Remediation Technologies Symposium (RemTech)

Sorptive Media Selection for PFAS Treatment in Drinking Water Using Rapid Small-Scale Column Tests – A Case Study

October 11, 2023; 2:20 pm - 2:50 pm
Fairmont Banff Springs

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Agenda

- Drinking Water Treatability Objectives
- RSSCT Setup & Results
- Media Changeout Projection
- Recommendation and Next Steps

Objectives

- Achieving PFAS concentrations as low as reasonably achievable “ALARA”.
  - ALARA is defined as a maximum of 30 ng/L for the sum of individual PFAS when analyzed at a detection limit of 5 ng/L or lower for each PFAS analyzed using the EPA Methods 533 and 537.1.
- Evaluate the feasibility of each technology to meet the treatment objective of ALARA for detected PFAS.
- Evaluate performance criteria for adsorptive media (breakthrough times and replacement intervals).
- Identify anticipated replacement frequency for each media tested.

RSSCT Setup & Results

Test Water

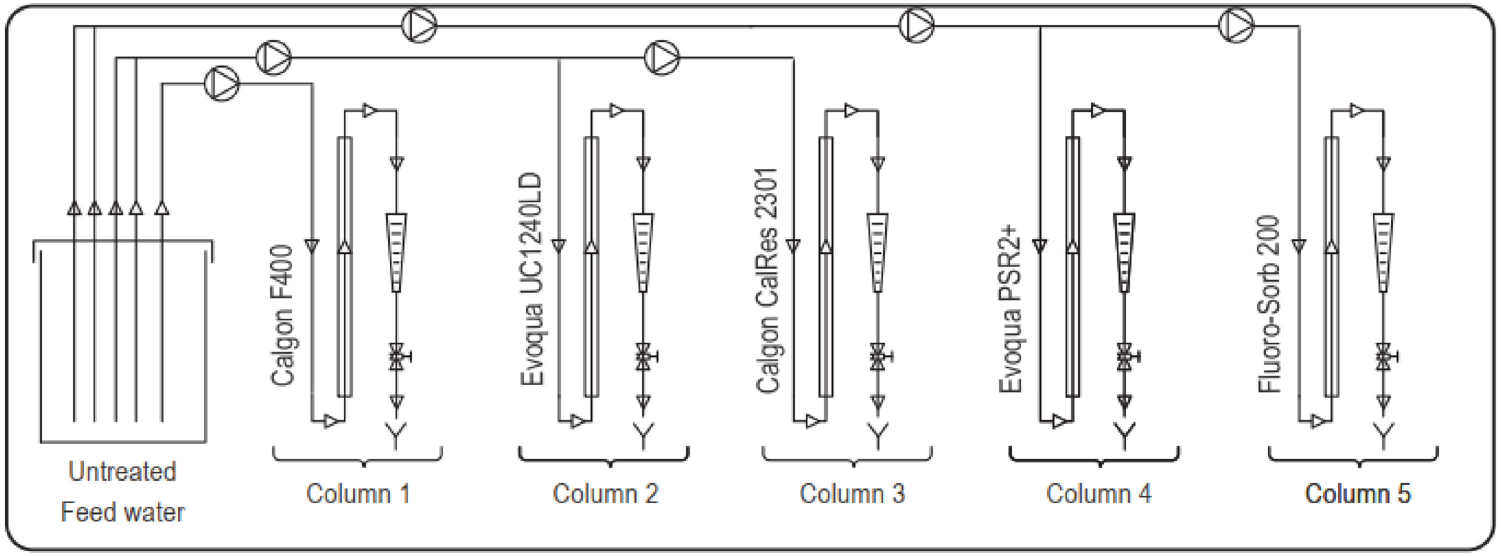
- Eight (8) 55-gallon drums of MF permeate (prior to UV) were collected for testing

Parameter	Units	Value	Parameter	Units	Value
General Chemical and Mineral Parameters					
pH	—	7.21	Iron	mg/L	0.009
TOC	mg/L	3	Manganese	mg/L	0.001
Alkalinity	mg/L CaCO3	14	Calcium	mg/L	5.25
Sulphate	mg/L	4	Magnesium	mg/L	1.45
Nitrate	mg/L as N	0.13			
Detected PFAS Chemicals (Modified EPA Method 537.1, 40 PFAS)					
Perfluorobutanoic acid (PFBA)				ng/L	3.7
Perfluoropentanoic acid (PFPeA)				ng/L	6.3
Perfluorohexanoic acid (PFHxA)				ng/L	6.1
Perfluoroheptanoic acid (PFHpA)				ng/L	4.0
Perfluorooctanoic acid (PFOA)				ng/L	4.3
Perfluorononanoic acid (PFNA)				ng/L	1.1 J
Perfluorobutanesulfonic acid (PFBS)				ng/L	1.1 J
Perfluoropentanesulfonic acid (PFPeS)				ng/L	0.95 J
Perfluorohexanesulfonic acid (PFHxS)				ng/L	11.7
Perfluorooctanesulfonic acid (PFOS)				ng/L	31.8
			Sum of Detected PFAS	ng/L	71.05

Notes:

J = Indicates an estimated value

RSSCT Setup and Media Tested



Media Type	Supplier	Product	Material
Granular Activated Carbon (GAC)	Calgon	Calgon F400-1	Bituminous GAC
	Evoqua	Evoqua UC1240LD	Sub-bituminous GAC
Ion Exchange (IX)	Calgon	Calgon CalRes 2301	Single-use Resin
	Evoqua	Evoqua PSR2+	Single-use Resin
Novel adsorbent	CETCO	Fluoro-Sorb® (FS) 200	Surface modified clay

RSSCT Design

- The design of the RSSCT column involves:
  - selecting the media size
  - operating conditions that are hydraulically similar to the full-scale system
  - mathematical relationships used to scale

$$Scale\ Factor = \frac{EBCT_{FS}}{EBCT_{SS}} = [\frac{d_{FS}}{d_{SS}}]^2 = \frac{t_{FS}}{t_{SS}}\ (constant\ diffusivity\ scale - up\ model)$$

where $EBCT_{FS}$ is the full-scale EBCT value, $EBCT_{SS}$ is the Small-Scale EBCT value, d_{FS} is the full-scale media diameter. d_{SS} is the Small-Scale media diameter, t_{FS} is the full-scale operating time, t_{SS} is the Small-Scale column operating time.

RSSCT Design

- The RSSCTs were configured under a modified ASTM International D6586-03.

Rapid Small-scale Column Test Design Parameters

Design Criteria	GAC	IX	FLUORO-SORB
Full-scale EBCT (minutes)	10	2	2
Full-scale Particle Size (mesh)	12 x 40	-	20 x 40
Full-scale Mean Particle Size (cm)	0.084	0.070	0.060
Diffusivity Relationship	Constant	Constant	Constant
Reynolds-Schmidt Number Product (small column)	500	1,150	850
Test Column Diameter (cm)	0.70	0.70	0.70
Test Column Bed Depth (cm)	3.0	2.0	2.0
Test Column Adsorbent Particle Size (mesh)	100 x 140	100 x 140	100 x 140
Small-scale Mean Particle Size (cm)	0.0127	0.0127	0.0127
Assumed Product Density (g/mL)	0.54	0.50	0.73
Adsorbent Mass (g)	0.627	0.385	0.576
Test Column Flow Rate (mL/min)	5.1	11.7	8.7
Small-scale EBCT (minutes)	0.228	0.066	0.091
Nominal No. of Bed Volumes	153,000	368,000	480,000
Test Duration per RSSCT (days)	24	17	30
Water Test Volume per Column (U.S. gallons)	47	75	100

Notes:

Two GAC and two IX tests were conducted.

cm = centimetre(s)

EBCT = empty bed contact time

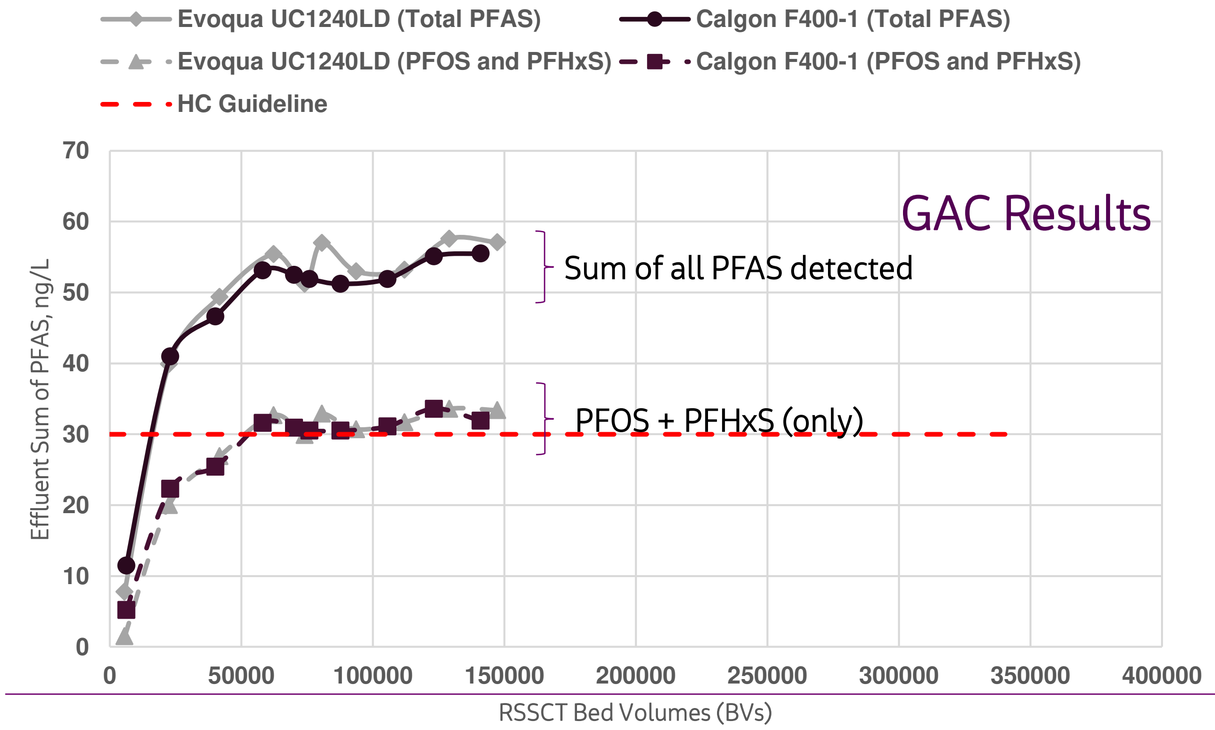
g/mL = gram(s) per millilitre

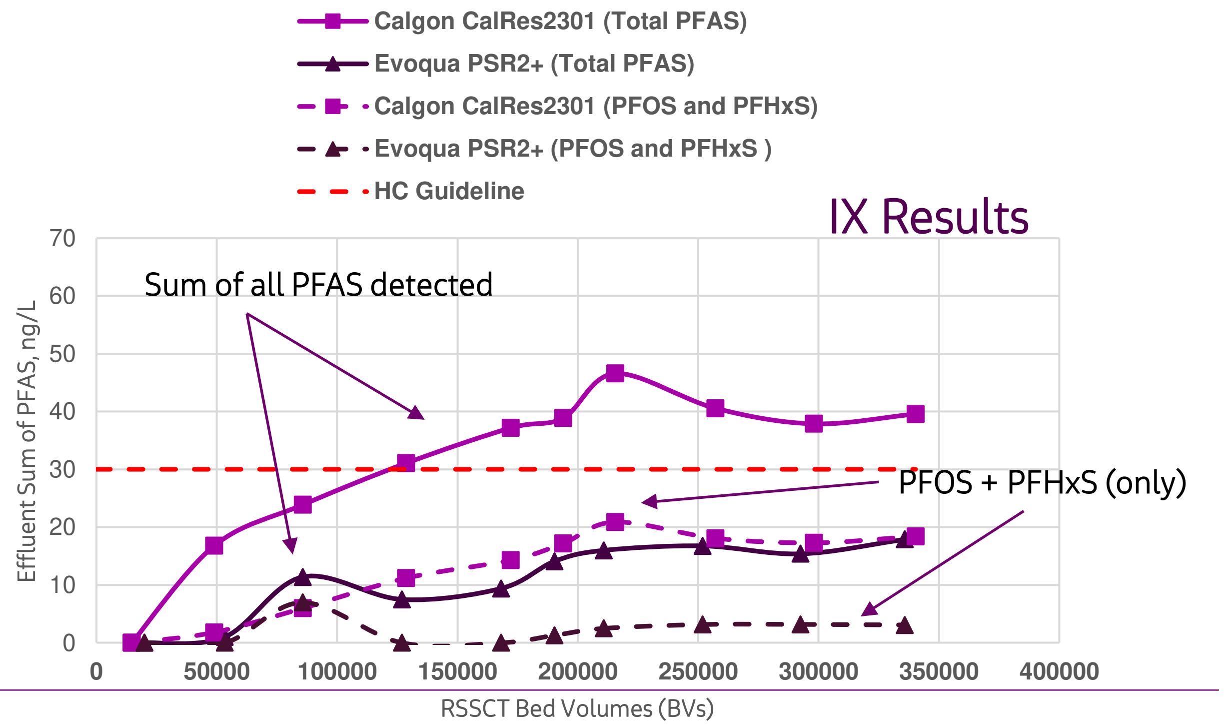
mL/min = millilitre(s) per minute

RSSCT Results

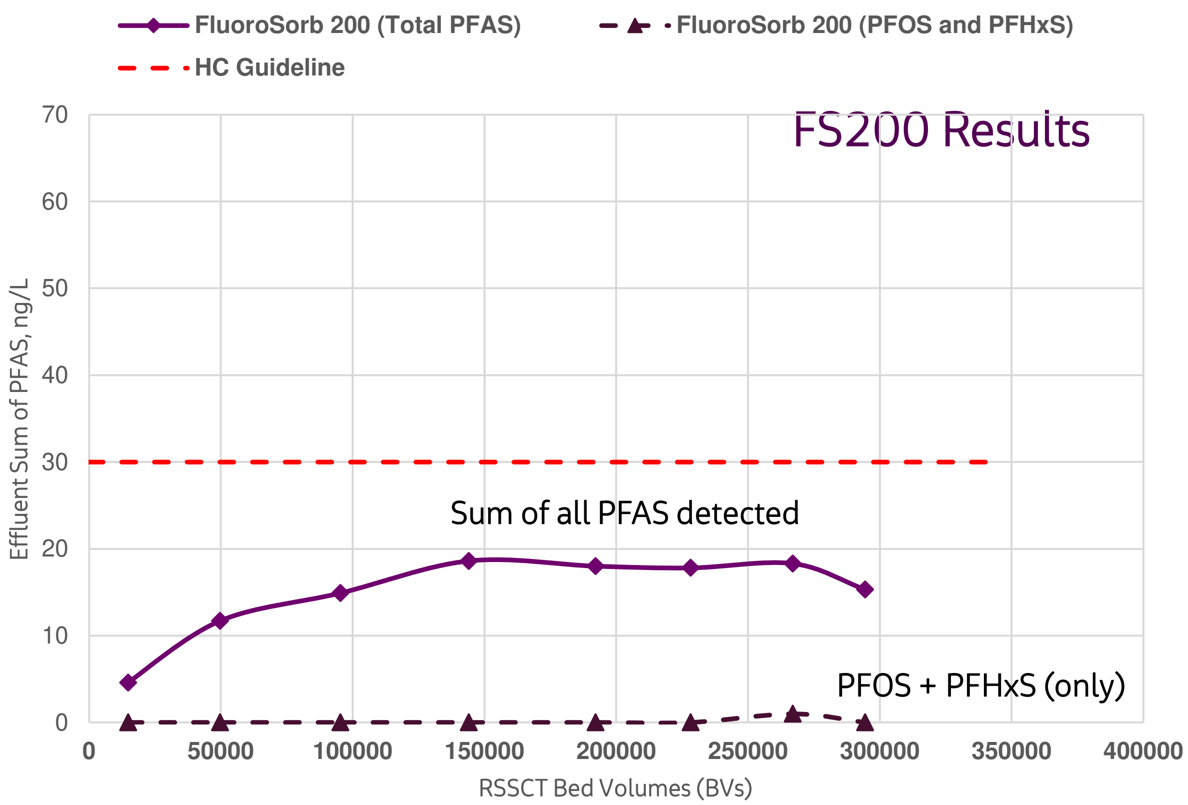
S: Start; M: Middle; E: End of the RSSCT test

Parameter	Unit	GAC (F400-1)			GAC (UC1240LD)			IX (CalRes 2301)			IX (PSR2+)			FS200		
		S	M	E	S	M	E	S	M	E	S	M	E	S	M	E
pH	—	7.08	7.62	7.58	7.07	7.52	7.52	7.03	7.24	7.38	7.03	7.16	7.43	7.02	7.34	7.42
TOC	mg/L	2	3	3	2	3	3	3	3	3	2	3	3	3	3	3
Alkalinity	mg/L $CaCO_3$	14	15	15	14	14	15	14	14	15	14	16	15	14	15	15
Sulphate	mg/L	4	4	5	5	4	5	4	5	5	4	4	5	5	5	5
Nitrate	mg/L as N	0.10	0.12	0.12	0.08	0.12	0.11	0.09	0.12	0.12	0.07	0.16	0.12	0.10	0.12	0.12





RSSCT Results (cont'd)



- Best Results (more BVs treated): Evoqua PSR2+ (IX) & FS200
- Footprint and conceptual level costs needed to determine what would be most economical

Media Changeout Projection

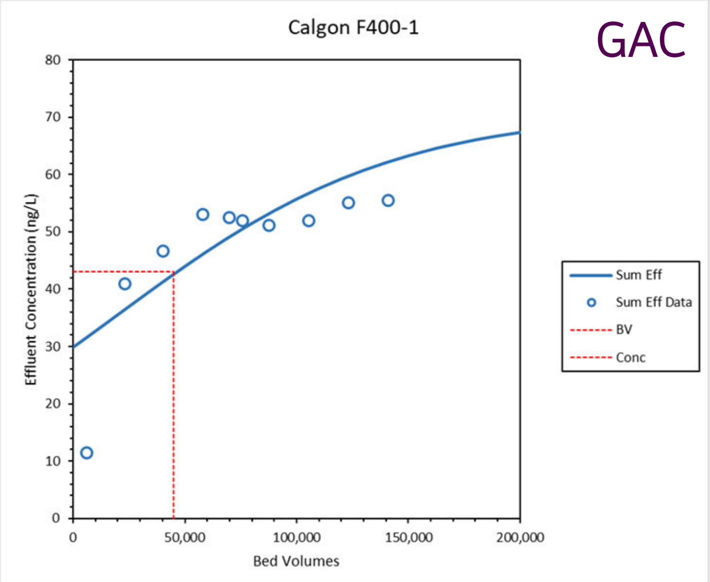
Modeling of Adsorption Breakthrough Curve

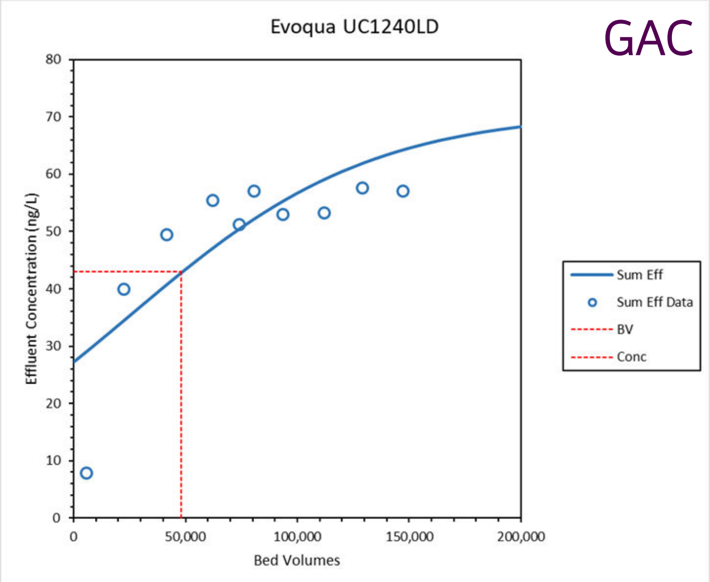
- Using the single-bed RSSCT results, projected media usage rates and changeout frequency for a full-scale lead-lag systems were calculated.
- Projection of adsorbent use rates and costs with the 60% breakthrough capacity using Yoon-Nelson empirical model

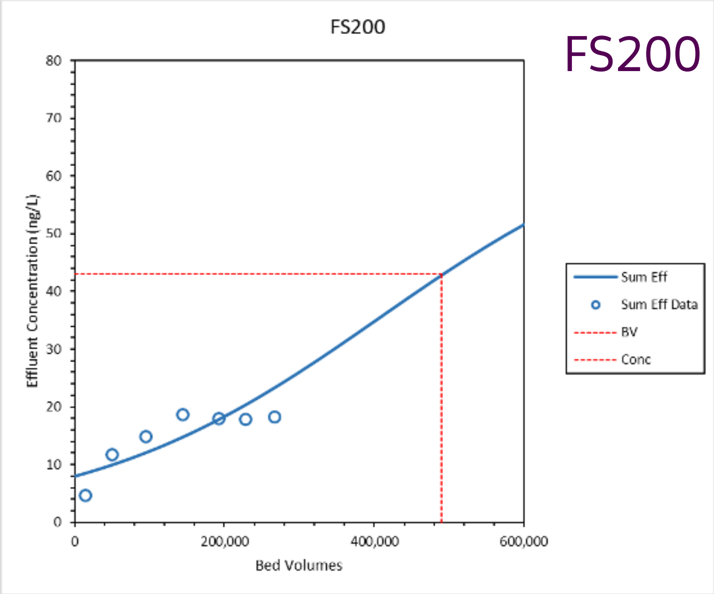
$$t = \tau + \frac{1}{k_{YN}} ln \frac{C}{C_0 - C}$$

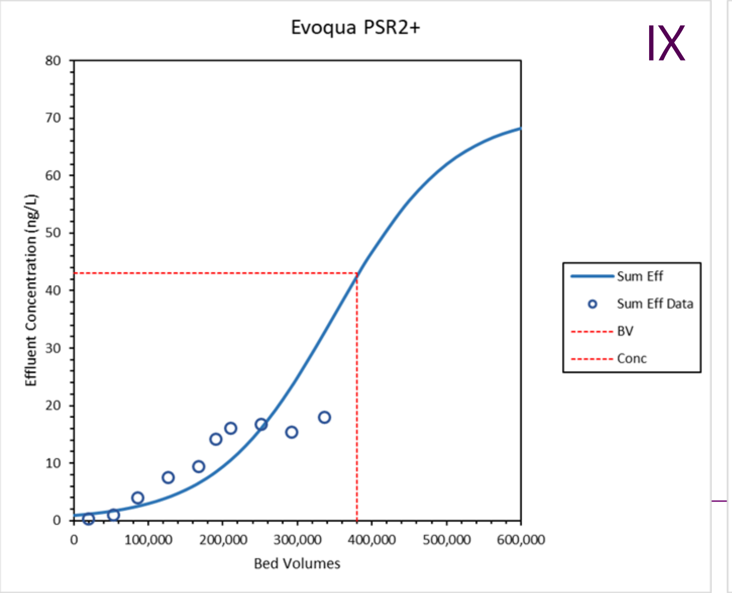
where t is the full-scale system operation time (days), τ is the time to reach 60% breakthrough, k_{YN} is the rate velocity constant (day^{-1}), C and C_0 are effluent and influent total PFAS concentrations, respectively.

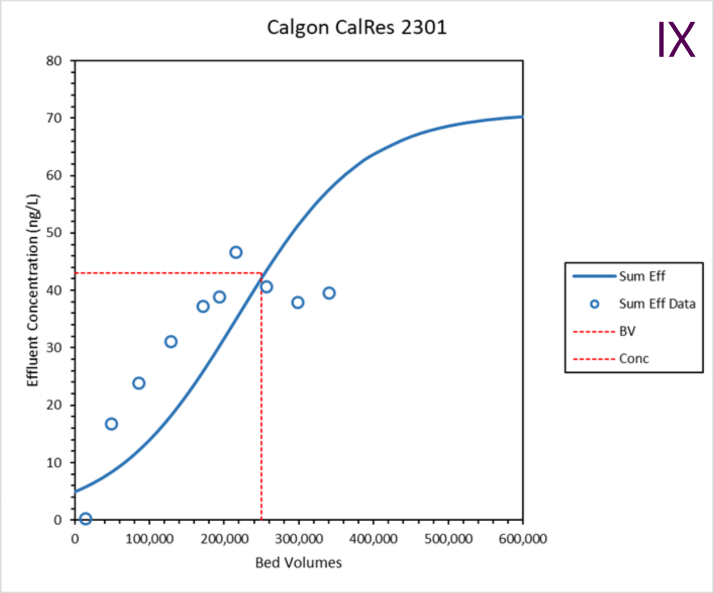
Media Performance and Changeout Projections











Changeout Projections

Description	GAC 20K lb [a]	GAC 40K lb [b]	IX	FS
Estimated Lead Bed Usage to Reach 60% Exhaustion [1]	45,000 BV (F400-1) 48,000 BV (UC1240)	45,000 BV (F400-1) 48,000 BV (UC1240)	380,000 BV (PSR2+) 250,000 BV (2301)	490,000 BV
Time frame to Changeout [2]	10 months (F400-1) 11 months (UC1240)	10 months (F400-1) 11 months (UC1240)	17 months (PSR2+) 11 months (2301)	22 months
Estimated System Effluent (Total PFAS, ng/L) Concentration at Changeout	19	19	14	14

Notes:

[a] Shorter version of 12 ft diameter vessel that is commercially available and holds 20,000 lb GAC

[b] Taller version of 12 ft diameter vessel that is commercially available and holds 40,000 lb GAC

1. Predicted from the Yoon-Nelson empirical modelling using RSSCT data
2. Assumes continuous operation at 40 ML/d EBCT of 10 min (GAC) and 2 min (IX and FS), respectively

Recommendations and Next Steps

Recommendations and Next Steps

- **Based RSSCT results:**
  - Evoqua PSR2+ and FS appeared to have the best PFAS removal performance with no clear differentiation between them.
  - FS200 is feasible but has not been implemented at full-scale in Canada and would require regulatory approval
- **To develop a conceptual cost estimate, the following should be considered:**
  - Site specific issues (power, space, soils, sewer capacity, hydraulic integration, site restoration)
  - Continuity of operations
  - Market conditions
  - Escalation

Thank You!

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