region 8 and CDPHE Webinar
November 1, 2018

PFAS Removal Using Household Water Treatment Systems: Point-of-use (POU)/Point-of-entry (POE)

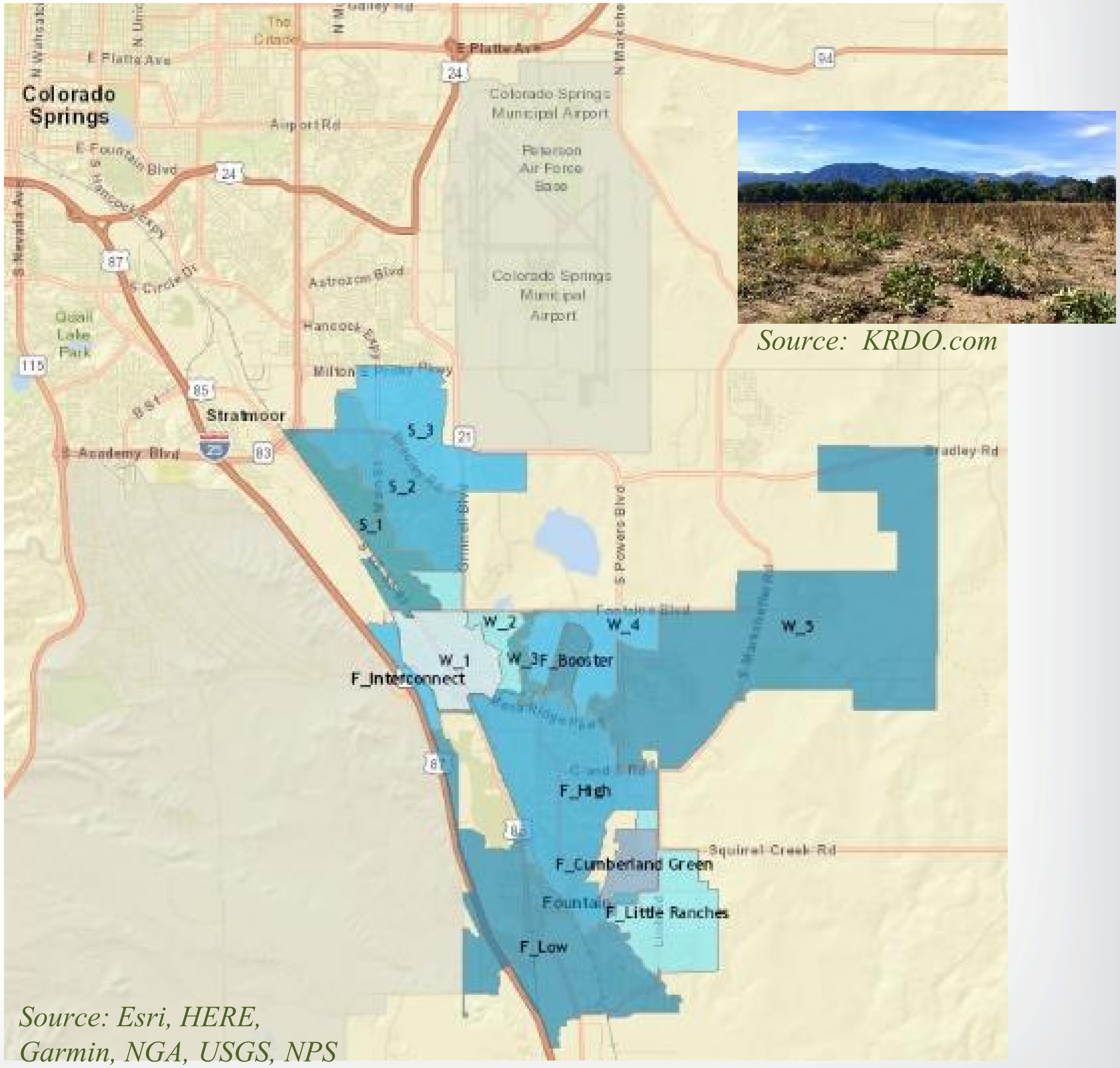
Source: Denver Post

Craig Patterson, Jonathan Burkhardt
USEPA, ORD, Cincinnati, Ohio
Stephen Dyment,
USEPA OSP, Denver, Colorado
Steven Merritt
USEPA Region 8, Denver, Colorado
Larry Zintek, Danielle Kleinmaier
USEPA Region 5, Chicago, Illinois
E. Radha Krishnan, Donald Schupp
APTIM, Cincinnati, Ohio

Extent of PFAS Contamination



Source: USGS
The Denver Post



Source: Esri, HERE, Garmin, NGA, USGS, NPS

Source: KRDO.com

PFAS Contaminants

Aqueous Film Forming Foam (AFFF) was used to fight fires at Peterson Air Force Base. As of August of 2016, a new product Phos-Chek 3 with shorter chain molecules is now being used.

U.S. Air National Guard photo by Airman 1st Class Amber Powell

Unregulated Contaminant Monitoring Rule 3 (UCMR3) PFAS detected in the Widefield Aquifer:

- Perfluorooctanoic Acid (PFOA)
- Perfluorooctane Sulfonate (PFOS)
- Perfluoroheptanoic Acid (PFHpA)
- Perfluorobutane Sulfonate (PFBS)
- Perfluorononanoic Acid (PFNA)
- Perfluorohexane Sulfonic Acid (PFHxS).

Potential health impacts: Cancer, liver, thyroid, pancreatic, kidney and fertility problems

Response Actions and Alternative Water Sources

- Surface water is being blended from Pueblo Reservoir to meet the PFOA/PFOS health advisory and PCE maximum contaminant levels (MCLs).
- Bottled water stations and water coolers provide alternative drinking water sources to residents living in the Widefield Aquifer region.

Source: Colorado Springs Gazette

Project Goal

To assess the removal effectiveness of target Per- and Poly- fluoroalkyl Substances (PFAS) using commercially available Point-of-Use (POU) and Point-of-Entry (POE) Reverse Osmosis (RO) treatment units and Granular Activated Carbon (GAC) adsorption systems for homes with private wells in Colorado's Widefield Aquifer. To meet this goal, the project purchased commercially available household water systems and conducted treatability studies on representative test waters.

Point-of-Use (POU)
Kitchen sink, end-of-faucet, and pour-thru devices

Point-of-Entry (POE)
Whole House; typically installed in a hot water tank room or a heated garage

R8 RARE Project Objectives

The project also documented:

- Ease of use during installation, startup, continuous and intermittent operation based on manufacturer instructions.
- Operation and maintenance schedules for replacement of RO units and GAC media based on manufacturer instructions and the representative test water quality.

Source: H2O Distributors

Test Water
Maximum PFAS Concentrations

CAS Number	PFAS Compounds	Carbon Chain Length	Target Concentration
375-95-1	Perfluorononanoic Acid (PFNA)	**C9**	200 ng/L
335-67-1	Perfluorooctanoic Acid (PFOA)	**C8**	800 ng/L
1763-23-1	Perfluorooctane Sulfonate (PFOS)	**C8**	1,600 ng/L
375-85-9	Perfluoroheptanoic Acid (PFHpA)	**C7**	200 ng/L
3871-99-6	Perfluorohexane Sulfonate (PFHxS)	**C6**	1,000 ng/L
375-73-5	Perfluorobutane Sulfonate (PFBS)	**C4**	300 ng/L

Test Water
Target Water Quality Characteristics

General Chemistry Water Parameters	
Temperature (°C)	RO: 25 ± 1°C, GAC: 20 ± 2.5°C
pH (pH Units)	8.2 ± 0.5
Turbidity (NTU)	<1 NTU
Free chlorine (mg/L)	<0.2 mg/L
TOC (mg/L)	RO: not specified (not adjusted) GAC: >1 mg/L (added as dehydrated NOM)
TDS (mg/L)	RO and GAC: 500 mg/L (added as NaCl)
Hardness (mg/L)	RO: 300 mg/L $CaCO_3$ (added as potassium chloride [KCl], magnesium sulfate [$MgSO_4$], sodium bicarbonate [$NaHCO_3$] and calcium sulfate [$CaSO_4 \cdot 2H_2O$]), GAC: not specified.

Reverse Osmosis Systems

POU/POE treatment tests on three RO systems (500-1000 gal/day):

- iSpring RCS5T (0.35 gpm)
- Hydrologic Evolution (0.7 gpm)
- Flexeon LP-700 (0.5 gpm)

iSpring

Hydrologic

Flexeon

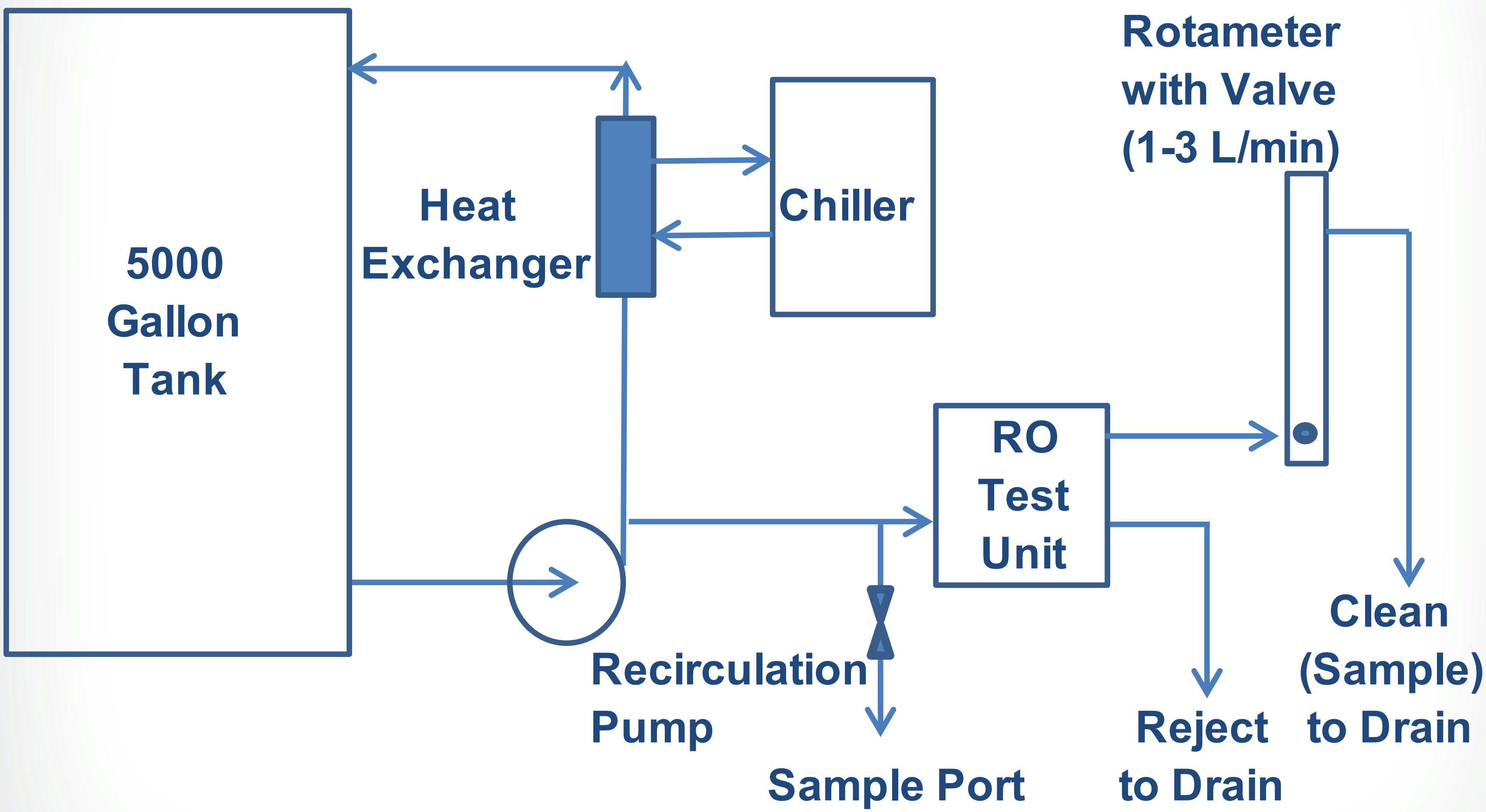
Sample Collection

Summary of RO System Specifications

RO system	iSpring RCS5T	HydroLogic Evolution RO1000	Flexeon LP-700
Rated Capacity[A]	500 GPD (0.35 gpm)	1,000 GPD (0.7 gpm)	700 GPD (0.5 gpm)
Filters Included	Sediment filter Carbon pre-filter CTO filter RO membrane Carbon post-filter	Carbon pre-filter 2 RO membranes	Sediment filter Carbon pre-filter 2 RO membranes Carbon post-filter
System Recovery[A]	50%	50%, using 1:1 fitting	38%
Booster Pump	Yes	No	No
Connections	3/8” Inlet ¼” Outlet (tubing included)	½” Inlet 3/8” Outlet (tubing included)	3/8” Inlet and Outlet (tubing not included)
Self-Supporting	Yes	Yes	No
Size (L x W x H)	8.5” x 15” x 18.5”	20.5” x 11” x 10”	18” x 10.5” x 32”
Weight	31 lbs	16 lbs	38 lbs

[A] Pressure and efficiency depend on the temperature and pressure of the feed water.

Reverse Osmosis Test Unit



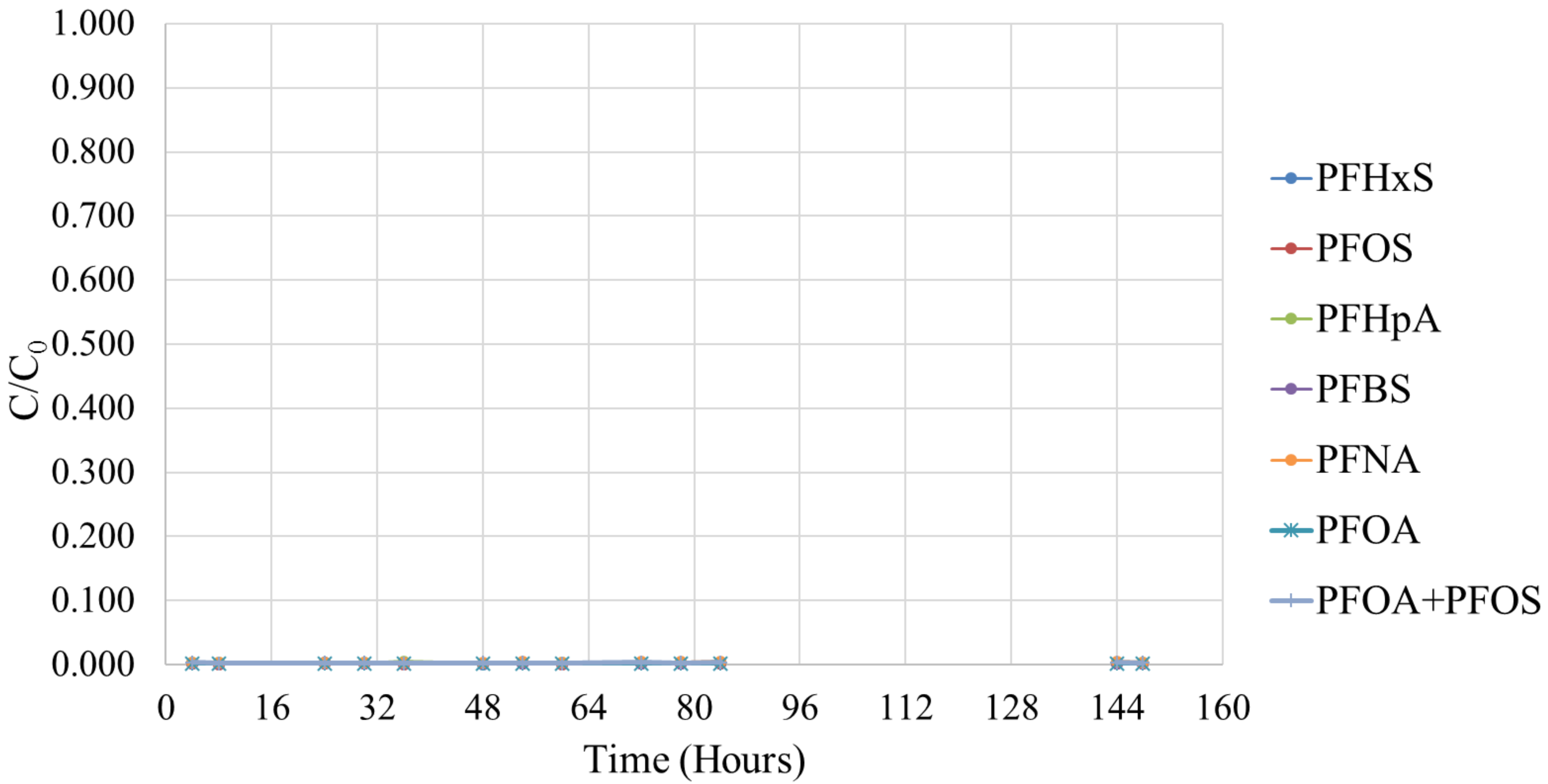
Sample Ports – Influent from 5000 gallon tank line and Effluent from RO permeate line.

RO System Sampling Plan

Day #	Day of Week	Time of Day	Sample Hour	Time of Day	Sample Hour	Time of Day	Sample Hour
Day 1	Tues	AM	Startup*	Noon	4 hr	PM	8 hr
Day 2	Wed	AM	24 hr	Noon	30 hr	PM	36 hr
Day 3	Thurs	AM	48 hr	Noon	54 hr	PM	60 hr
Day 4	Fri	AM	72 hr	Noon	78 hr	PM	84 hr
Day 5	Sat	2 Day Stagnation Period*					
Day 6	Sun						
Day 7	Mon	AM	144 hr	PM	148 hr	PM	Shutdown*
Day 8	Tues	Ship					

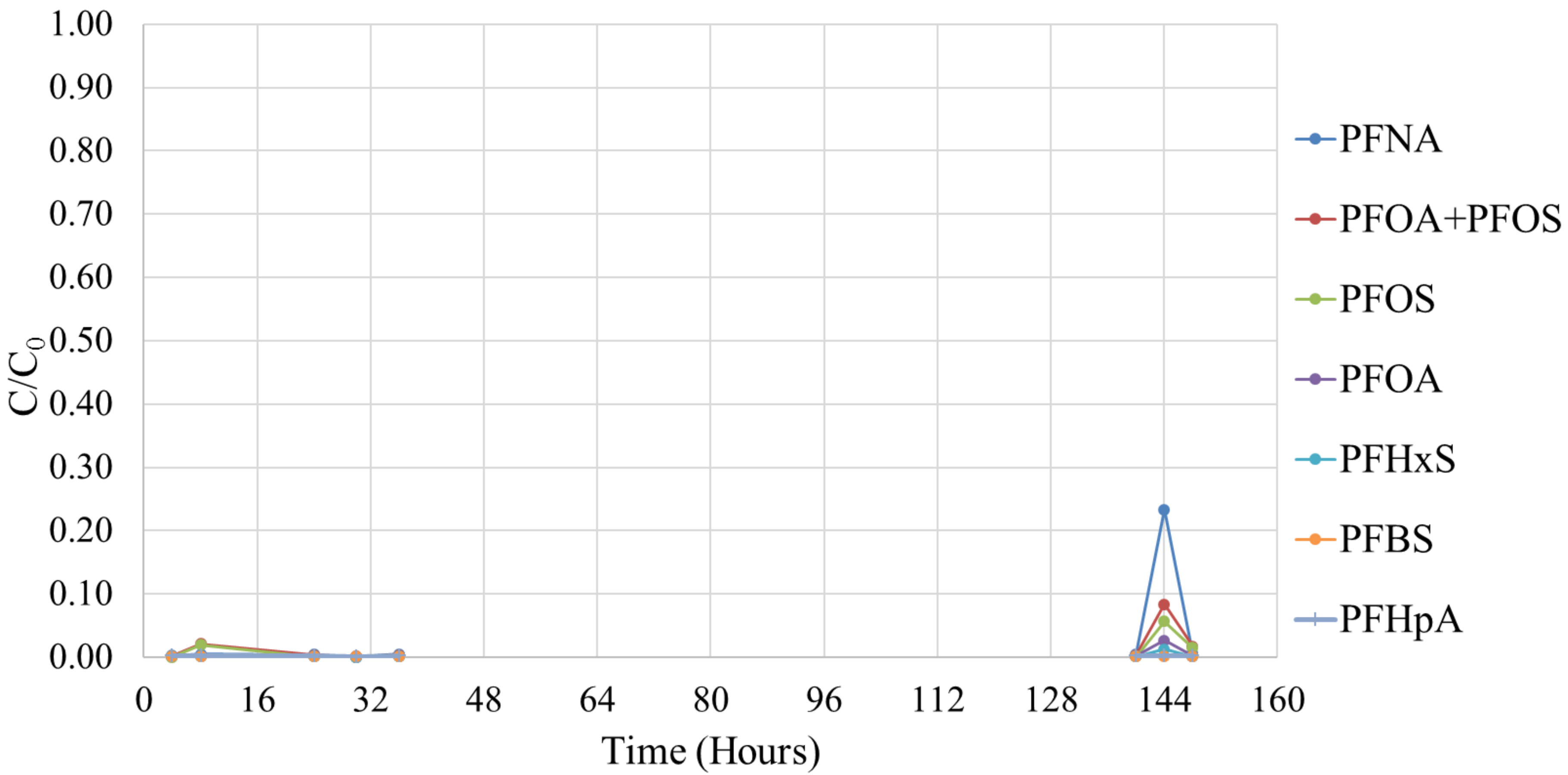
* No samples collected

PFAS Removal vs. Time iSpring RO#1



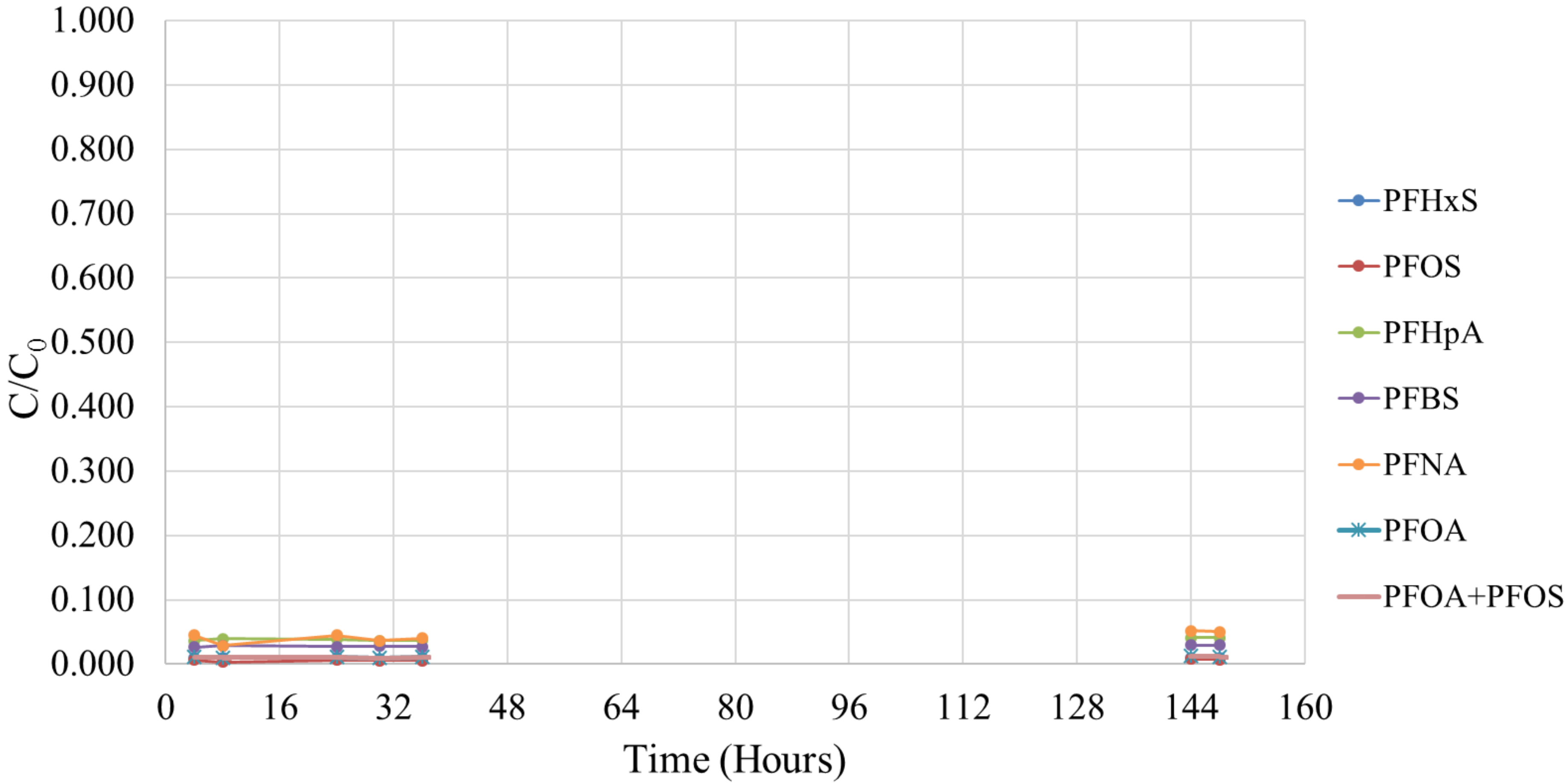
All effluent PFAS results were non-detect

PFAS Removal vs. Time Hydrologic RO#2



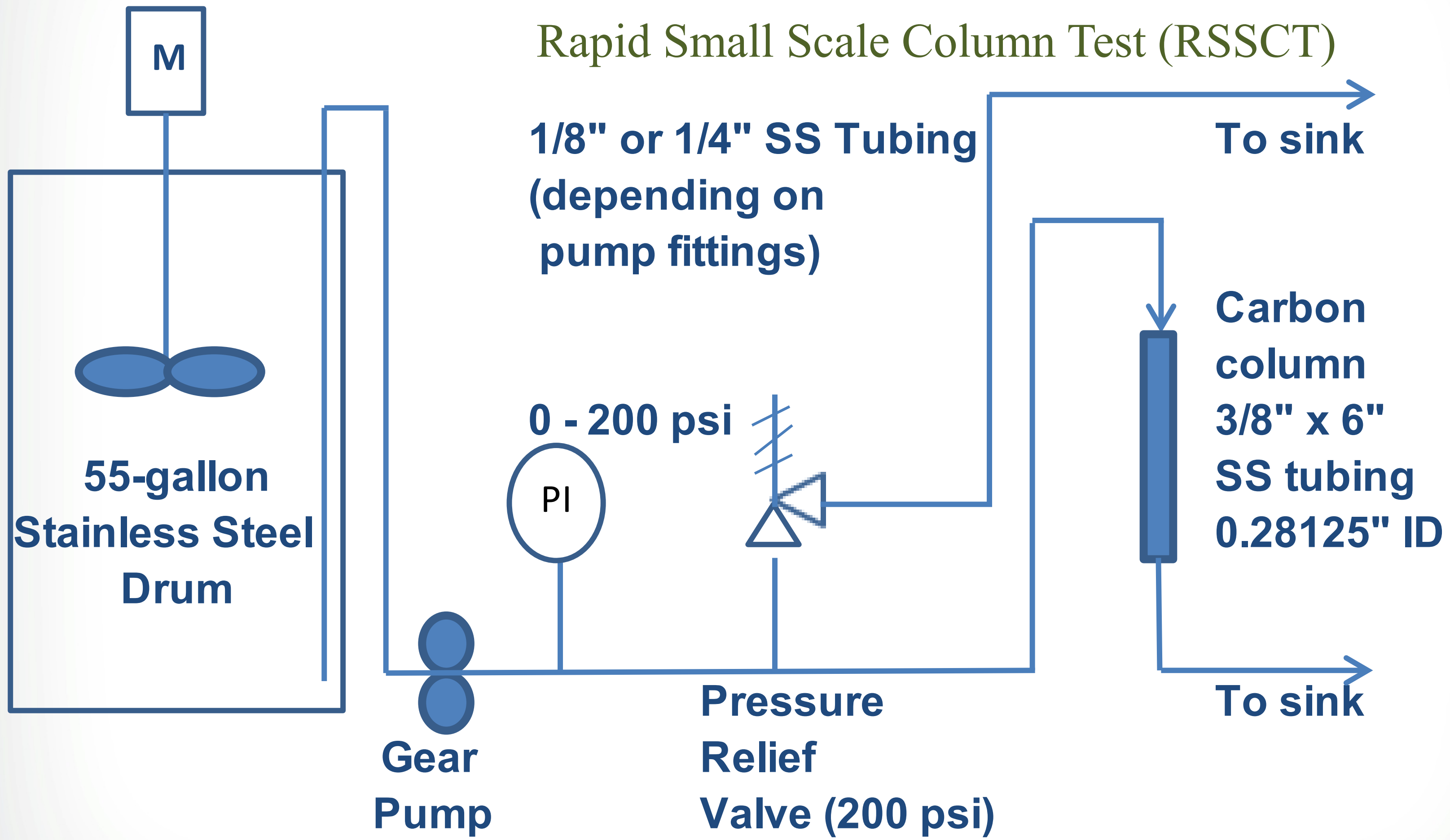
6 of 42 PFAS results were greater than non-detect

PFAS Removal vs. Time Flexeon RO#3



All effluent PFAS results were non-detect

GAC Test Unit



Sample Ports - Influent from 55 gallon drum, Effluent from SS tubing every 30 min for 8 hrs.

GAC RSSCT Media

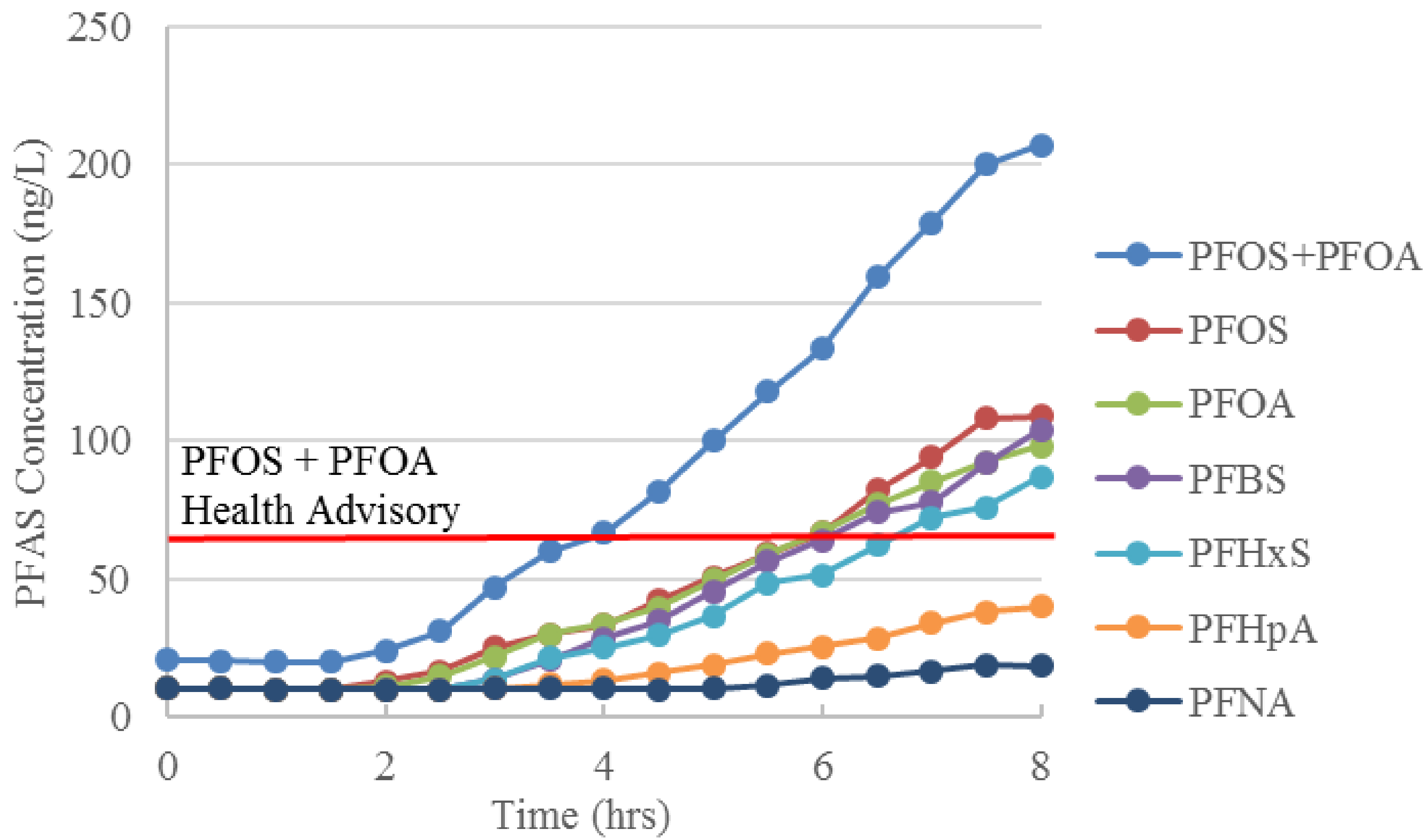
Commercially available GAC media tested:

- Evoqua 12x30 Mesh RSSCT 170x200 Mesh
- Calgon 12x40 Mesh RSSCT 170x200 Mesh

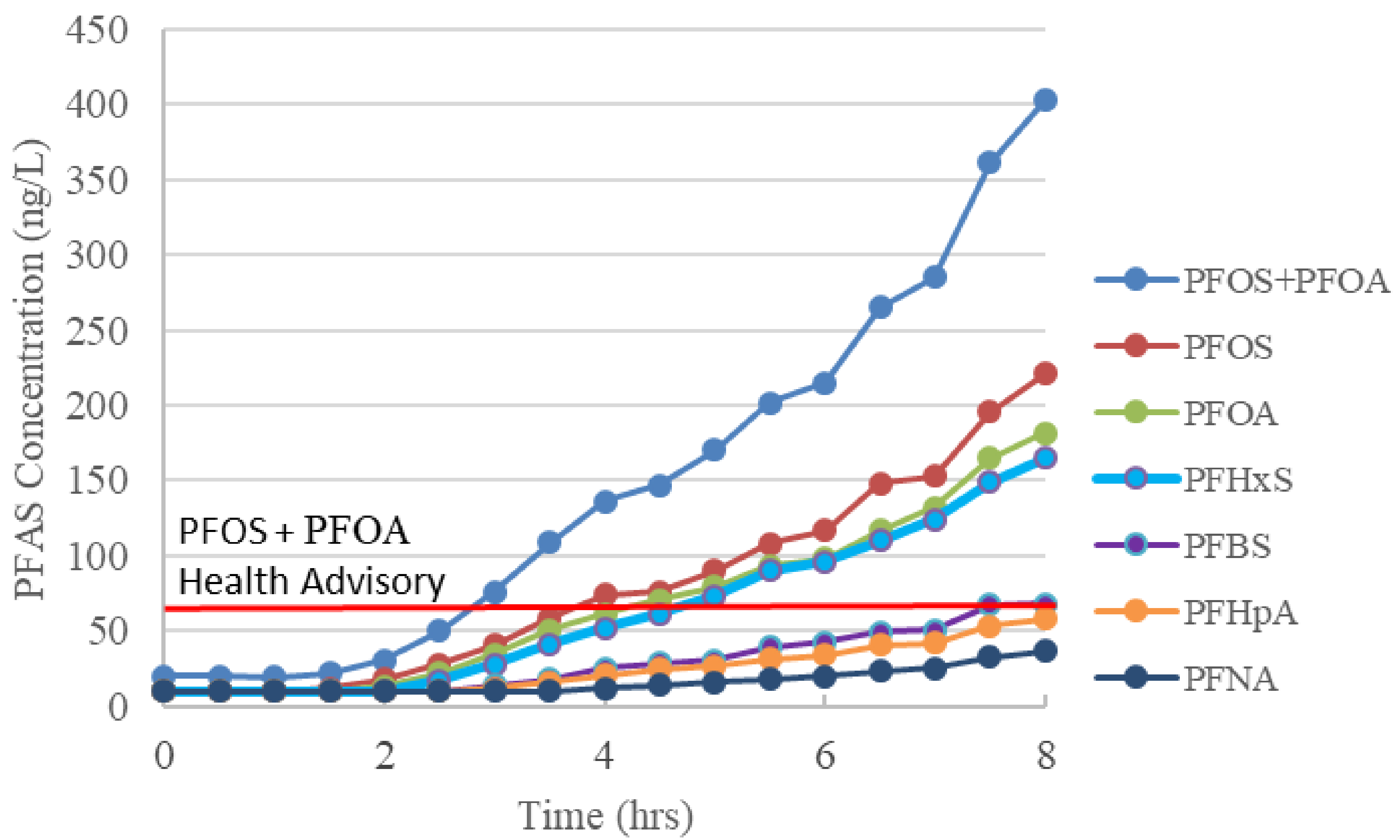
GAC

Grinding and Sieving GAC to meet RSSCT Mesh Screen Sizes

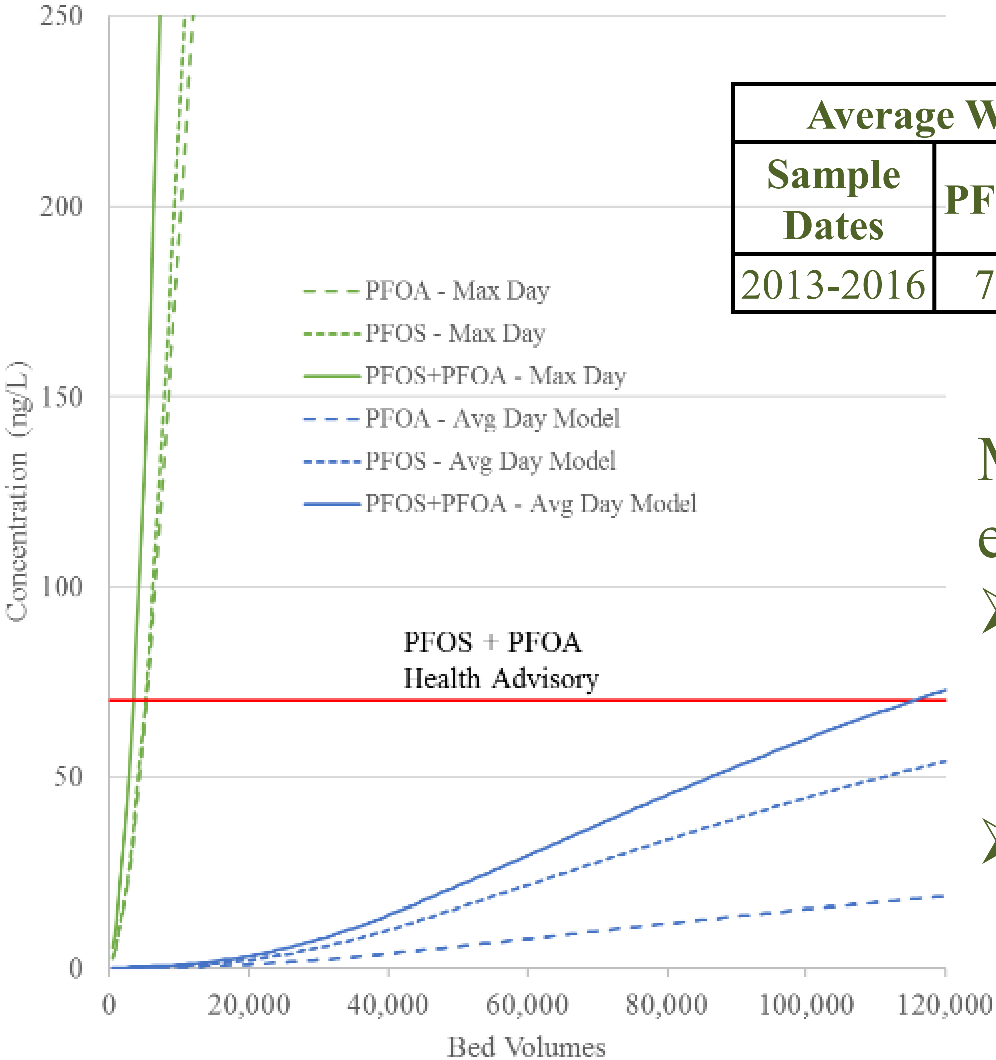
Maximum PFAS Concentrations vs. Time Evoqua GAC#1



Maximum PFAS Concentrations vs. Time Calgon GAC#2



Average PFAS Conc. vs. Bed Volumes Evoqua GAC#1

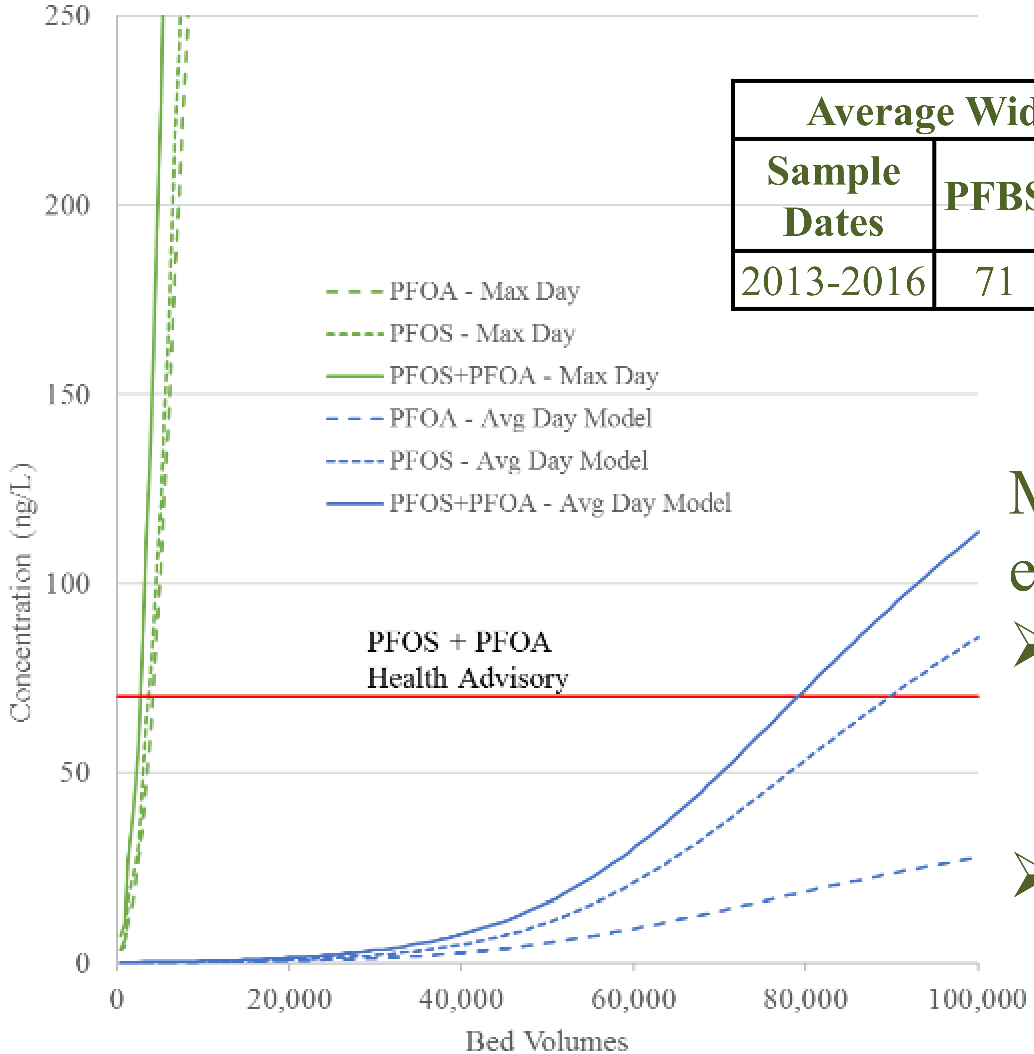


Average Widefield Aquifer PFAS Concentrations (ng/L)							
Sample Dates	PFBS	PFHxS	PFNA	PFHpA	PFOA	PFOS	PFOS+ PFOA
2013-2016	71	203	16	24	43	137	180

Model results of PFOS and PFOA effluent concentrations

- Predicted Max. PFOS+PFOA > HAL of 70 ng/L after 3,400 BVs (24 days of operation)
- Predicted Avg. PFOS+PFOA > HAL of 70 ng/L after 115,000 BVs (2.2 years of operation)

Average PFAS Conc. vs. Bed Volumes Calgon GAC#2



Average Widefield Aquifer PFAS Concentrations (ng/L)							
Sample Dates	PFBS	PFHxS	PFNA	PFHpA	PFOA	PFOS	PFOS+ PFOA
2013-2016	71	203	16	24	43	137	180

Model results of PFOS and PFOA effluent concentrations

- Predicted Max. PFOS+PFOA > HAL of 70 ng/L after 2,700 BV (19 days of operation)
- Predicted Avg. PFOS+PFOA > HAL of 70 ng/L after 79,000 BVs (1.5 years of operation)

RO Modification for Point-of-Entry Use

RO = $500

RO Booster Pump = $880

6’2”

31”

Requires at least a 4’x4’ Room

28”

25”

= $2000 before installation, Weight: 150 lbs

Large Whole House Carbon Tanks Required for PFAS Removal (10 min EBCT each)

One 4-5 GPM Non-Backwashing Whole House Carbon Water Filter ($539) 35”(H) x 9”(D) tank with 30 lbs (1 cu ft) of GAC (Source: H_2O Distributors)

Two Large Whole House Backwashing Carbon Water Filter ($3990) 65”(H) x 16”(D) tank with 240 lbs (8 cu ft) of GAC (Source: H_2O Distributors)

EPA

GAC Modification for PFAS Removal

Well Water Flow must be restricted to 5 gpm

=

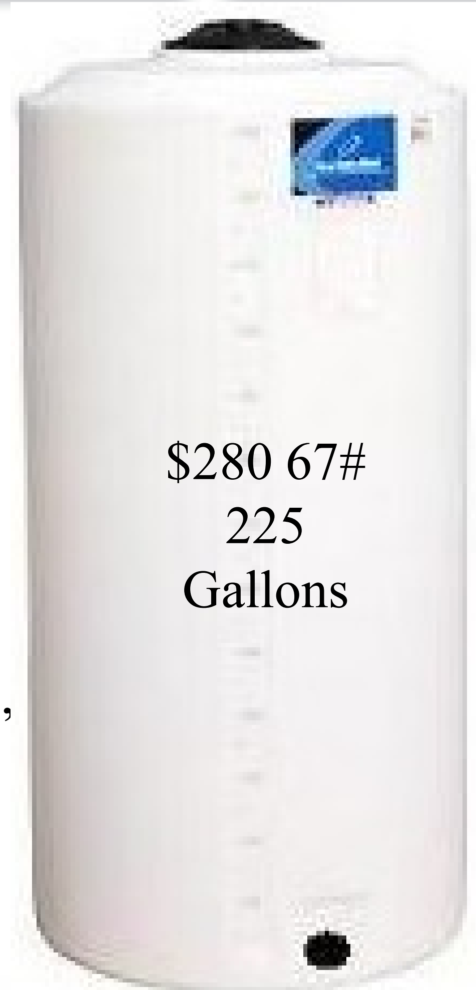
$4000 before installation, Weight: 330 lbs

Small GAC System for PFAS Removal

Well Water Flow must be restricted to 0.5 gpm*

35'

9"



31"

6'2"

Requires at least a 4'x4' Room

28"

25"

= $1200 before installation, Weight: 200 lbs

Conclusions

- The three RO systems tested successfully removed PFAS from the influent water to below analytical detection for a majority of the sampling events. However, long-term performance of the membrane systems was not tested.
- RSSCT data estimated that the coal-based Calgon F-600 GAC would have a lifetime of 20 days compared to the coconut-based Evoqua GAC lifetime of 33 days based on maximum PFAS concentrations tested before exceeding the EPA's HAL of 70 ng/L for PFOS and PFOA.
- Modeling the results for lower concentrations (average daily concentrations) gave bed lives of 1.5 years for the Calgon F-600 GAC and 2.2 years for the Evoqua Coconut carbon. However, additional pilot-tests should be performed to ensure the use of the best performing GAC for each application.

Conclusions

- If properly designed based on the source water characteristics, POU/POE water systems can provide relatively inexpensive treatment barriers for PFAS removal in the home.
- Analysis of PFAS samples is costly for homeowners and can be a major hurdle in effective removal of PFAS from household water supplies.
- Proper operation and maintenance and conservative replacement of POU/POE components and media may be one way to circumvent the high cost of monitoring treated household drinking water.

Disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and managed, or partially funded or collaborated in, the research describe herein. It has been subjected to the Agency's peer and administrative review and has been approved for external publication. Any opinions expressed in this paper are those of the author (s) and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Questions?

Patterson.Craig@epa.gov