

PFAS Treatment: GAC vs. IX



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Introductions



Eric Forrester

- *Business Development Manager*
- PFAS Applications

Agenda

Background

- Calgon Carbon
- PFAS

IX Overview & Case Study

- Ion Exchange
- IX for PFAS Removal
- Municipal Case Study

GAC Overview & Case Study

- Granular Activated Carbon
- GAC for PFAS Removal
- Municipal Case Study

Comparing GAC & IX

- General Approach
- Hypothetical #1
- Hypothetical #2

Calgon Carbon



CORPORATE PROFILE

\$619.8 MILLION

2017 net sales

75 YEARS

experience

1,400+ EMPLOYEES

25 OFFICES

sales and service

20 FACILITIES

Manufacturing, reactivation,
equipment

240 PATENTS

WHO IS CALGON CARBON CORPORATION

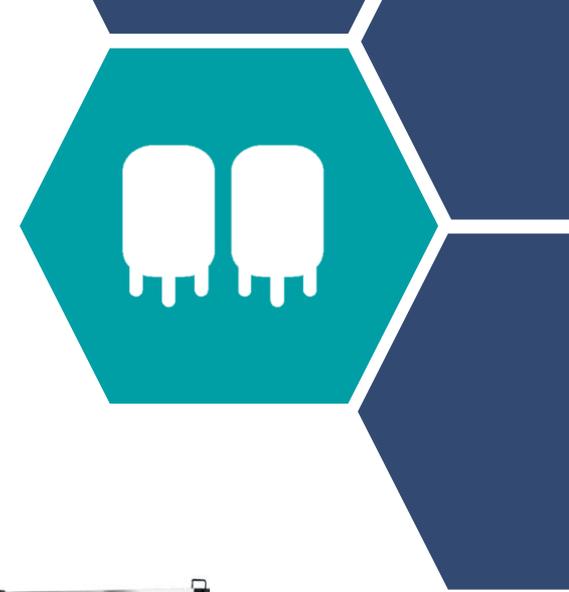
- World's largest producer of granular activated carbon
- Solves customer purification and separation problems with an array of technologies
- Water treatment is core competency with a diverse product portfolio



GLOBAL PRESENCE



ADVANCED PRODUCTS & SERVICES



INNOVATIVE EQUIPMENT ADDRESSES HIGH-END MARKET NEEDS



**CARBON ADSORPTION
SYSTEMS**



ULTRAVIOLET TECHNOLOGY



**BALLAST WATER
TREATMENT**



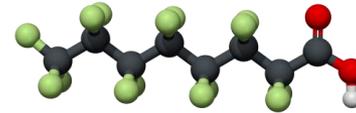
ION EXCHANGE SYSTEMS

PFAS Background

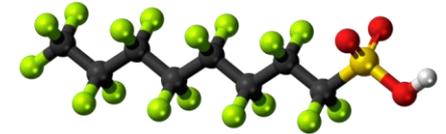


PFAS OVERVIEW

- WHAT ARE PFAS?
- Poly- and perfluoroalkyl substances
- Class of man-made fluorinated compounds



PFOA Molecule



PFOS Molecule

Health Advisory:
70 ppt
Combined
PFOA / PFOS



WHY ARE THEY A PROBLEM?

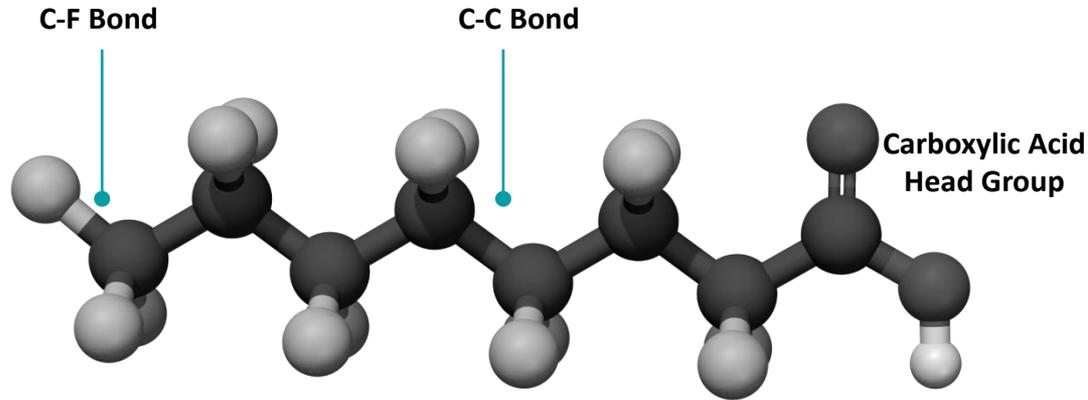
- Contaminates drinking water and food
- Highly persistent / resistant to degradation
- Accumulate in the body

WHERE DO THEY COME FROM?

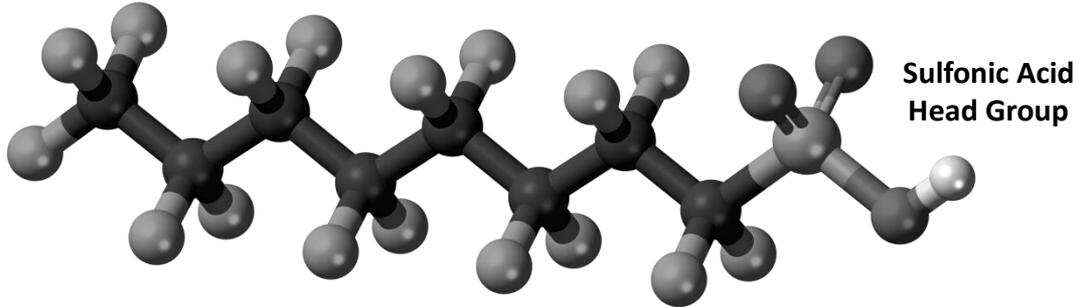
PFAS are used in a variety of products as a surface-active agent



PFAS Molecular Characteristics



PFOA MOLECULE



PFOS MOLECULE



CHEMICALLY STABLE

- Carbon Chain backbone
- C-F Bond



RELATIVELY HIGH MOLECULAR WEIGHT



TYPICALLY LOW VAPOR PRESSURE



EASILY INFILTRATES INTO GROUNDWATER & SOIL



BIOACCUMULATES IN ORGANISMS

REMOVING PFAS FOR 15 YEARS

OUR EXPERIENCE WITH PFAS REMOVAL

- Granular Activated Carbon (GAC), Ion Exchange Resin (IX), and CCC's Equipment Line are **proven treatment solutions** for PFAS removal
- **Over 45 installations** for PFAS removal across the United States
- Offer **complete solution** including activated carbon, equipment, on-site installation and exchange services, reactivation and financing



Proven products and solutions for drinking water, wastewater, remediation and POET



Carbon reactivation to thermally destroy PFAS and enable the reuse of activated carbon



Unrivaled technical service



Laboratory & field testing for tailored solutions



Applications Engineers and R&D team dedicated to solving customer problems

Ion Exchange Resin



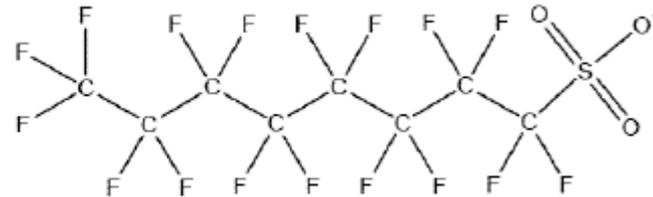
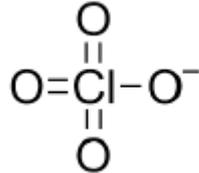
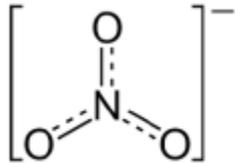
Introduction to IX Resin

- Ion Exchange (IX) uses resins which are synthetic polymers
- IX resins are used to remove dilute solutions and concentrate the ions into a relatively small volume
- Commonly used for perchlorate and nitrate removal



Introduction to IX Resin

- IX resins exchange either the cations or anions for other cations or anions
 - Nitrate, perchlorate, (most) PFAS are anions



- Single pass resin is most common for perchlorate and PFAS applications
 - Resin is not regenerated but incinerated at the end of service cycle
- IX resins are selective to perchlorate and PFAS

MUNICIPAL CASE STUDY

CONTEXT

Municipality in Colorado encounters PFAS in drinking water

APPROACH

Field Pilot Test

Determine efficacy of proposed treatment system

- Four x 10-ft diameter vessels, lead-lag operation
- 424 ft³ IX resin per vessel
- 2.5 minutes contact time



Municipal Case Study – Influent Concentrations

- PFNA – Non-Detect
- PFBS – 50 ppt
- PFHxS – 100 ppt
- PFHpA – 14 ppt
- PFOS – 100 ppt
- PFOA – 25 ppt



CDPHE HAL (139)



UCMR3 (289)

Municipal Case Study

Pilot System	Media	Column Diameter (in.)	Bed Length (in.)	Empty Bed Contact Time (min.)	Bed Volumes Per Hour (BV/hr.)	Flow Rate (gpm)	Linear Velocity (gpm/sf)
#1	Filtrisorb® 400 carbon	4	108	10	6.4	0.58	6.65
	Resin #1	4	36	2.61	23	0.73	8.37
#2	Resin #2	2	24	2	29.4	0.16	7.33
	Resin #3	2	24	2	29.4	0.16	7.33
#3	Resin #4	2	36	1.44	40	0.34	15.5

Pilot Skid Photos

System #1



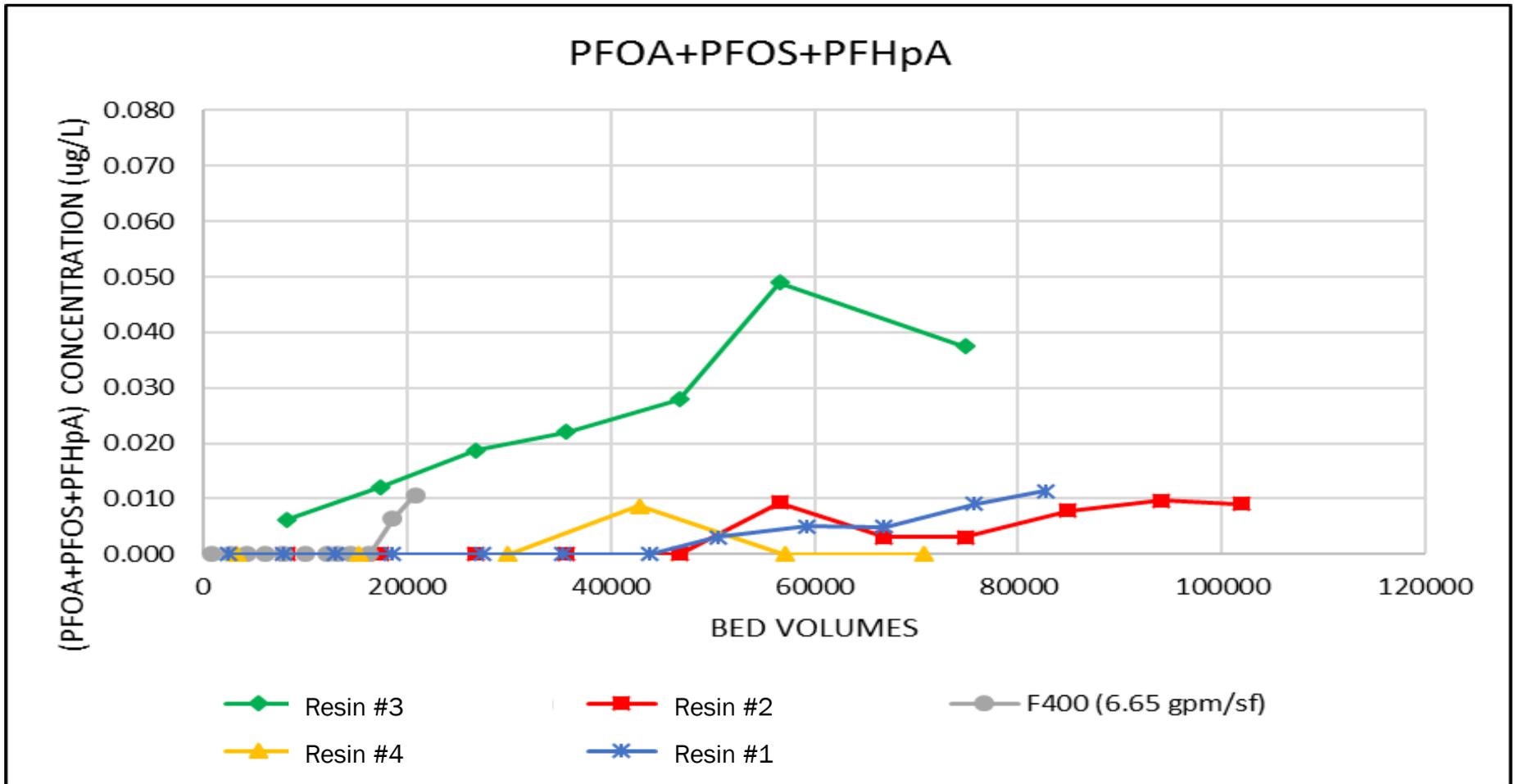
System #2



System #3



Media Breakthrough Curves



IX TAKEAWAYS



IX IS EFFECTIVE AND PROVEN FOR PFAS

- Long chain
- Short chain



NOT ALL PRODUCTS ARE CREATED EQUAL

- Design matters



TESTING IS REQUIRED FOR ACCURATE TECHNOLOGY COMPARISON

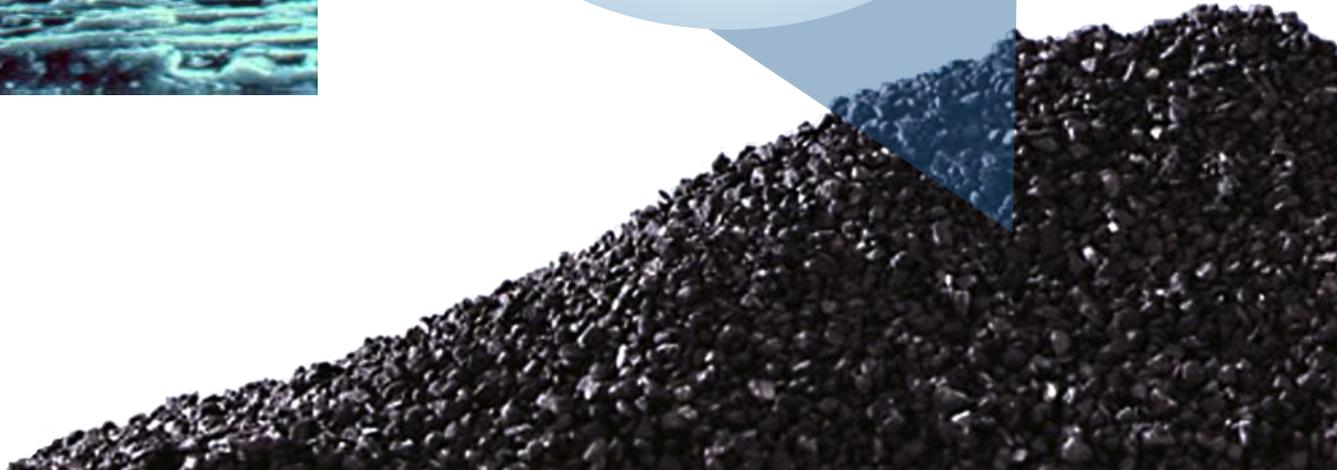
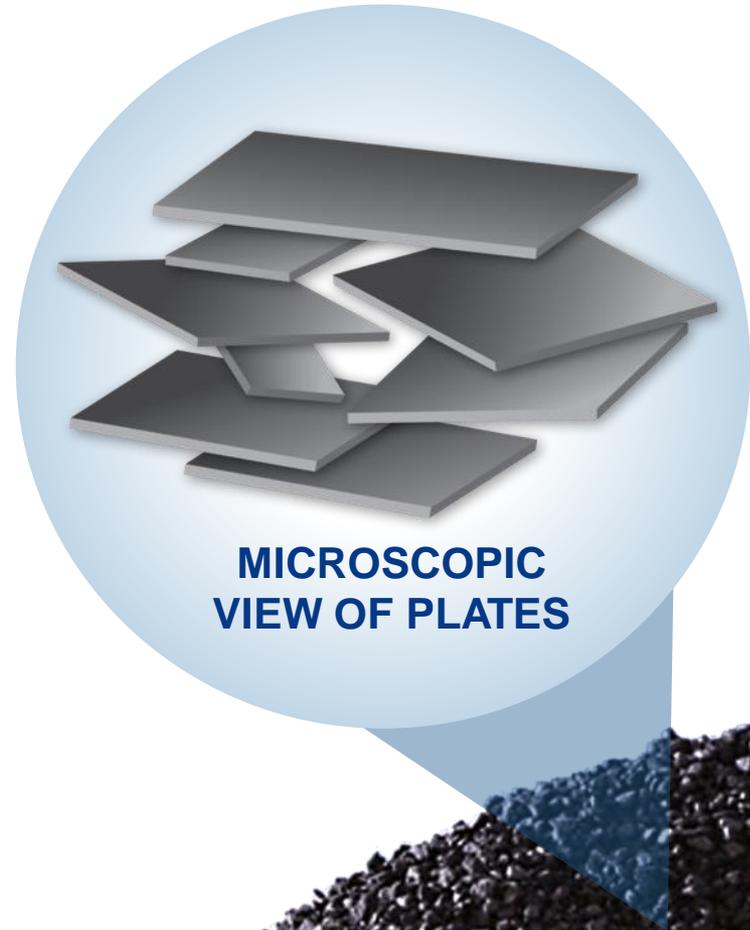
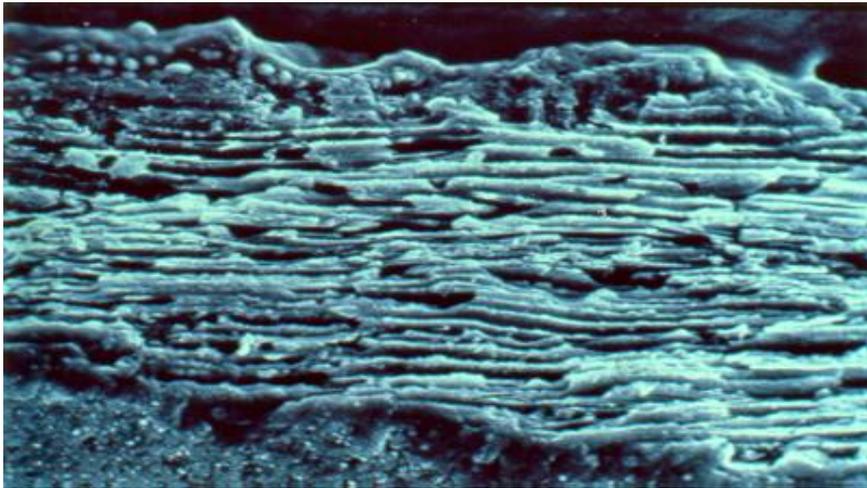
- Utility specific

Granular Activated Carbon



Granular Activated Carbon (GAC)

1,000,000X Magnification



A black and white photograph of a football field with bleachers. In the foreground, a hand is held palm up, holding a small pile of dark, granular material. The field is marked with yard lines and numbers like 20, 30, and 40. The bleachers are visible in the background.

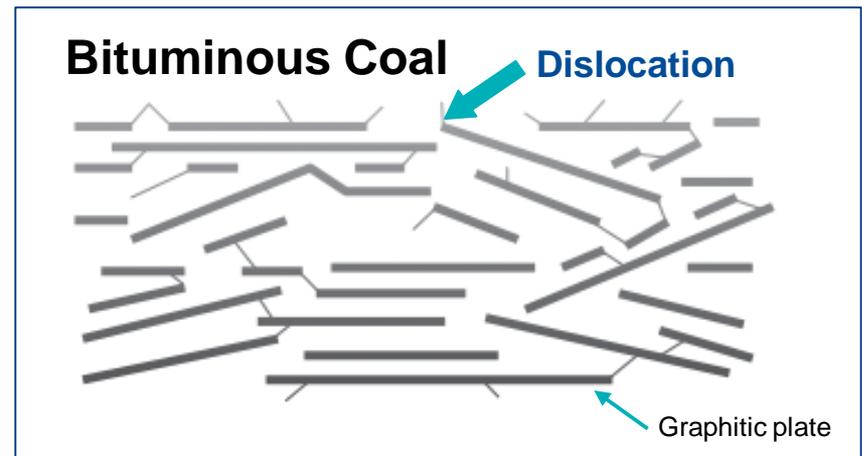
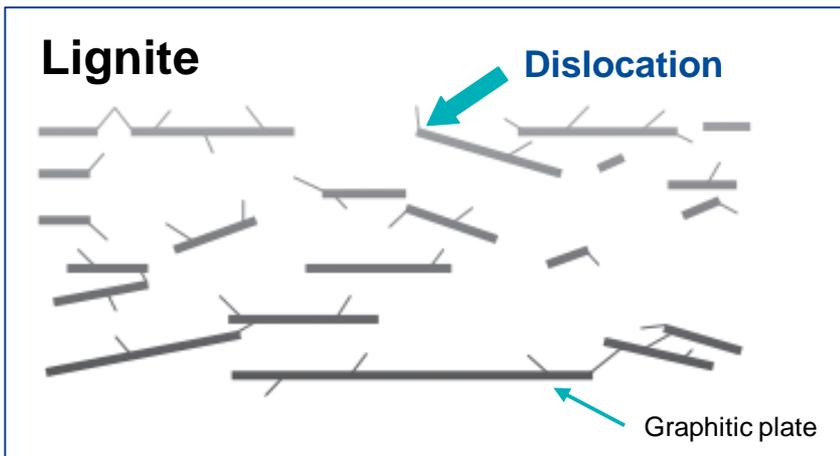
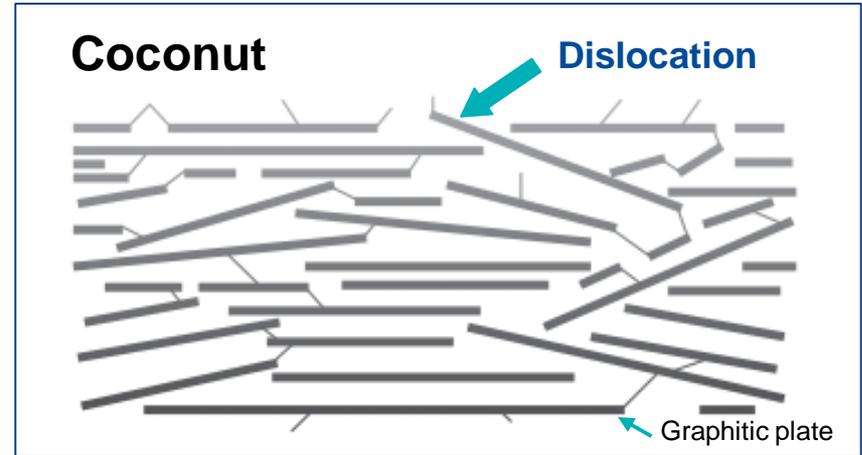
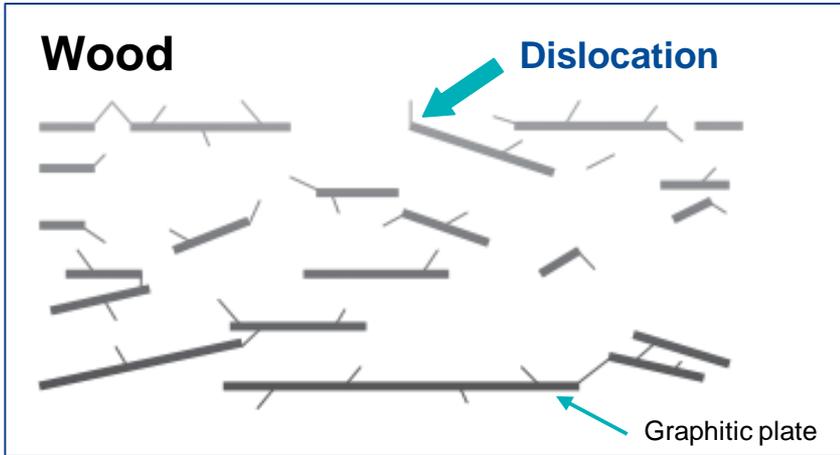
**HOW MUCH
SPACE IS
INSIDE?**

**1 HANDFUL HAS
THE SURFACE
AREA OF A
FOOTBALL FIELD**

Base Material Makes a Difference



Internal Fingerprint of Starting Material



IMPORTANCE OF TESTING



WHY

Extremely difficult to quantify performance without testing

Many factors influence the effective service life of GAC:

- Temperature
- pH
- Contact Time
- Contaminant Concentration
- Contaminant Mix

GOALS

- Feasibility
- Product Comparison
- Service Life Estimation
- Treatment Technology Comparison

TYPES

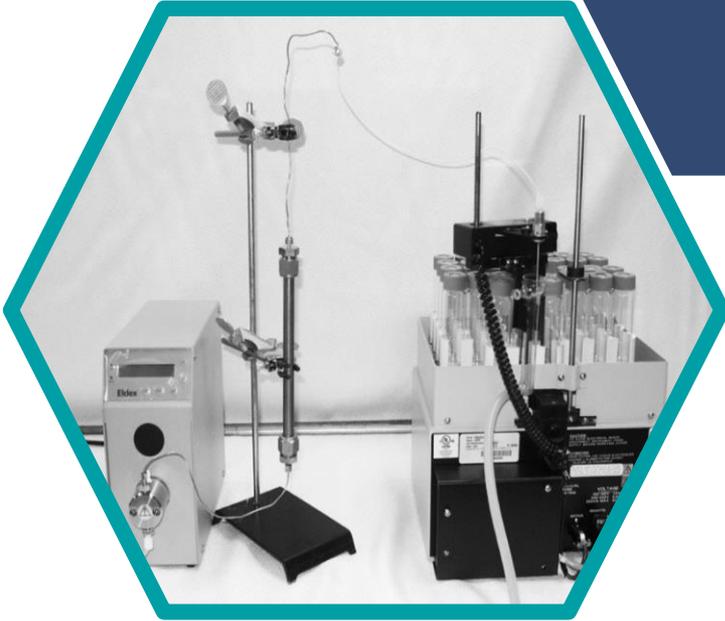
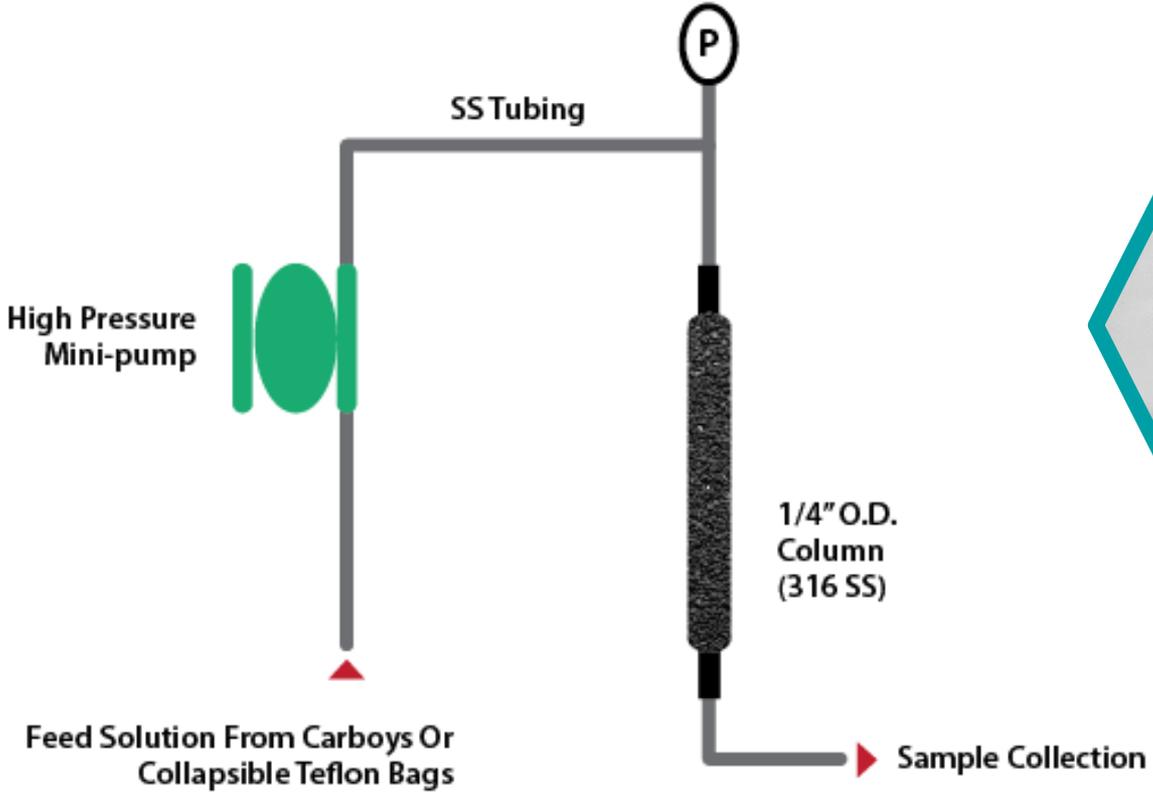
Bench Scale

- Isotherm
- ACT/RSSCT

In-Process

- Pilot Column

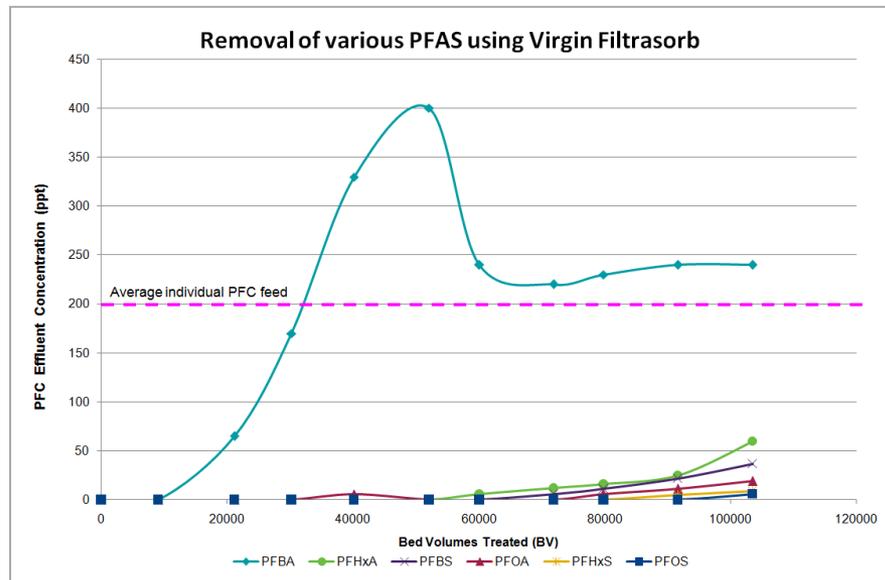
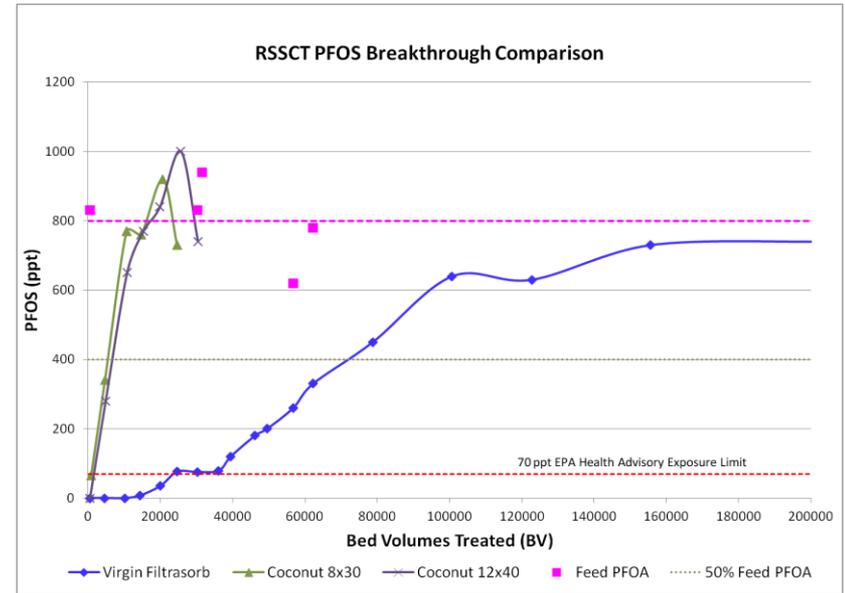
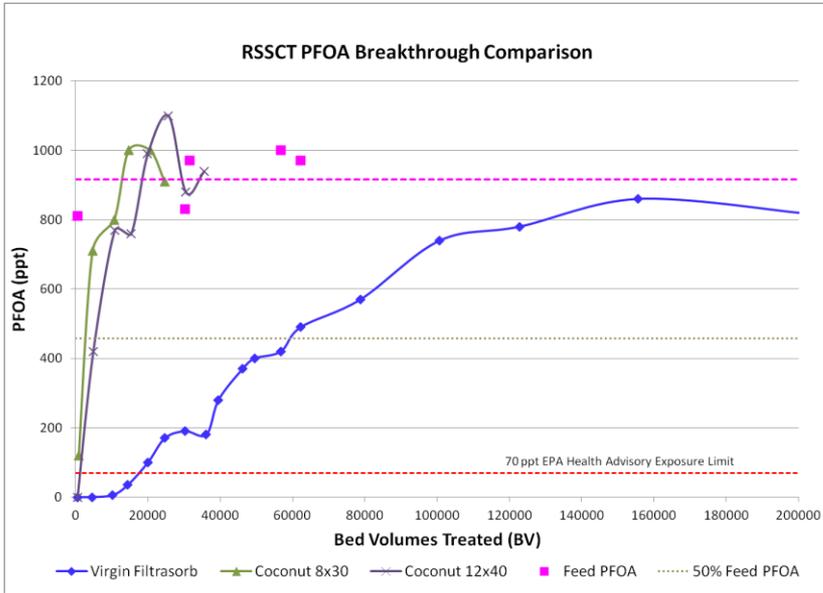
COLUMN TEST (ACT or RSSCT)



Published Test Data

AWWA Journal – January 2018

Remediation Journal – December 2018



MUNICIPAL CASE STUDY

CONTEXT

Municipality in New York encounters PFAS in drinking water

APPROACH

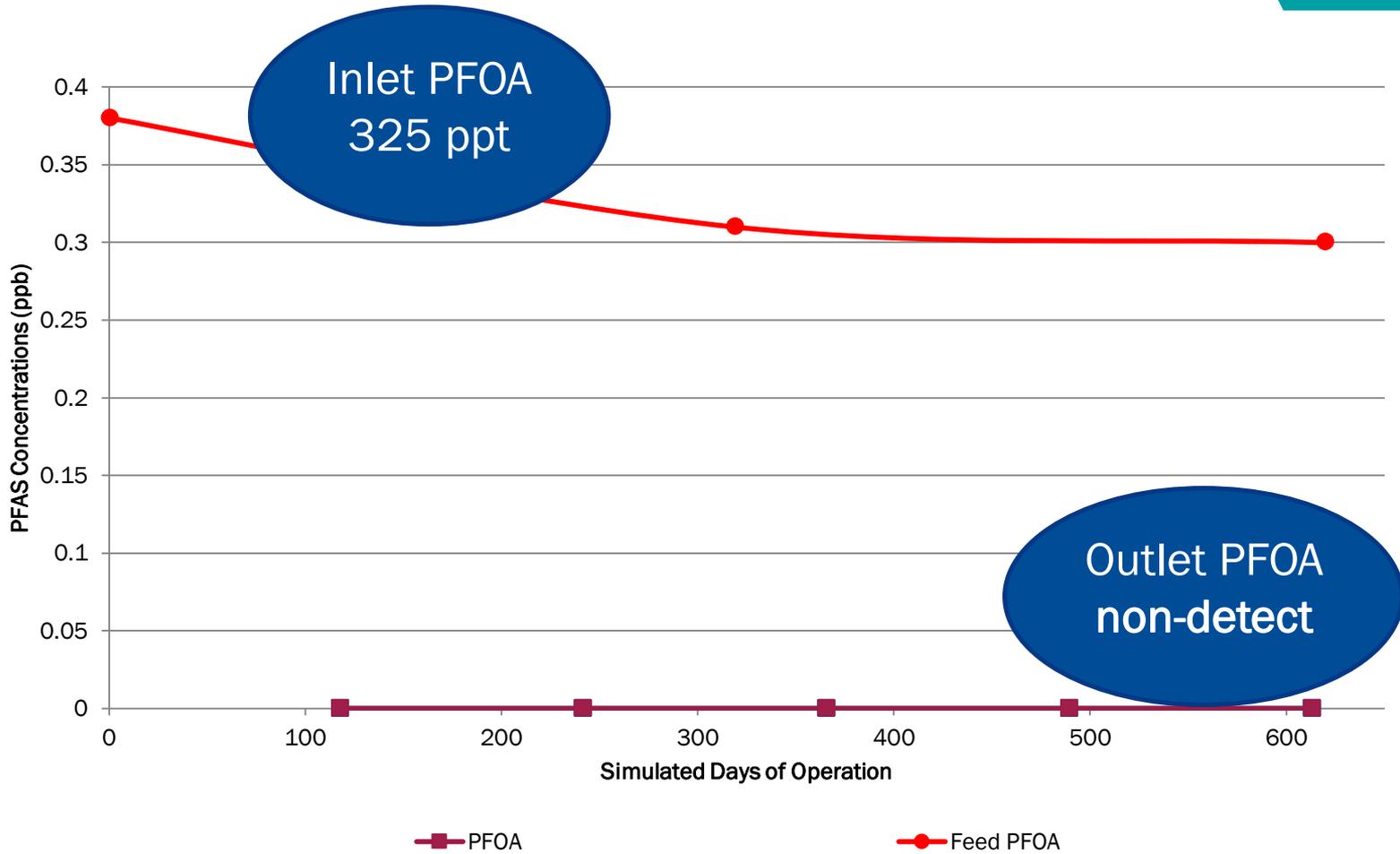
Lab Column Test

Determine efficacy of proposed treatment system

- Two x 12-ft diameter vessels, lead-lag operation
- 40,000 lb GAC per vessel
- 13 minutes contact time



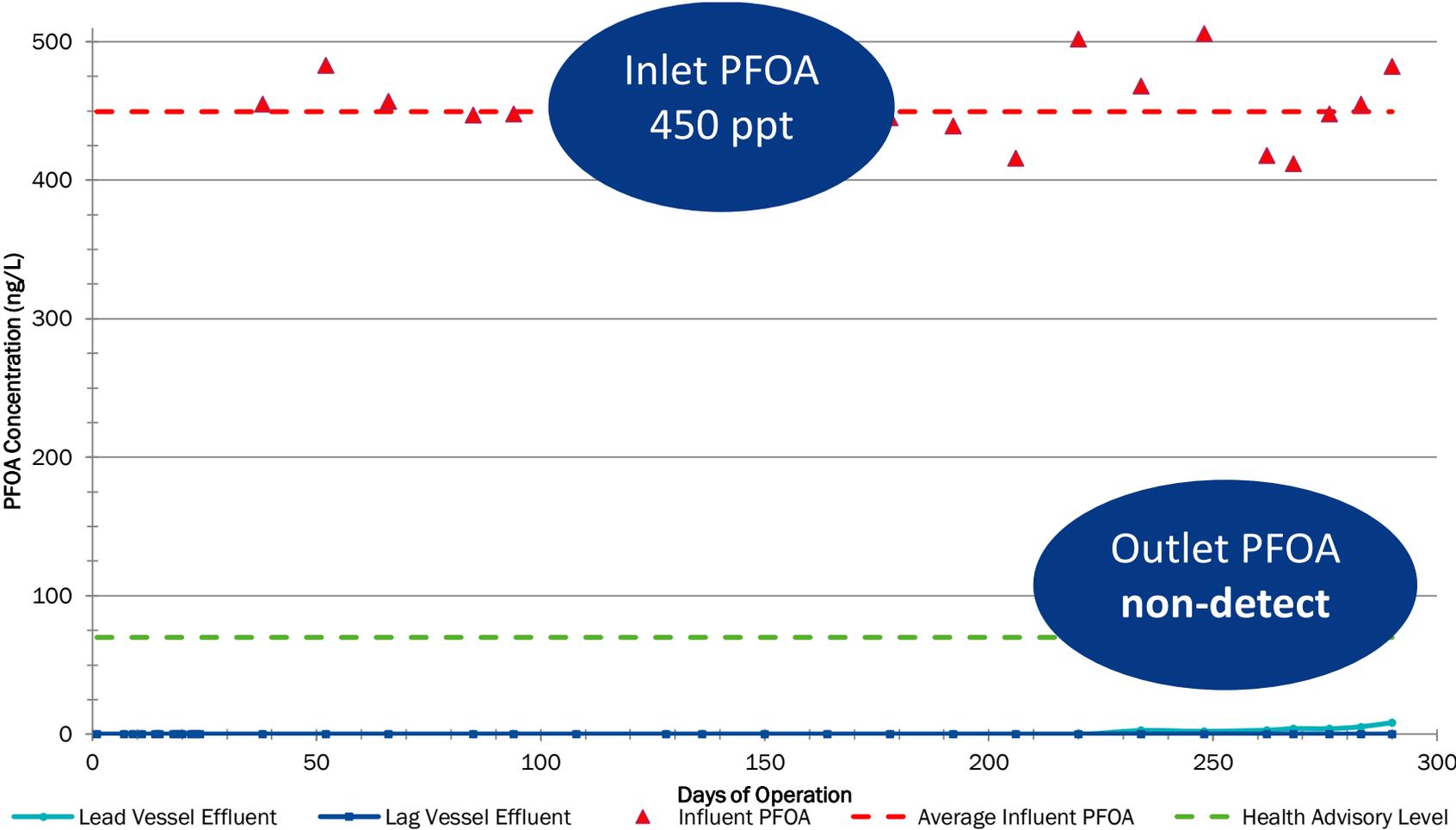
LAB DATA





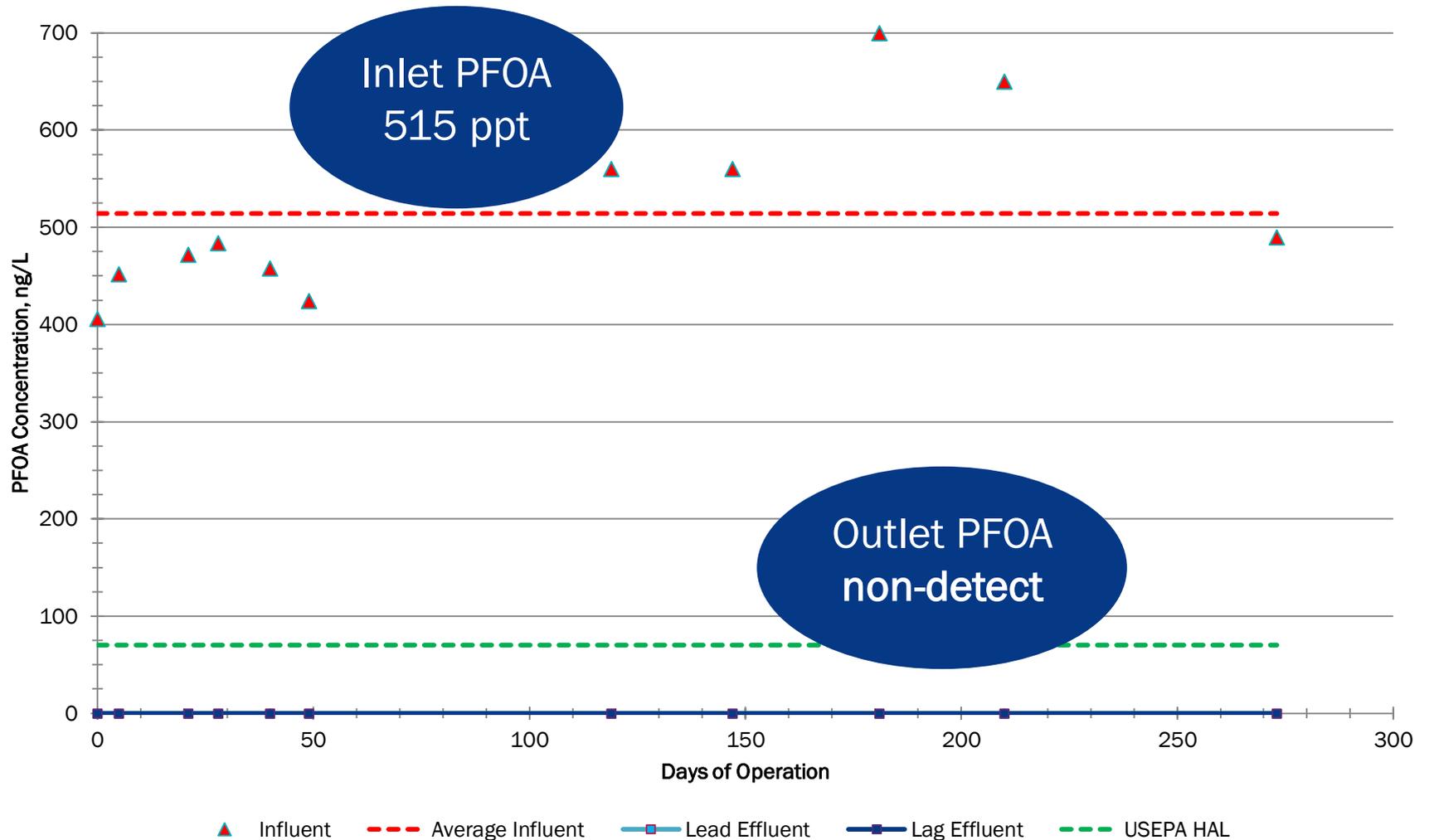
FIELD DATA

TEMPORARY EQUIPMENT



FIELD DATA

PERMANENT EQUIPMENT



GAC TAKEAWAYS



GAC IS EFFECTIVE AND PROVEN FOR PFAS

- Long chain
- Short chain

NOT ALL PRODUCTS ARE CREATED EQUAL

- Design matters

TESTING IS REQUIRED FOR ACCURATE TECHNOLOGY COMPARISON

- Utility specific

PFAS Removal Toolbox



PFAS REMOVAL

GAC vs. RO vs. IX



Advantages of Select Treatments

Granular Activated Carbon (GAC)

Most studied technology

Will remove 100% of the contaminants, for a time

Good capacity for some PFAS

Will remove a significant number of disinfection byproduct precursors

Will help with maintaining disinfectant residuals

Will remove many co-contaminants

Likely positive impact on corrosion (lead, copper, iron)

Anion Exchange Resin (PFAS selective)

Will remove 100% of the contaminants, for a time

High capacity for some PFAS

Smaller beds compared to GAC

Can remove select co-contaminants

High Pressure Membranes

High PFAS rejection

Will remove many co-contaminants

Will remove a significant number of disinfection byproduct precursors

Will help with maintaining disinfectant residuals

PFAS REMOVAL

GAC vs. RO vs. IX



Issues to Consider

EPA is evaluating these issues to document where and when they will be an issue

Granular Activated Carbon (GAC)

GAC run time for short-chained PFAS (shorter run time)
Potential overshoot of poor adsorbing PFAS if not designed correctly
Reactivation/removal frequency
Disposal or reactivation of spent carbon

Anion Exchange Resin (PFAS selective)

Run time for select PFAS (shorter run time)
Overshoot of poor adsorbing PFAS if not designed correctly
Unclear secondary benefits
Disposal of resin

High Pressure Membranes

Capital and operations costs
Membrane fouling
Corrosion control
Lack of options for concentrate stream treatment or disposal

PFAS REMOVAL

GAC vs. RO vs. IX

1. Preliminary System Design

- “On paper”
- Capital cost estimate

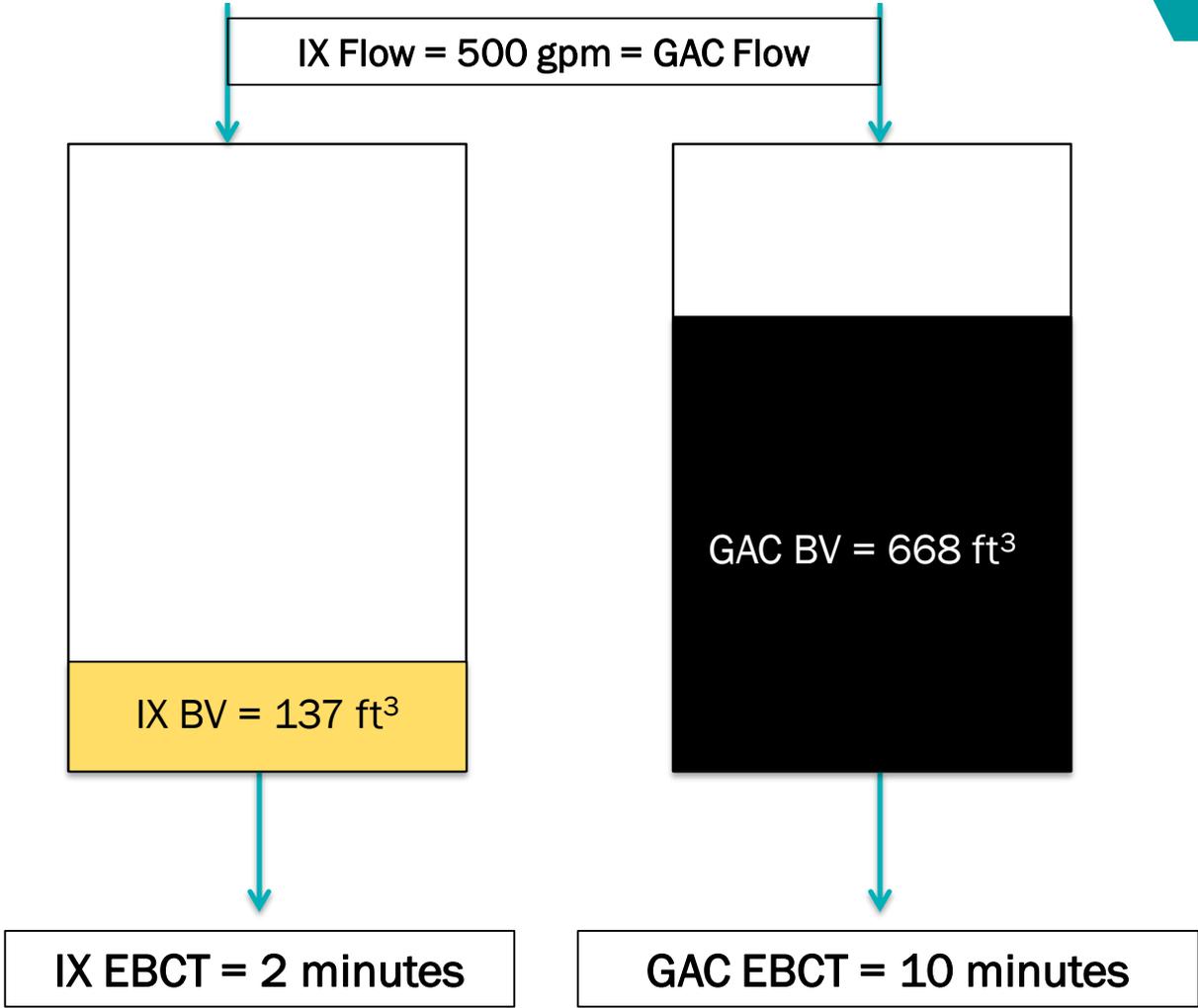
2. Performance testing

- Design verification
- Media consumption rate
- O&M cost estimate

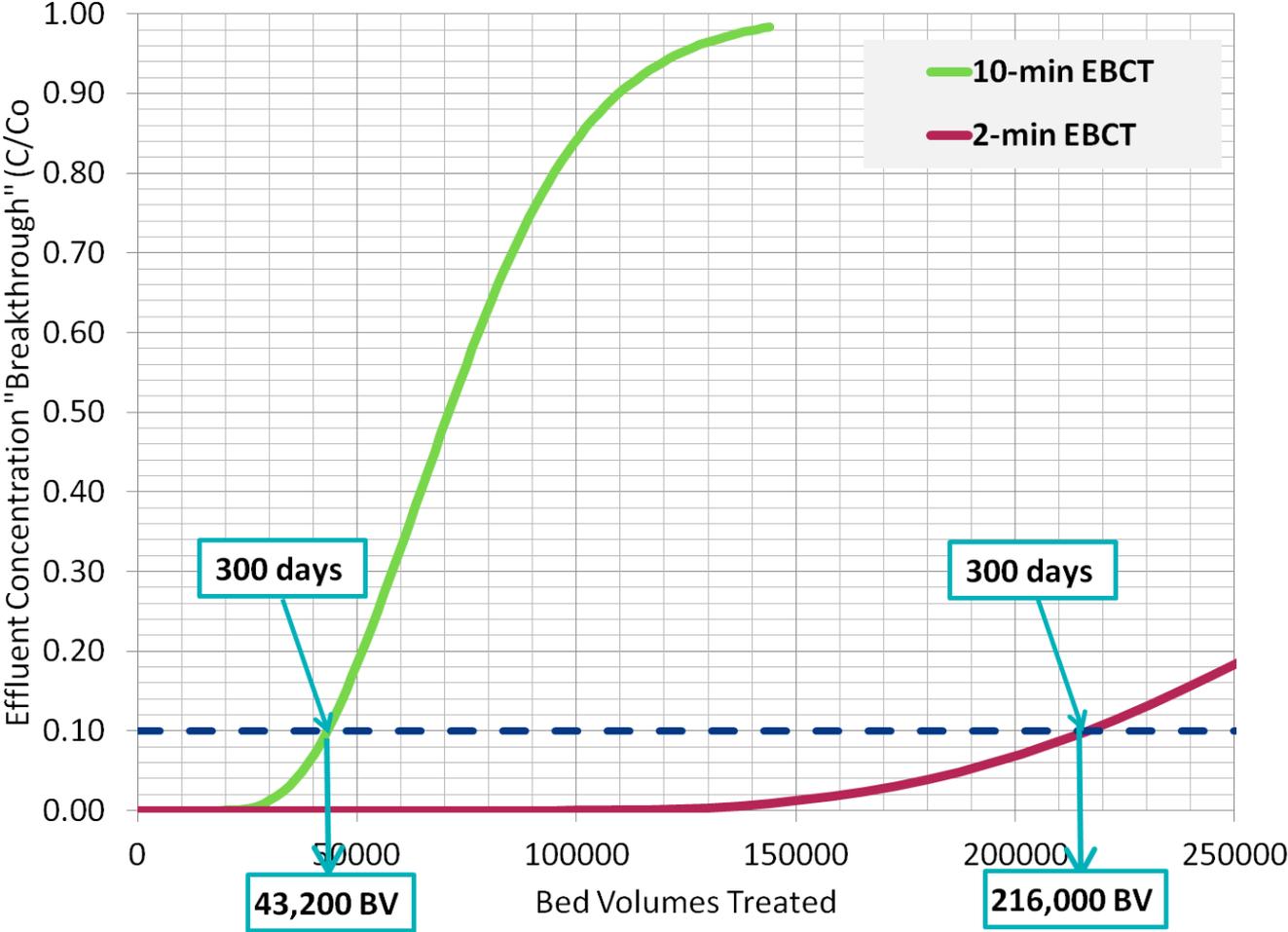
3. Evaluate Options

- NPV – 5, 10, 20 years
- Funding Options – CapEx vs. OpEx preference
- Other Considerations – footprint, co-contaminants

Bed Volumes GAC & IX



READING BREAKTHROUGH CURVES



HYPOTHETICAL #1



CONTEXT

Municipality in New York encounters PFAS in drinking water

APPROACH

Lab Column Test

Determine efficacy of proposed treatment system

- Two x 12-ft diameter vessels, lead-lag operation
- 40,000 lb GAC per vessel
- 13.2 minutes contact time

Hypothetical IX System:

- Two x 10-ft diameter vessels, lead-lag operation
- 353 ft³ resin per vessel
- 3.5 minutes EBCT

SIDE BY SIDE: Equivalent Service Life



Hypothetical #1 - GAC	
Flow (MGD)	1
Capital Cost	\$ 445,000
GAC Media Cost (\$/lb)	\$ 1.75
Service Life (days)	450
Service Life (BVs)	45,000
O&M Cost (10 year NPV, 6%)	\$ 419,000
Lifecycle Cost (10 year NPV, 6%)	\$ 864,000

Hypothetical #1 - IX	
Flow (MGD)	1
Capital Cost	\$ 410,000
IX Media Cost (\$/cf)	\$ 275.00
Service Life (days)	450
Service Life (BVs)	170,000
O&M Cost (10 year NPV, 6%)	\$ 581,000
Lifecycle Cost (10 year NPV, 6%)	\$ 991,000

GAC
13% *less expensive*

SIDE BY SIDE: Break Even



Hypothetical #1 - GAC	
Flow (MGD)	1
Equipment Capital Cost	\$ 445,000
GAC Media Cost (\$/lb)	\$ 1.75
Service Life (days)	450
Service Life (BVs)	45,000
O&M Cost (10 year NPV, 6%)	\$ 419,000
Lifecycle Cost (10 year NPV, 6%)	\$ 864,000

Hypothetical #1 - IX	
Flow (MGD)	1
Equipment Capital Cost	\$ 410,000
IX Media Cost (\$/cf)	\$ 275.00
Service Life (days)	575
Service Life (BVs)	217,500
O&M Cost (10 year NPV, 6%)	\$ 454,000
Lifecycle Cost (10 year NPV, 6%)	\$ 864,000

GAC & IX
Equivalent lifecycle costs

DISCUSSION

- Co-contaminants
- Permitting
- Economic sensitivity



HYPOTHETICAL #2



CONTEXT

Municipality in Colorado encounters PFAS in drinking water

APPROACH

Field Pilot Test

Determine efficacy of proposed treatment system

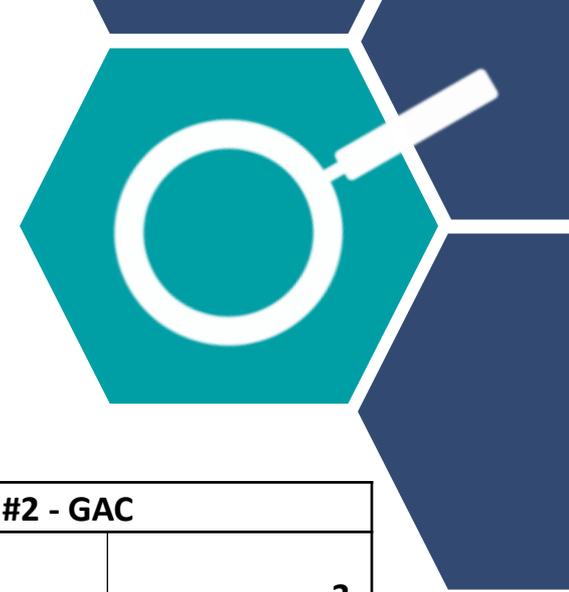
- Four x 10-ft diameter vessels, lead-lag operation
- 424 ft³ IX resin per vessel
- 2.5 minutes contact time

→

Hypothetical GAC System:

- Eight x 10-ft diameter vessels, lead-lag operation
- 20,000 lb GAC per vessel
- 10 minutes contact time

SIDE BY SIDE: Pilot Data

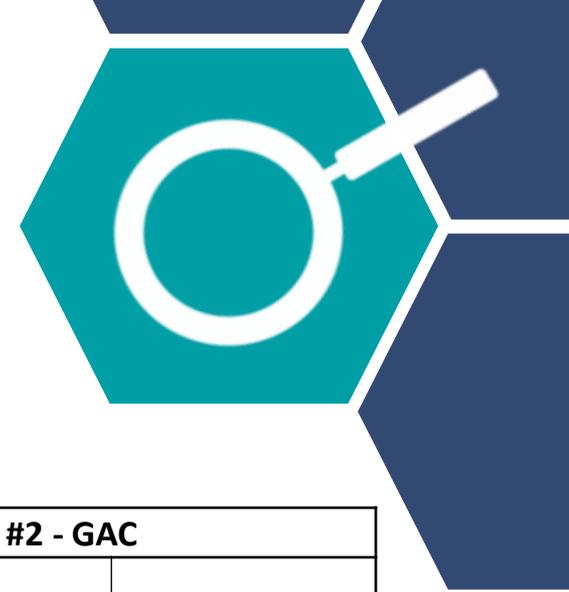


Hypothetical #2 - IX	
Flow (MGD)	3
Capital Cost	\$ 986,000
IX Media Cost (\$/cf)	\$ 275
Service Life (days)	210
Service Life (BVs)	100,000
O&M Cost (10 year NPV, 6%)	\$ 2,963,000
Lifecycle Cost (10 year NPV, 6%)	\$ 3,949,000

Hypothetical #2 - GAC	
Flow (MGD)	3
Capital Cost	\$ 1,420,000
GAC Media Cost (\$/lb)	\$ 1.75
Service Life (days)	135
Service Life (BVs)	20,000
O&M Cost (10 year NPV, 6%)	\$ 2,828,000
Lifecycle Cost (10 year NPV, 6%)	\$ 4,248,000

IX
7% less expensive

SIDE BY SIDE: Break Even



Hypothetical #2 - IX	
Flow (MGD)	3
Capital Cost	\$ 986,000
IX Media Cost (\$/cf)	\$ 275
Service Life (days)	210
Service Life (BVs)	100,000
O&M Cost (10 year NPV, 6%)	\$ 2,963,000
Lifecycle Cost (10 year NPV, 6%)	\$ 3,949,000

Hypothetical #2 - GAC	
Flow (MGD)	3
Capital Cost	\$ 1,420,000
GAC Media Cost (\$/lb)	\$ 1.75
Service Life (days)	155
Service Life (BVs)	22,350
O&M Cost (10 year NPV, 6%)	\$ 2,529,000
Lifecycle Cost (10 year NPV, 6%)	\$ 3,949,000

GAC & IX
Equivalent lifecycle costs

DISCUSSION

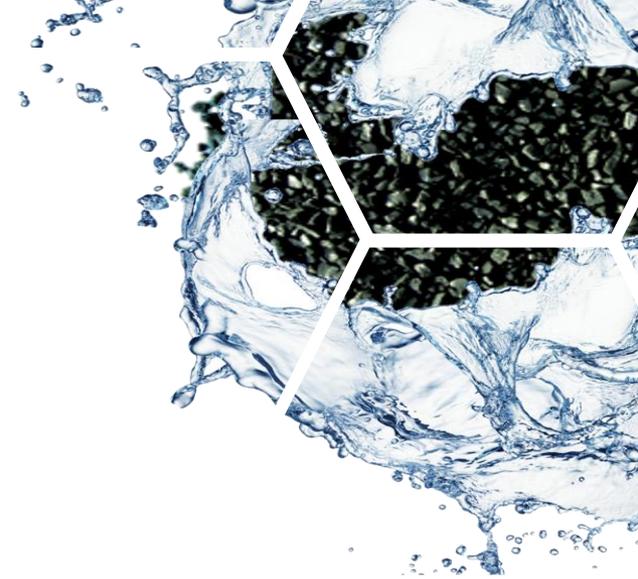
- Footprint
- Backwashing
- Nitrate
- Economic sensitivity



Conclusion



FINAL TAKEAWAYS



GAC & IX ARE EFFECTIVE AND PROVEN FOR PFAS

- Long chain
- Short chain
- Precursor/replacement compounds

NOT ALL PRODUCTS ARE CREATED EQUAL

- Base material influences performance
- Water quality influences performance

TESTING IS REQUIRED FOR ACCURATE TECHNOLOGY COMPARISON

- Utility specific
- Performance influences economics

Thank you for your time. Questions?

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