PFAS Removal from Drinking Water: Granular Activated Carbon vs. Ion Exchange

CalgonCarbon
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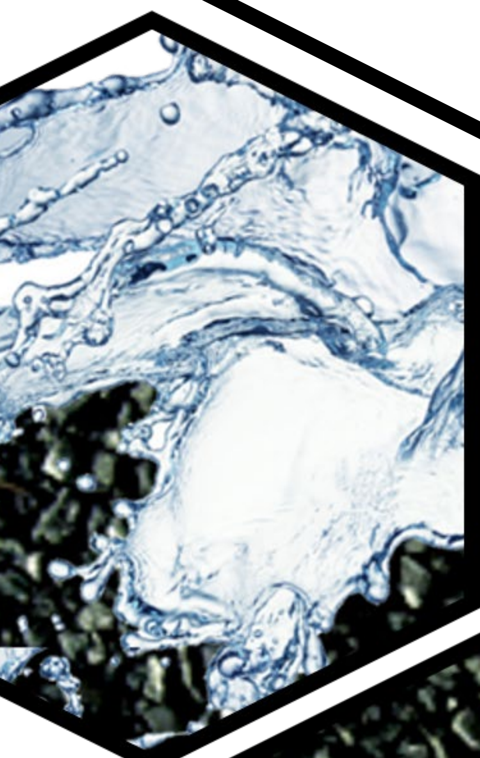
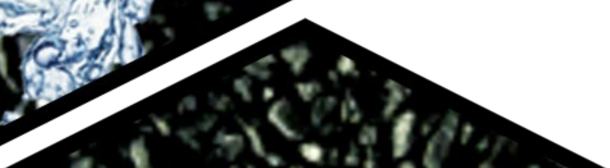
Topics

- **Pilot Study Goals**
- **Pilot Configuration**
- **Notable Results to Date**
  - Source Material Comparison
  - Linear vs. Branched Isomers
  - IX Performance
  - GAC vs. IX Performance
- **Economic Analyses**
- **Conclusions**

Pilot Study Goals

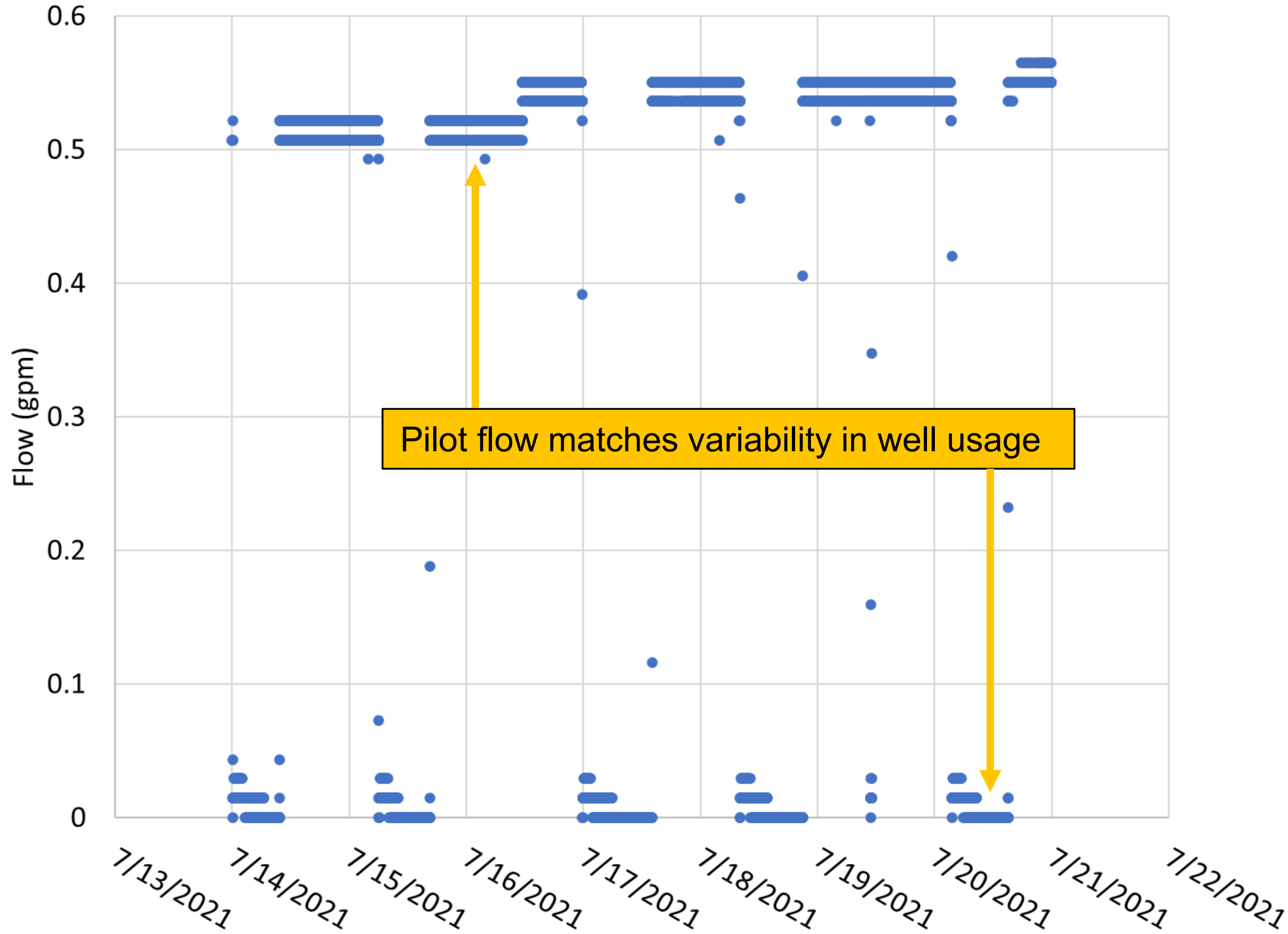
- Directly compare the performance of GAC and IX in a scalable manner
- Match pilot-scale HLR to full-scale HLR.
- Collect and analyze influent and effluent samples for multiple water quality parameters.
- Use performance data to:

1) evaluate effluent concentrations vs bed volumes
2) estimate expected capital and operational cost
3) identify most favorable medias for this site

Pilot Configuration

- Two Granular Activated Carbons (GACs)
  - Filtrasorb® 400 (bituminous coal-based)
  - Sub-bituminous coal-based
  - Both GACs >1000 mg/g iodine number
- Two Anion Exchange Resins
  - Macroporous
  - Gel-Type
- Bi-Weekly PFAS Analyses by Center for PFAS Solutions
  - EPA Methods 537 & 533
- Monthly general water quality analyses by Eurofins
  - Anions (e.g. sulfate, nitrate, & chloride)
  - Alkalinity
  - Total Organic Carbon (TOC)
  - pH

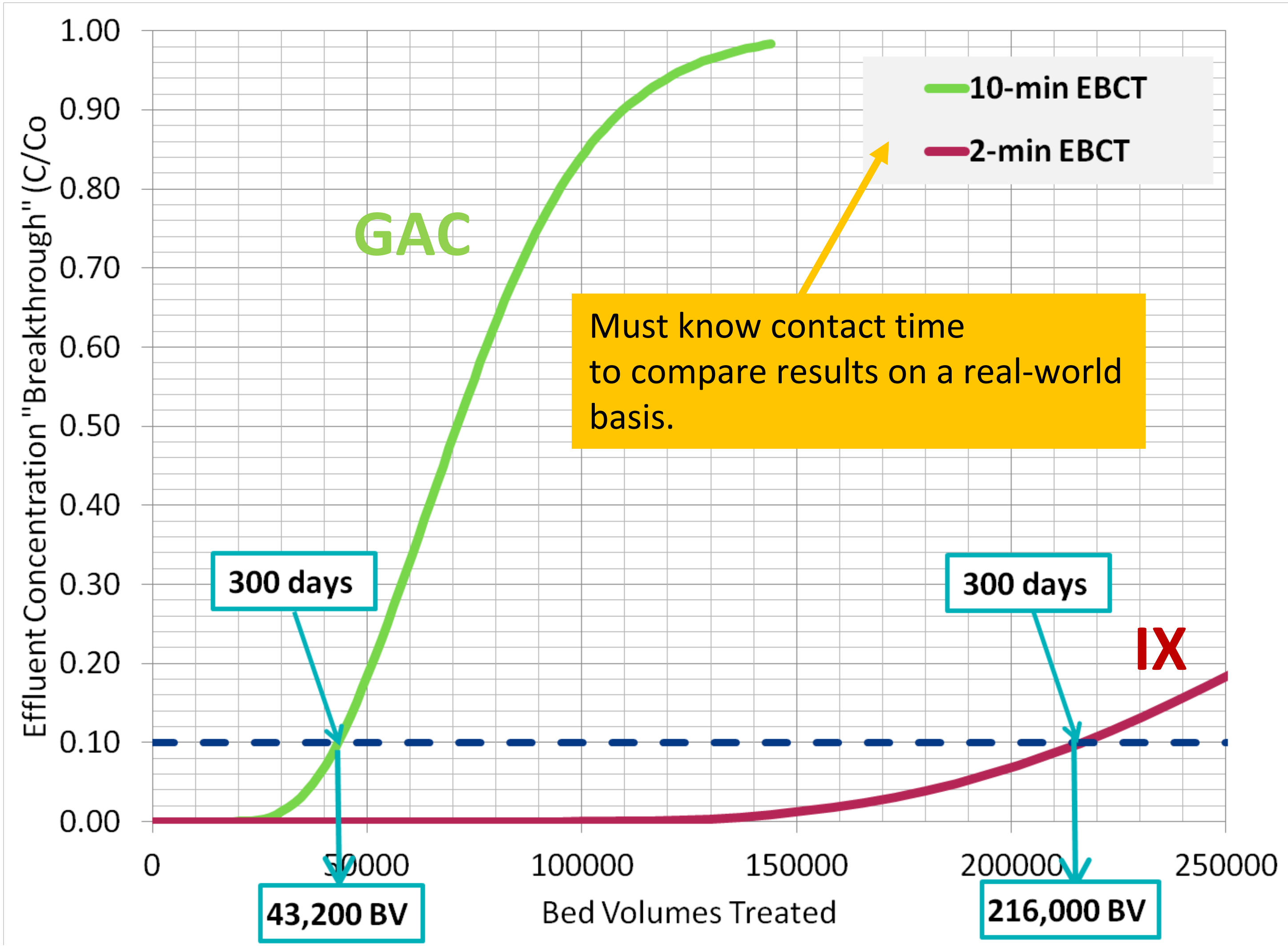
Pilot Configuration: Flow Rates



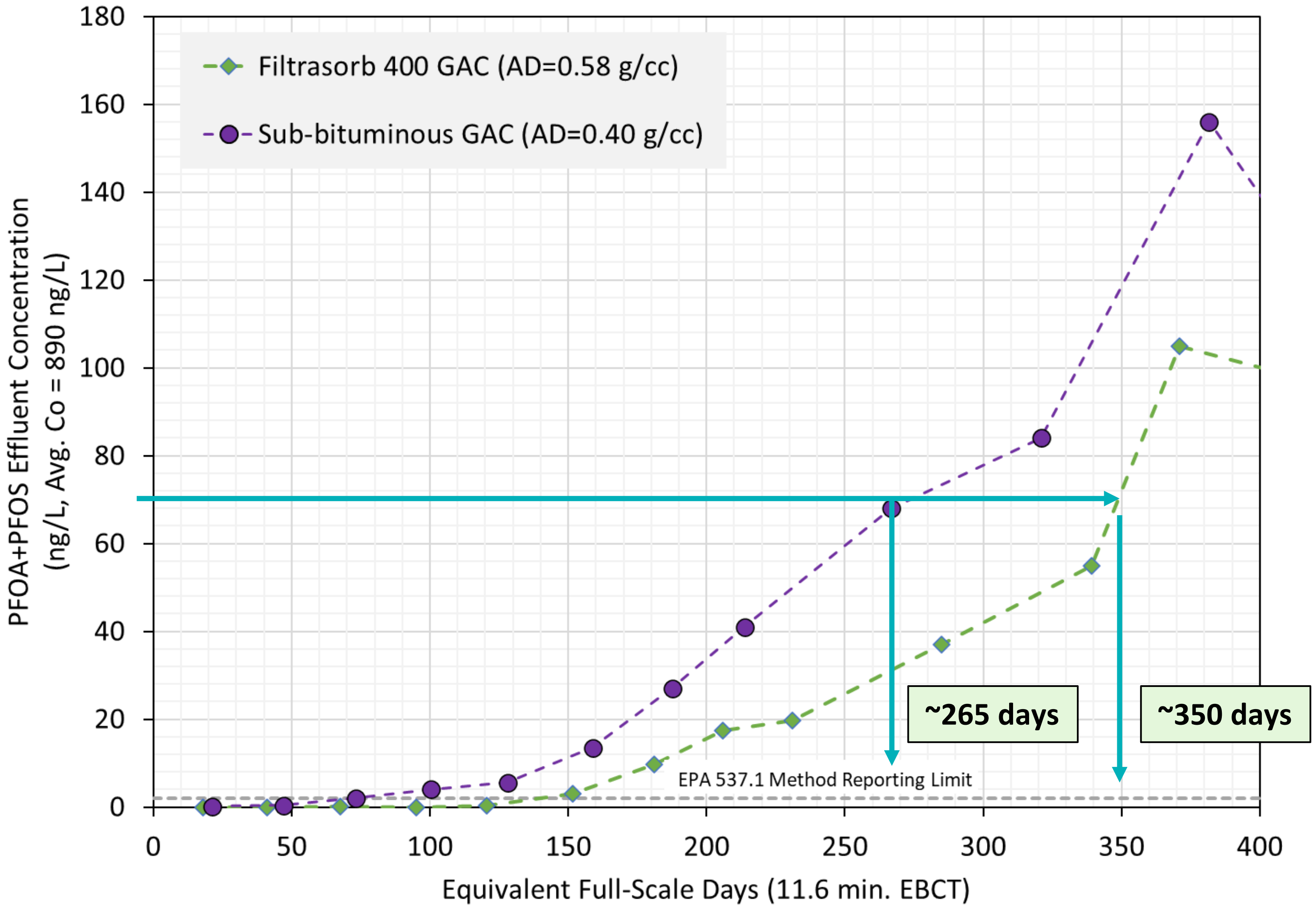
Pilot Configuration: Water Quality

Analyte	Result	Qualifier	RL	MDL	Unit
Nitrogen, Nitrate	3.0		0.50	0.25	mg/L
Sulfate	9.5		5.0	1.5	mg/L
Chloride	82		20	10	mg/L
Iron	0.019	J B	0.21	0.016	mg/L
Total Alkalinity as CaCO3 to pH 4.5	14		8.0	2.6	mg/L
Total Hardness	81		50	15	mg/L
Specific Conductance	340		5.0	1.7	umhos/cm
Total Organic Carbon	0.56	J	1.0	0.50	mg/L

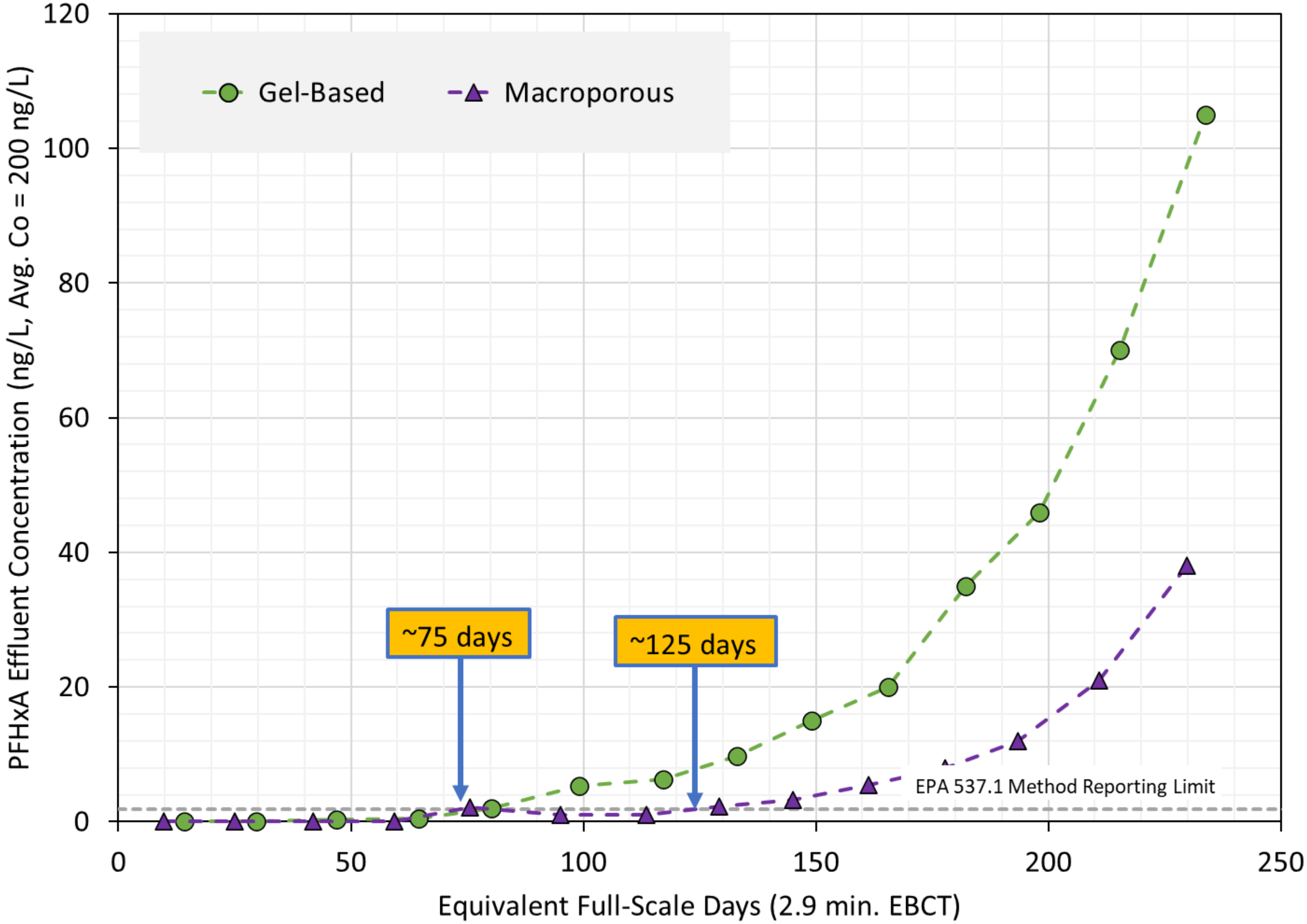
Notable Results: Understanding Breakthrough Curves



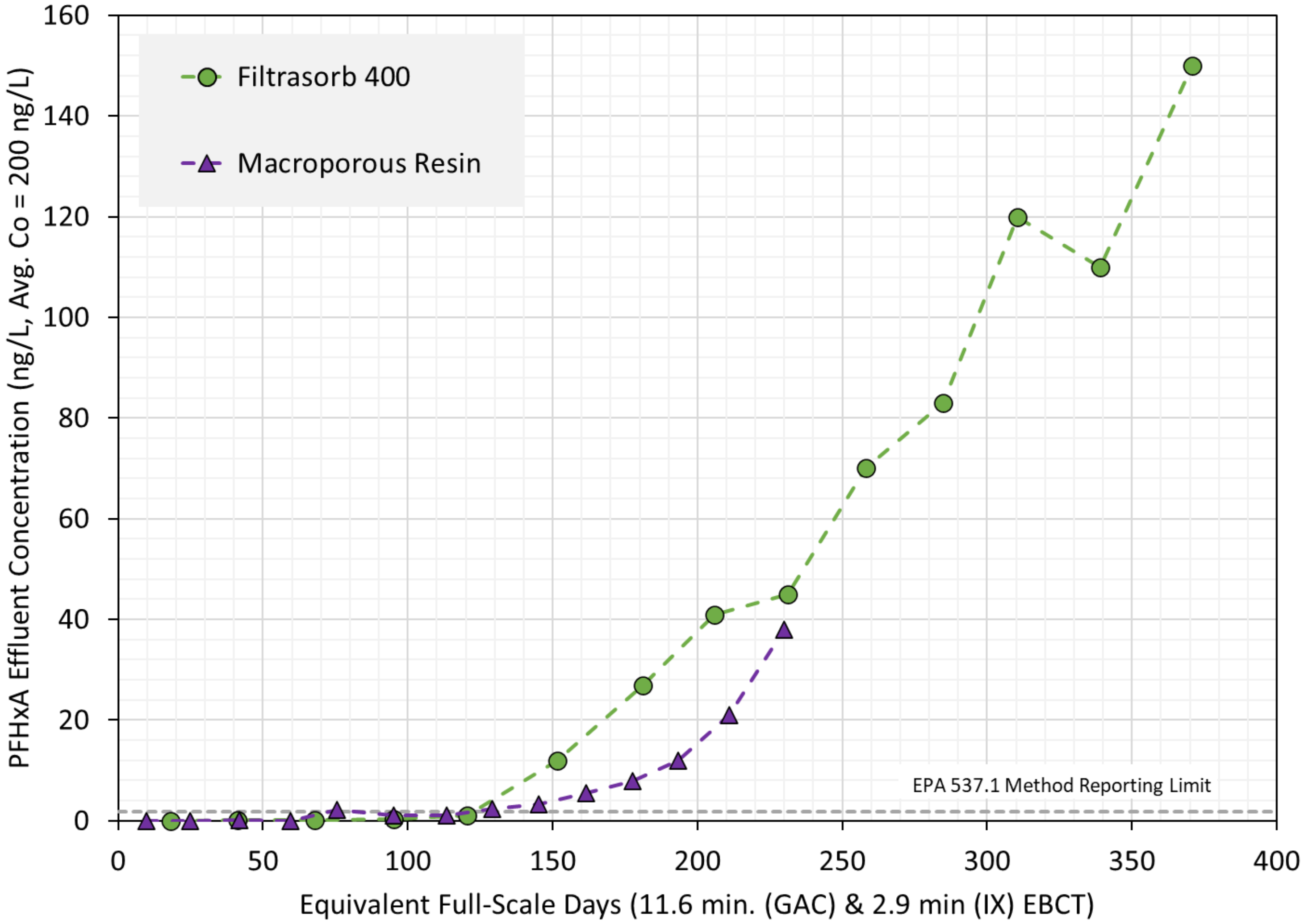
Notable Results: GACs – PFOA & PFOS



Notable Results: Macroporous vs. Gel-Type

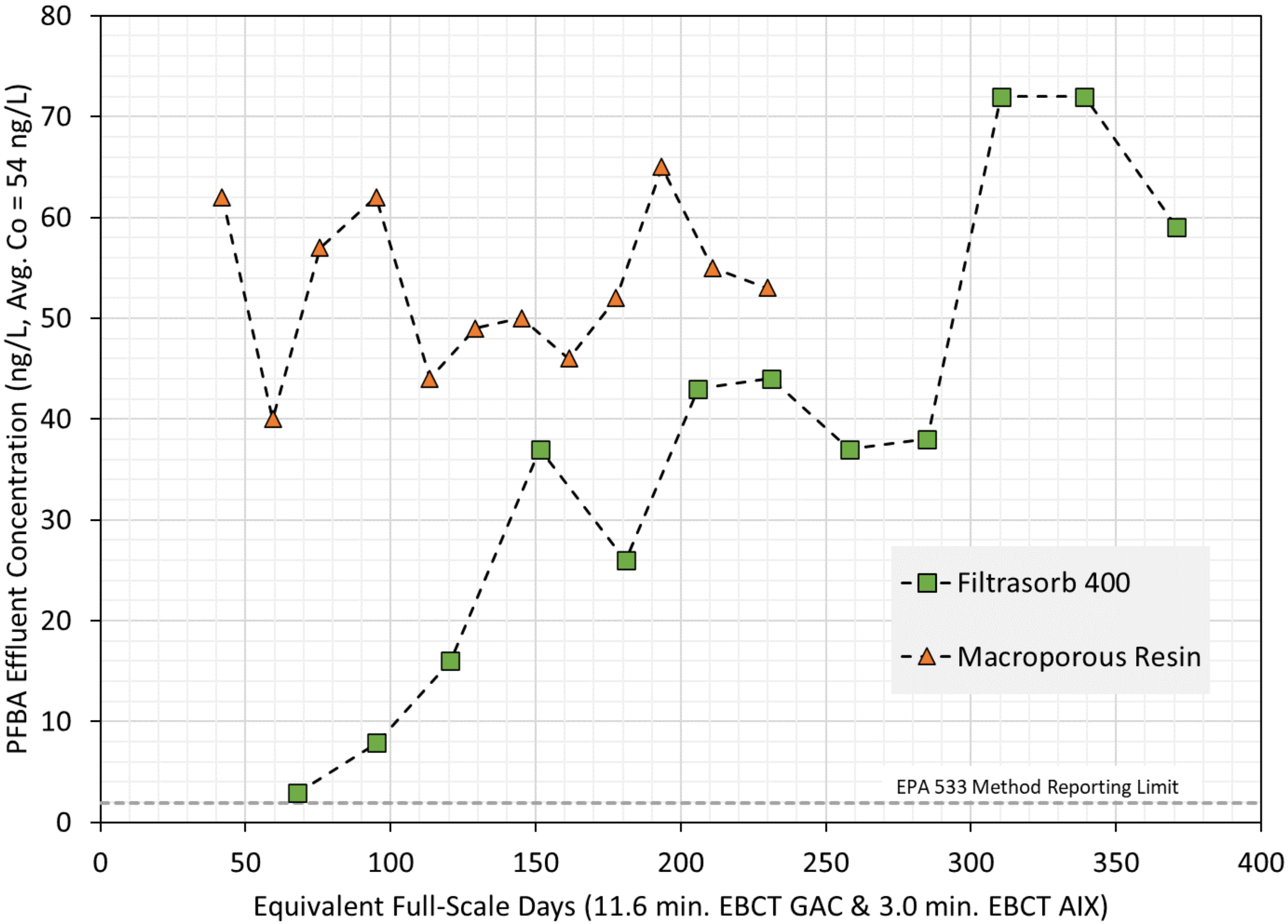


Notable Results: GAC vs. IX



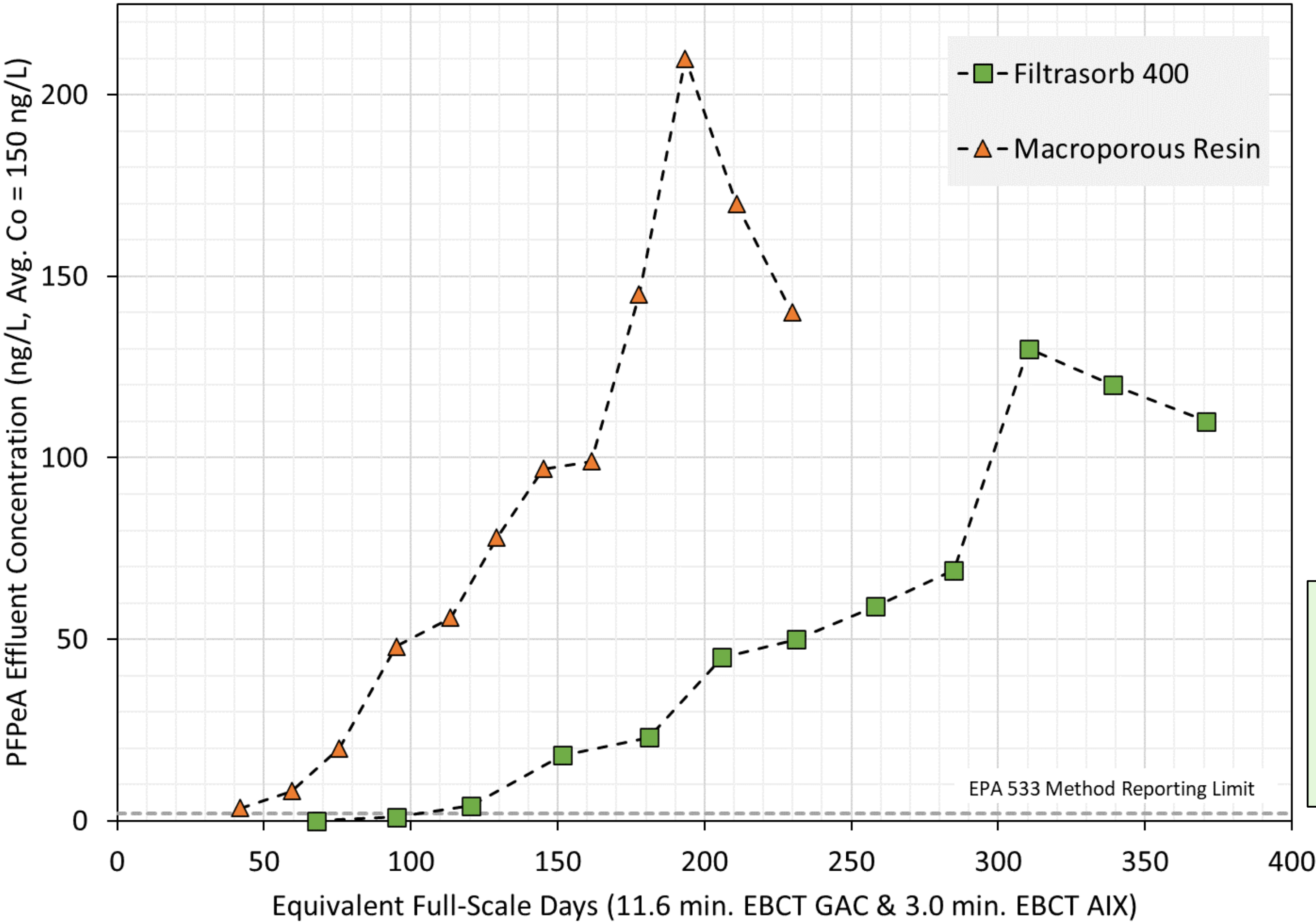
Nearly identical time to PFHxA breakthrough with both GAC and resin.

Notable Results: PFBA ("short-chain" PFAS)



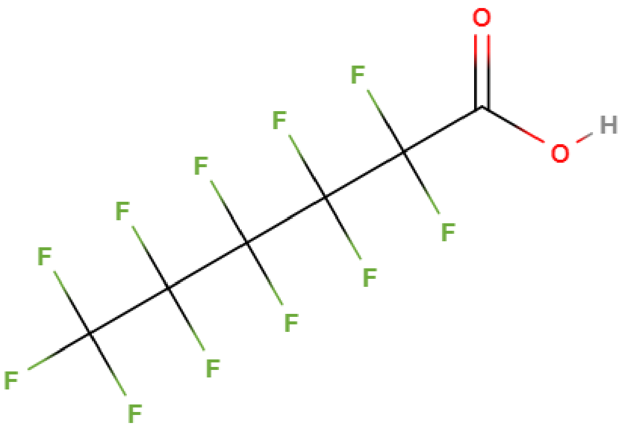
No appreciable removal of PFBA by best-performing resin.

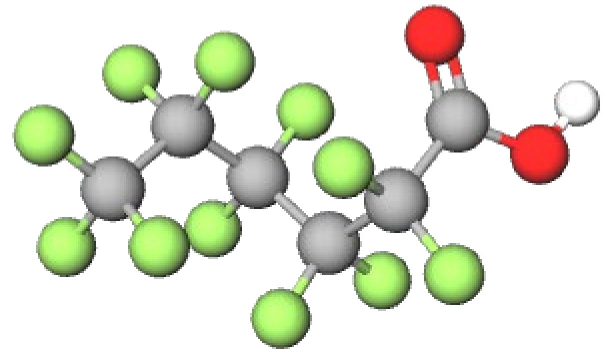
Notable Results: PFPeA ("short-chain" PFAS)



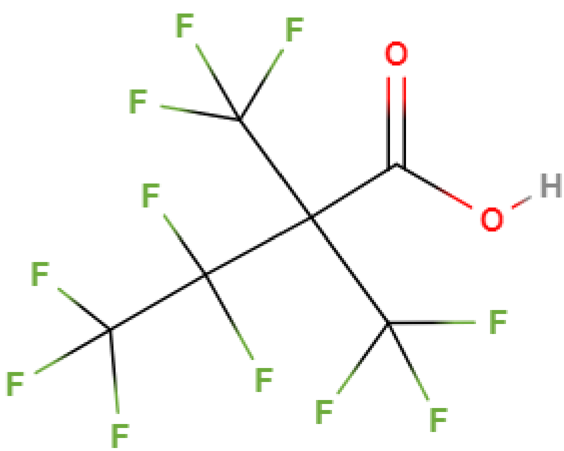
Markedly more favorable removal of PFPeA using F400.

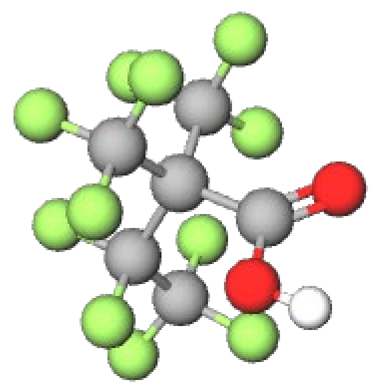
Branched vs. Linear Removal – PFHxA





Linear Isomer

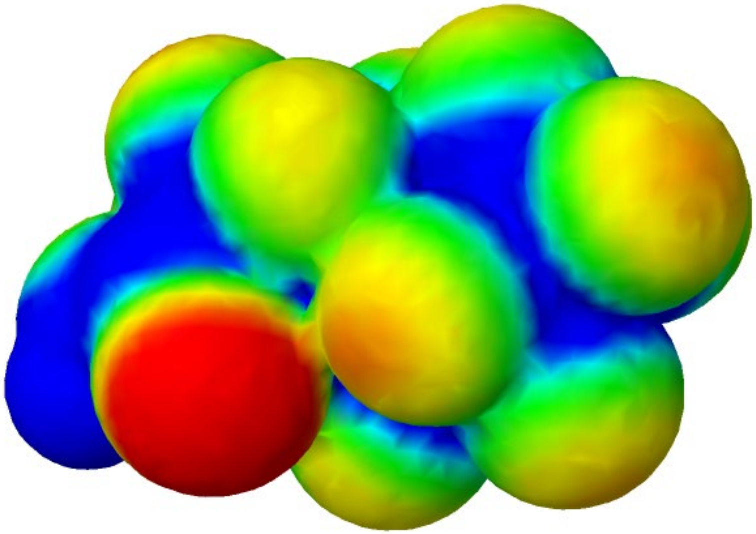




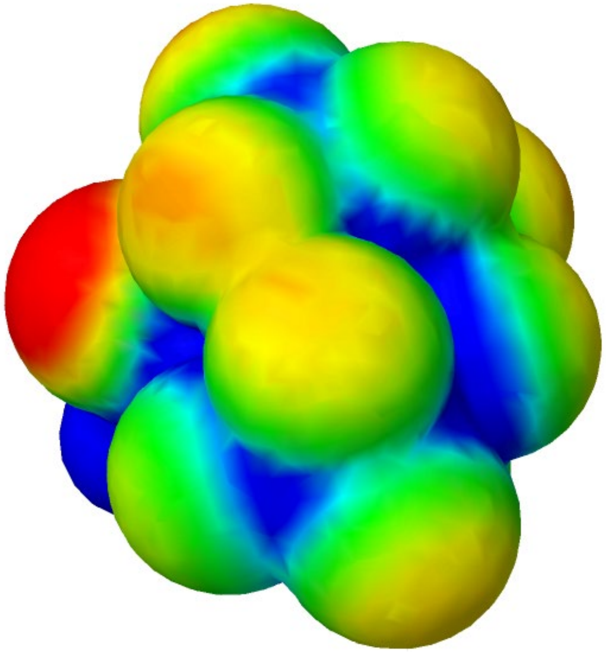
Branched Isomer

Branching results in steric hindrance affecting adsorption

How does structure impact adsorption?

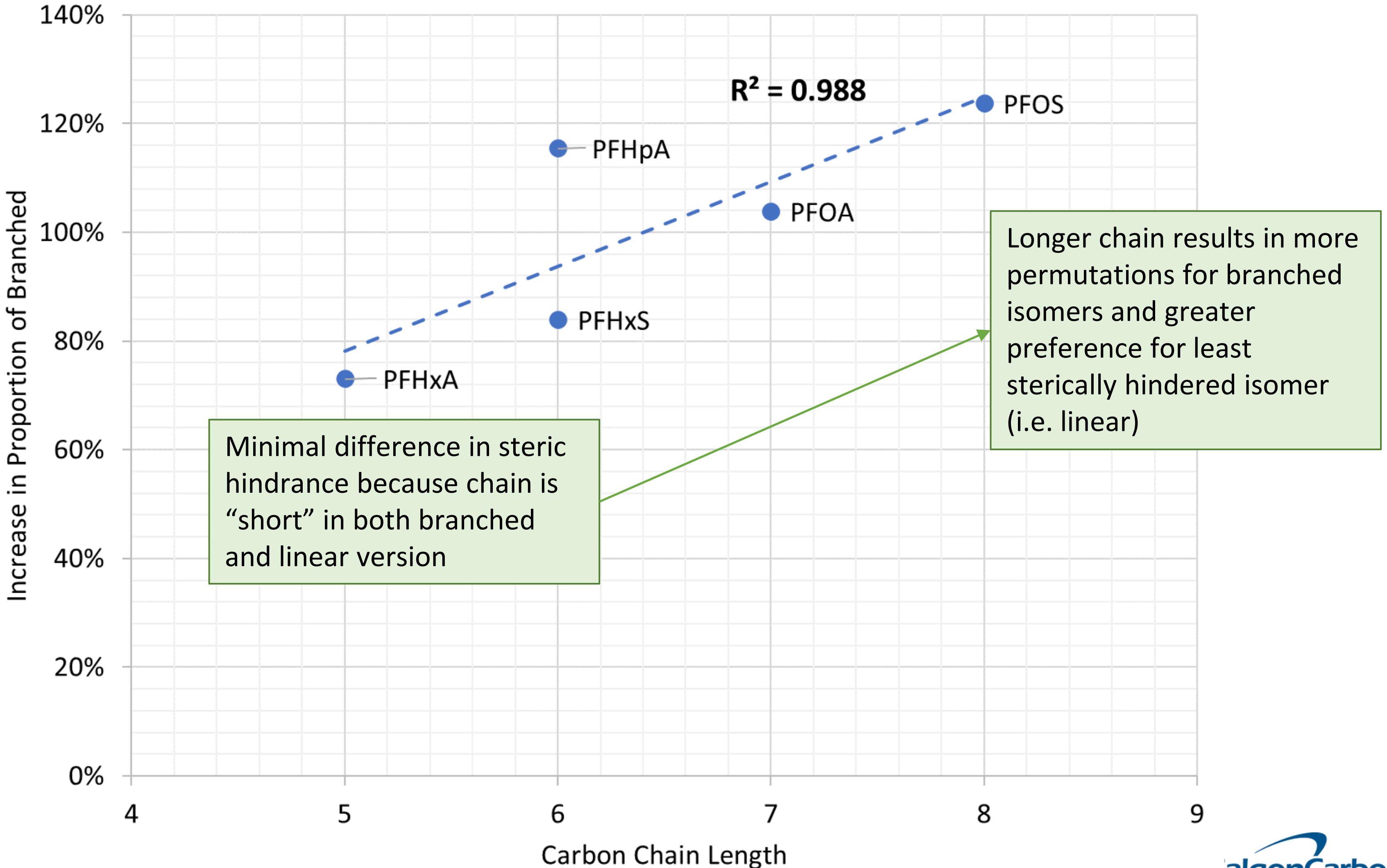


Linear Isomer



Branched Isomer

Impact of Carbon Chain Length on Selectivity of Linear over Branched



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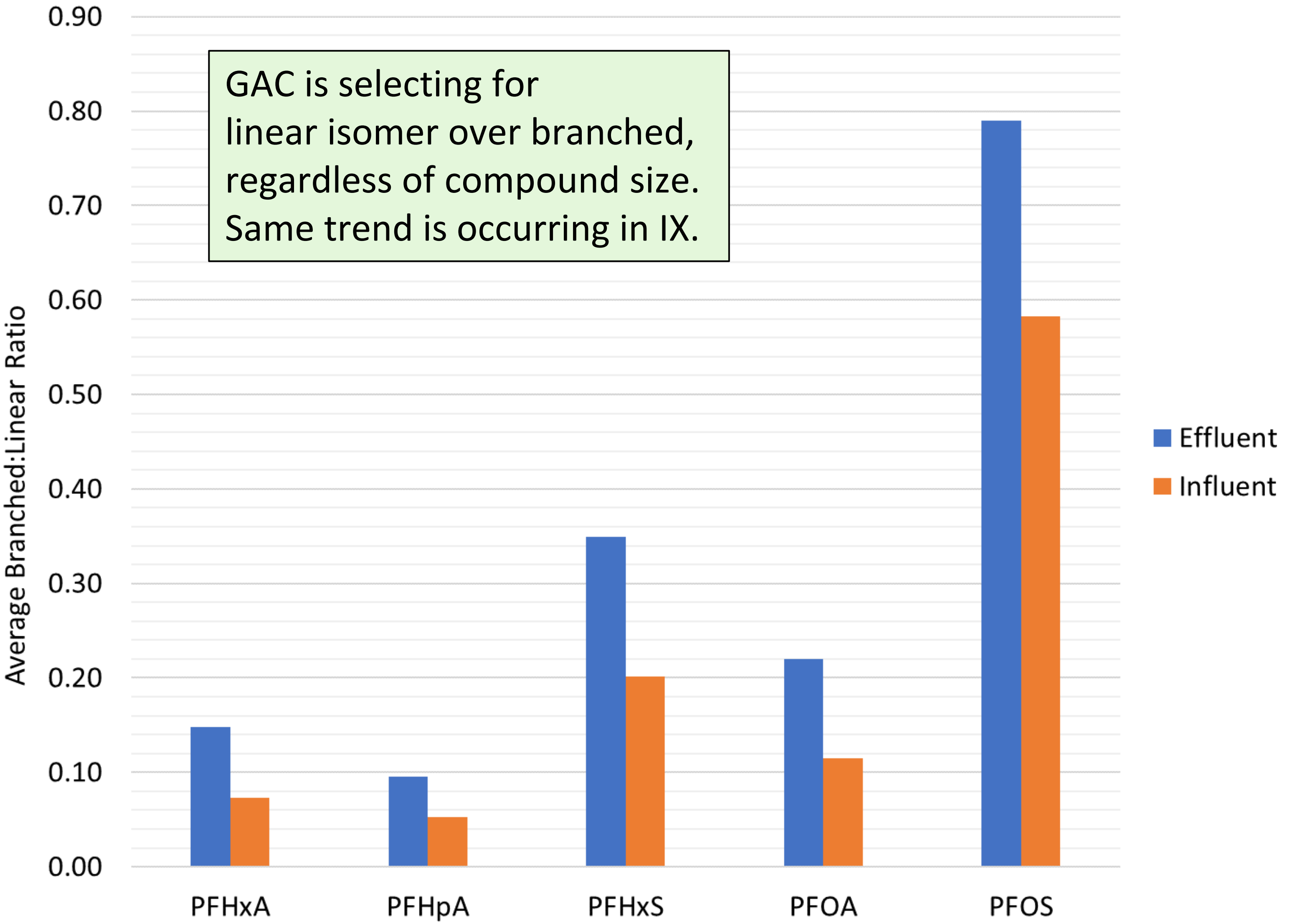
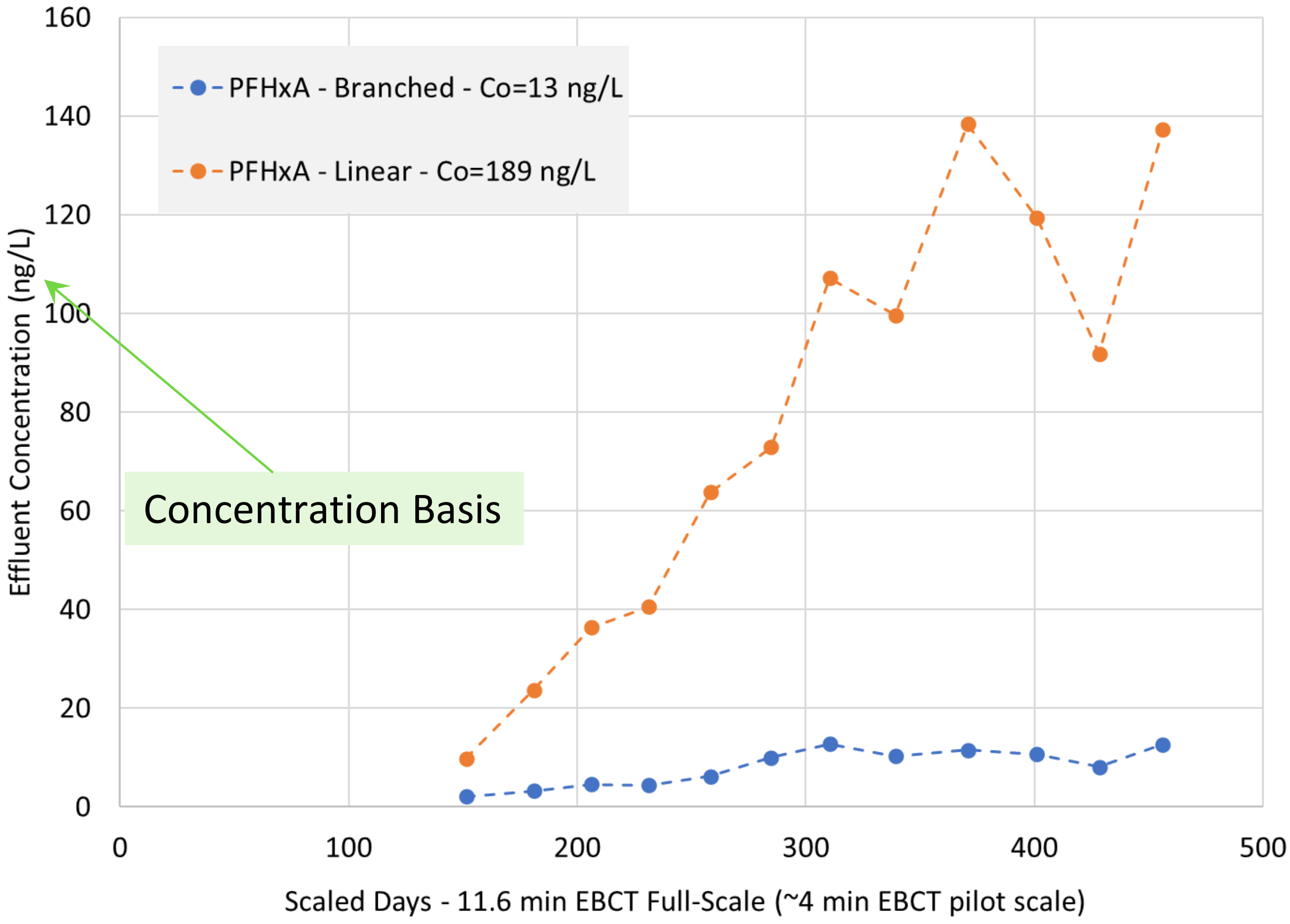
Notable Results: Branched vs. Linear Removal – GAC Trend



Removal of PFHxA through Reagglomerated Bituminous GAC



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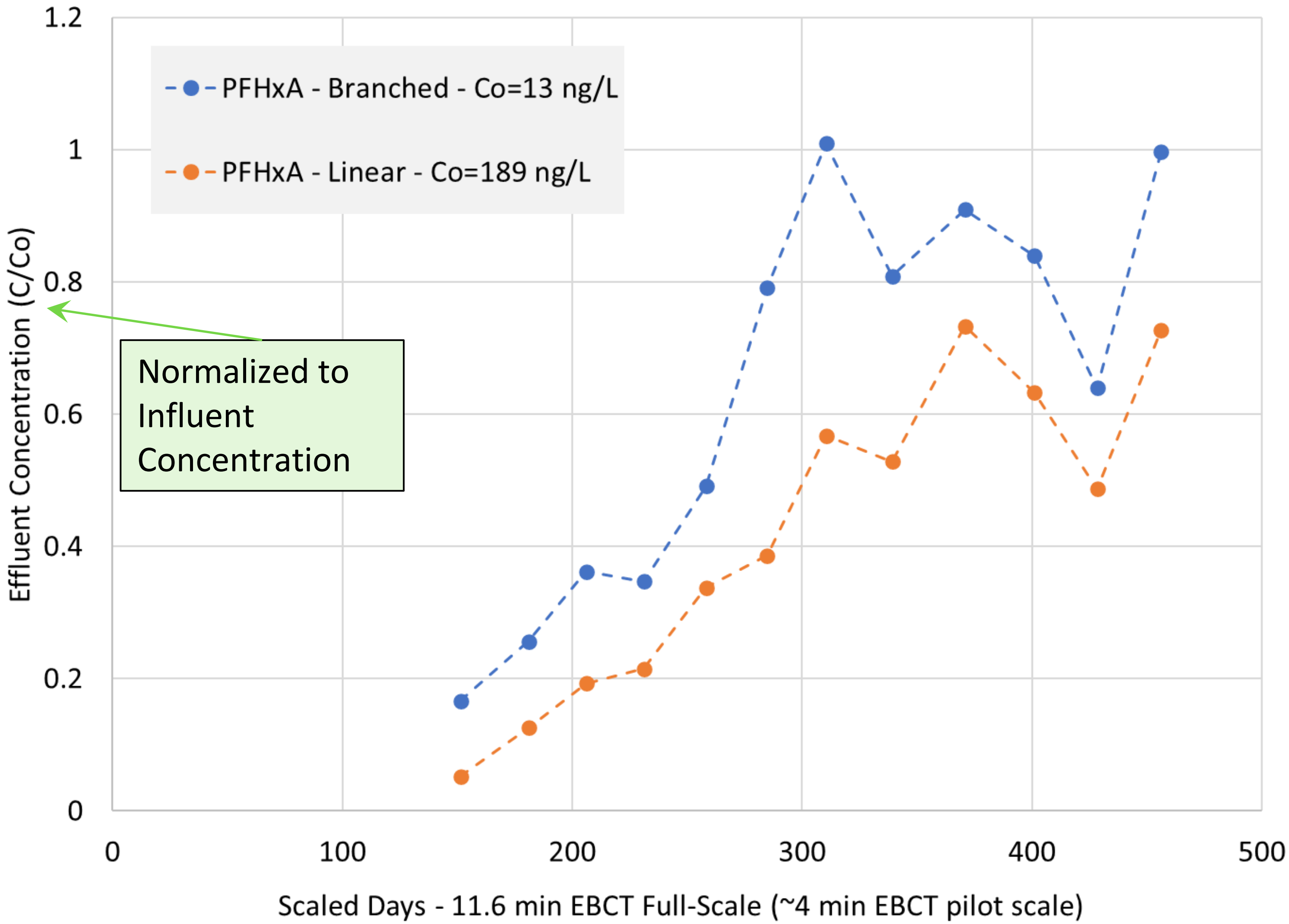
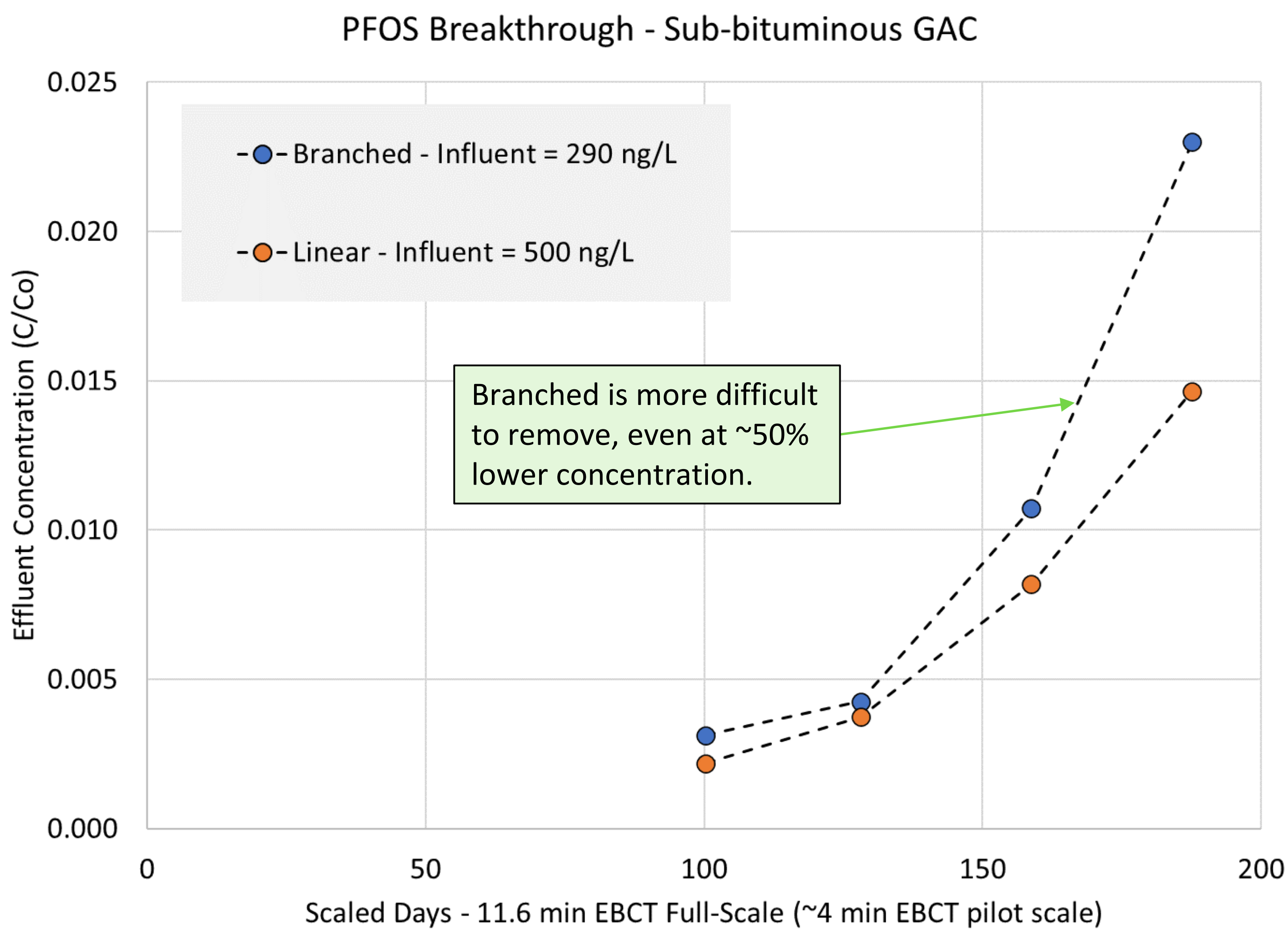
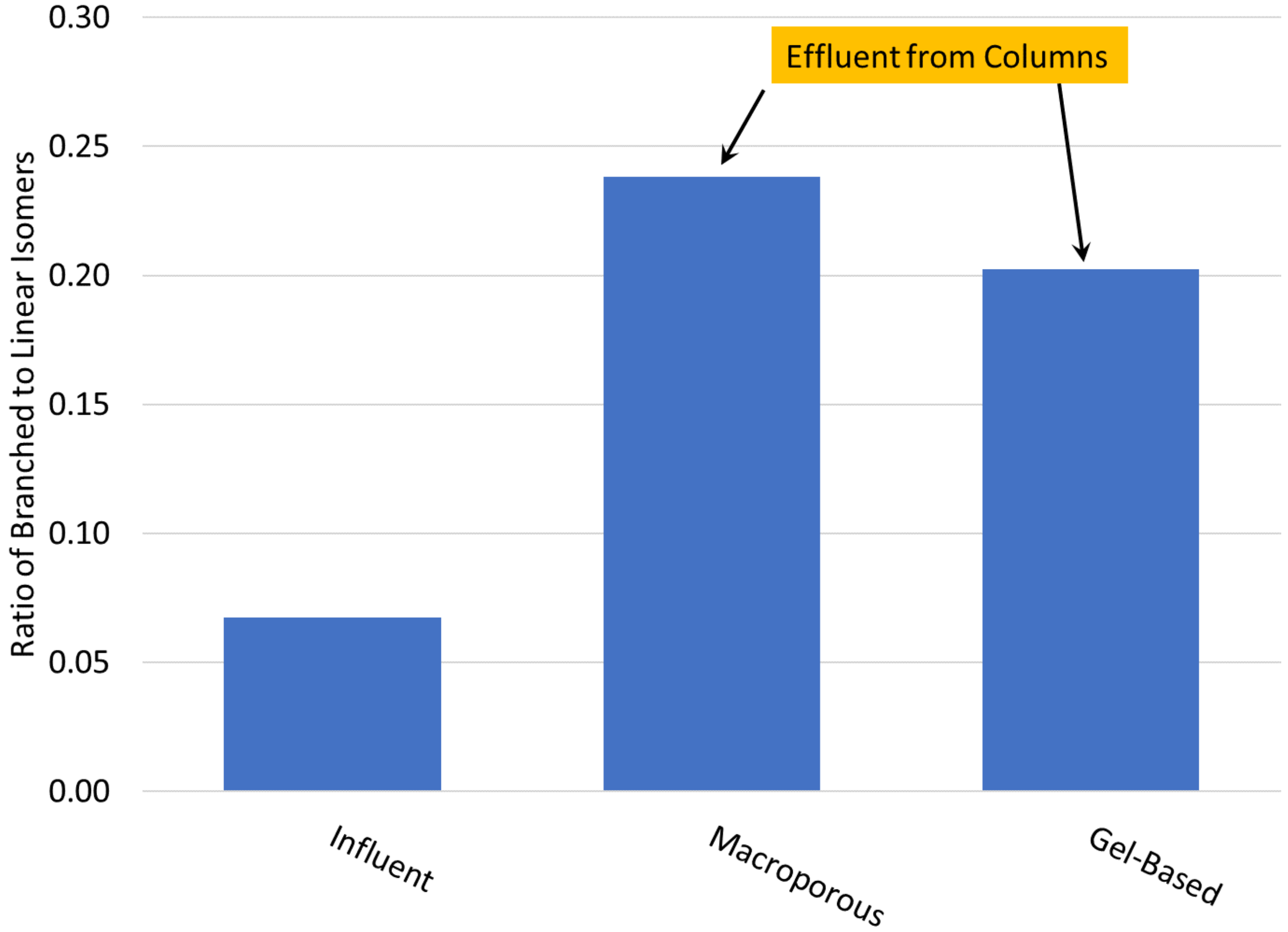


Notable Results: Branched vs. Linear Removal – Sub-Bituminous GAC



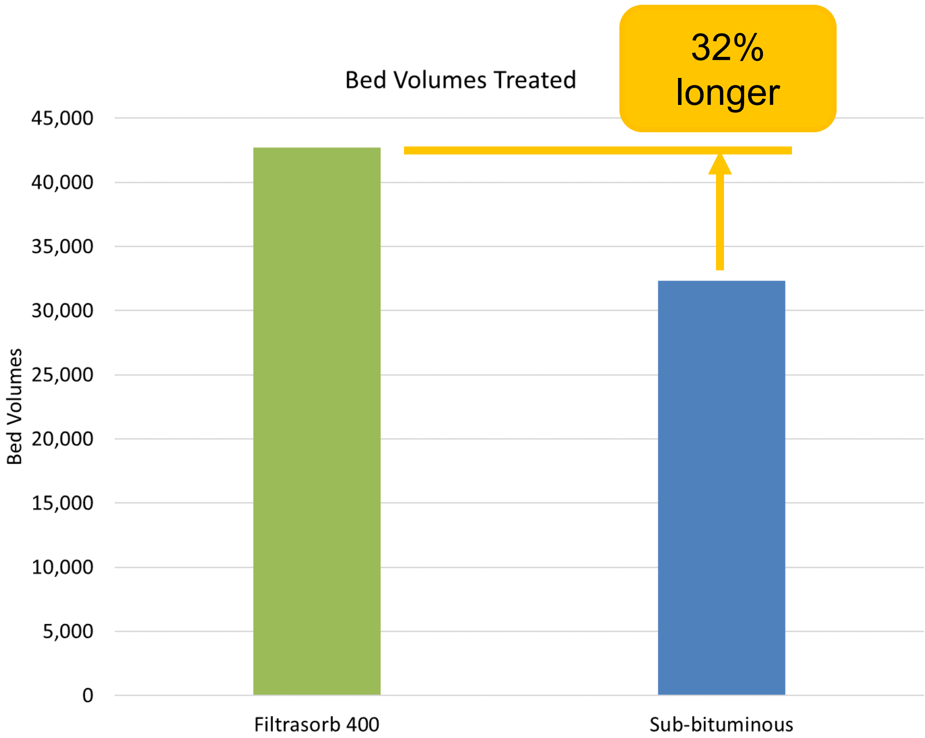
Isomer Selectivity of Resins

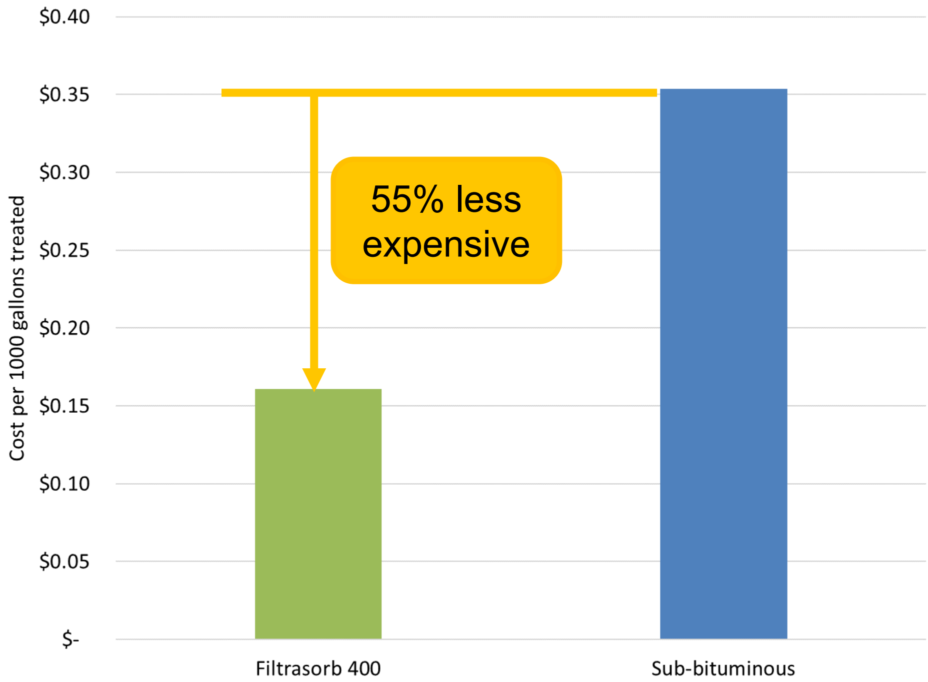


Lifecycle Costs of Treatment

- 20-Year Net Present Value
- 6% Annual Interest Rate
- Upfront particulate filtration for IX system (+$50,000)
- Hazardous Disposal Costs: $90 per cubic foot
  - IX resin (non-regenerable)
  - sub-bituminous carbon (non-reactivatable)
- Costs include media installation.
- Treating 1000 gallons-per-minute (gpm)

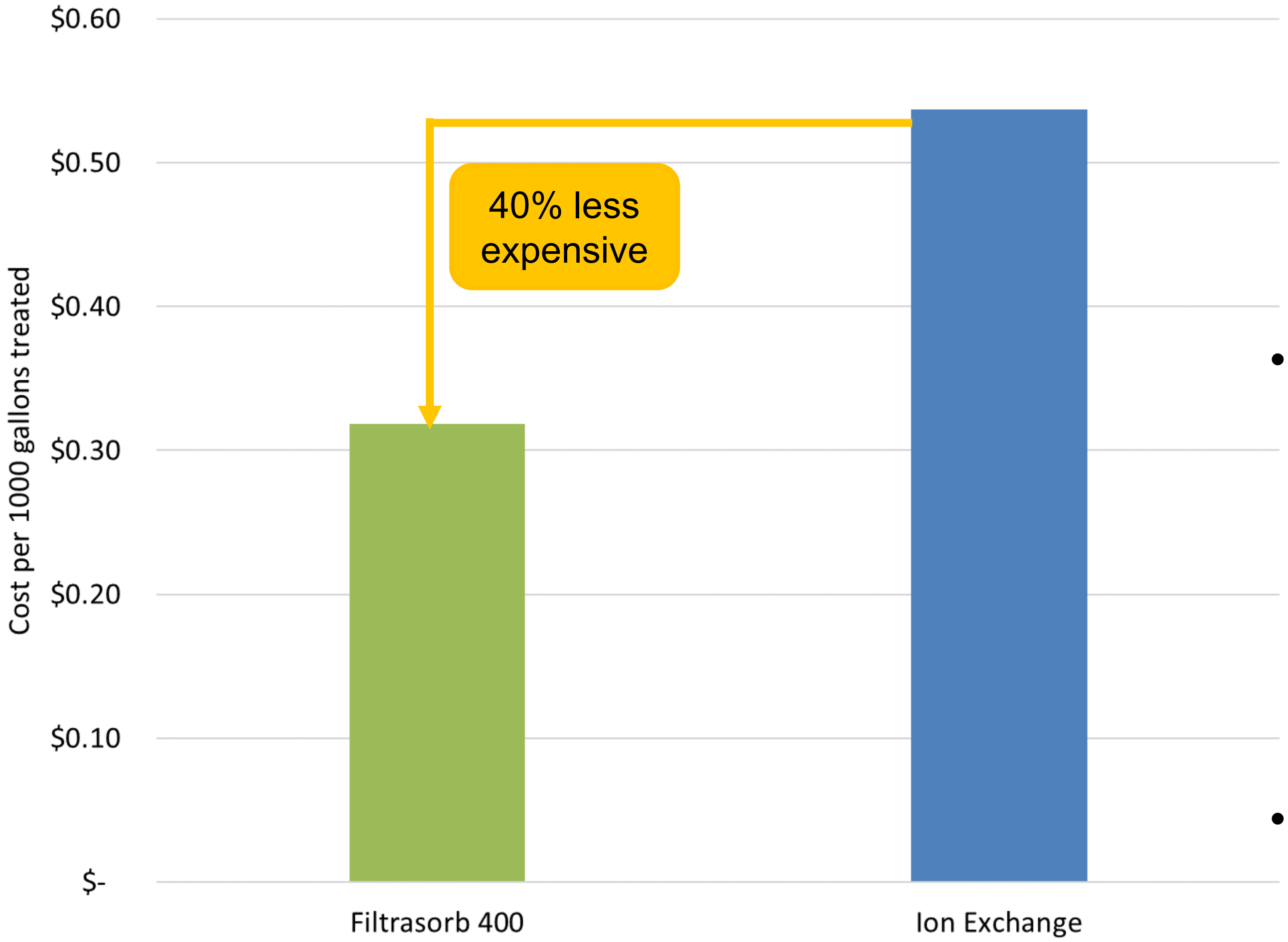
GAC Cost vs. Performance:
PFOA+PFOS to 70 ppt EPA HAL





- **Reagg. Bituminous:** <u>markedly lower lifecycle cost</u> even considering:
  - 15% higher price per pound for virgin material;
  - 20,000 lb fill weight vs. 14,000 lb fill weight (sub-bituminous has 30% lower density).
- Primarily due to higher cost of sub-bituminous media disposal

GAC vs. IX Cost:
Initial Detection of PFHxA



- Both products provided the same full-scale runtime to initial detection: 130 days
  - GAC = 16,000 bed volumes
  - IX resin = 64,500 bed volumes
- Primarily due to higher cost of IX media disposal

Summary

- GAC demonstrated better run time than IX for removal of two short chain PFAS compounds: **PFBA and PFPeA**
- Reagg. Bit. GAC and Macro IX had the same run time for PFHxA removal
- Cost Considerations:
  - Future disposal options are unknown
    Reactivation (cheap) vs. RCRA hazardous disposal ($90/ft^3 currently)
- **Continuing considerations with Case Study 2:**
  - No breakthrough yet of any PFAS longer than PFHxA;
  - Dual media system may allow "complete" PFAS removal;
  - Slower HLR implications on resin under investigation.

Conclusions

- Low background anion concentration means little competition with PFAS for exchange sites: IX performing well but still need economic comparison.
- Lead-lag (IX-GAC) system may allow for improved water quality with regards to PFAS removal… but must be tested first in piloting.
- Branched-to-linear ratio <u>must be </u>known to have any accuracy in predicting performance of medias.
- More data needed for economic analysis of GAC versus IX resin for PFOA and PFOS removal.
- **Pilot, pilot, pilot….**

Acknowledgements

- Pilot Operation, Sampling, and Maintenance

  Municipal Services Commission, New Castle, DE
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  Ryan Jaeger, Water Utility Supervisor

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  Seetha Coleman, PhD, CEO
  Charles R. Powley, PhD, Chief Scientist

THANK YOU FOR YOUR TIME. QUESTIONS?

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Pilot Configuration: Equipment

Notable Results: PFAS Analytes (537)

Analyte	Abreviation
Perfluorobutanesulfonic acid	PFBS
Perfluorohexanoic acid	PFHxA
Hexafluoropropylene oxide dimer acid	HFPO-DA
Perfluoroheptanoic acid	PFHpA
Perfluorohexanesulfonic acid	PFHxS
4,8-dioxa-3H-perfluorononanoic acid	ADONA
Perfluorooctanoic acid	PFOA
Perfluorooctanesulfonic acid	PFOS
Perfluorononanoic acid	PFNA
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS
Perfluorodecanoic acid	PFDA
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA
Perfluoroundecanoic acid	PFUnA
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUdS
Perfluorododecanoic acid	PFDoA
Perfluorotridecanoic acid	PFTrDA
Perfluorotetradecanoic acid	PFTA

Notable Results: PFAS Analytes (533)

Analyte	Abreviation	C
Perfluorobutanoic acid	PFBA	
Perfluoropentanoic acid	PFPeA	
1H,1H,2H,2H-Perfluorohexane sulfonic acid	4:2FTS	
Perfluoropentane sulfonic acid	PFPeS	
Perfluoroheptane sulfonic acid	PFHpS	
1H,1H,2H,2H-Perfluorooctane sulfonic acid	8:2FTS	