

Using GAC and Ion Exchange Resins to Remove PFAS and Similar Compounds from Drinking Water





Quick Background

- PFAS contamination is localized, yet widespread
- •There are presently over 5,000 known species within the PFAS family
- Most are highly treatable
- System design is critical
- •In nearly all cases, one of the following solutions is selected:
 - Granular Activated Carbon
 - Anion Exchange Resin







- Granular Activated Carbon (GAC) 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



CALGON CARBON PFAS TREATMENT LOCATIONS



CalgonCa

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 run time for short-chained PFAS (shorter run time)

(GAC)

Potential overshoot of poor adsorbing PFAS if not designed correctly

Reactivation/removal frequency

Disposal or reactivation of spent carbon

Anion Exchange Resin Run time for select PFAS (shorter run time)

(PFAS selective) 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



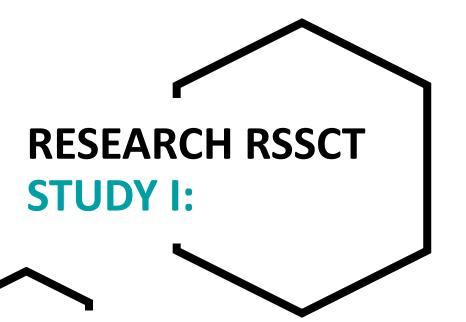
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PFAS Performance Testing Results







Four GAC products evaluated under identical operating conditions and influent water quality

COMPARISON OF VARIOUS GAC FOR PFOA AND PFOS REMOVAL

Carbon	Description	
Filtrasorb – Virgin	Bituminous Reagglomerated Coal 12x40 mesh	
TN5	Direct activated Coconut 8x30 mesh	
OLC	Direct activated Coconut 12x40 mesh	
Filtrasorb – React	Reactivated Bituminous Reagglomerated Coal 12x40 mesh	



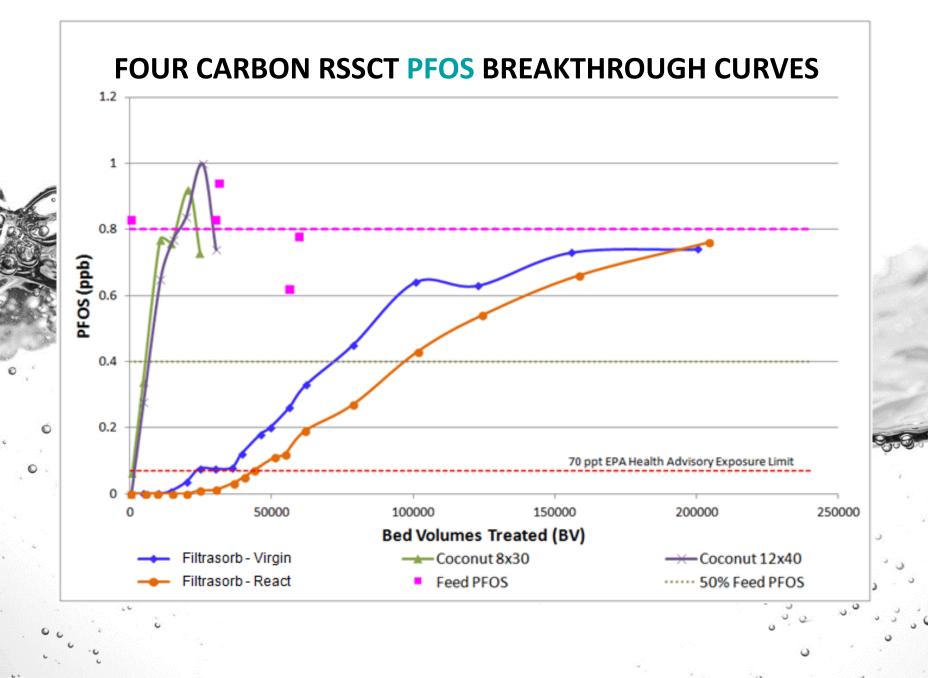
GAC COMPARISON TEST CONDITIONS

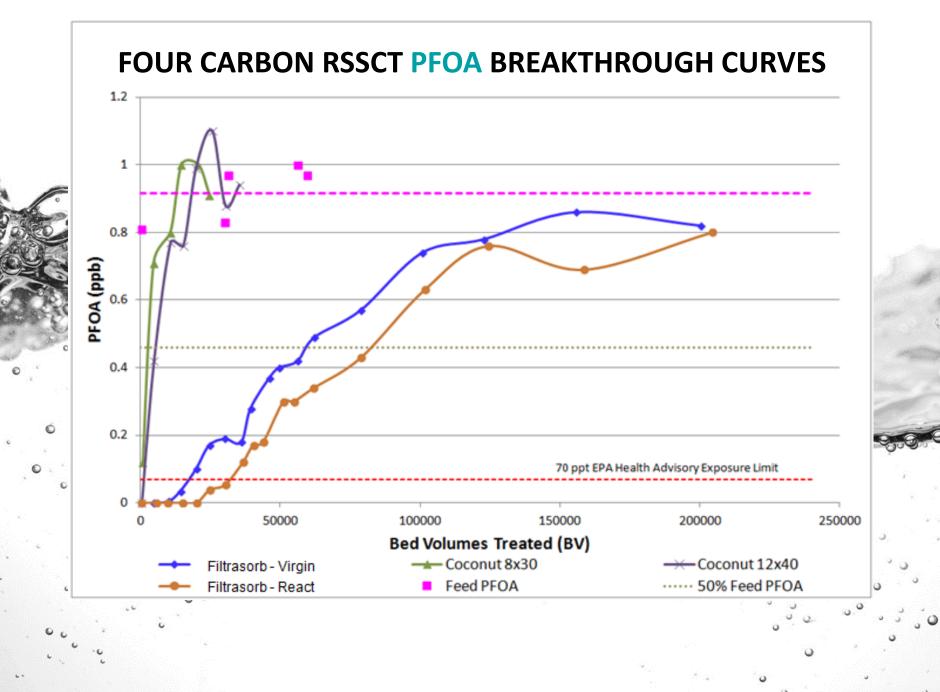


OPERATING PARAMETERS

- 10 minutes empty bed contact time (EBCT)
- Center Township, PA groundwater
- Water did not have PFAS as received
- Water was spiked to contain:
 - 920 ppt of PFOA (target 1,000 ppt)
 - 800 ppt of PFOS (target 1,000 ppt)
- 1.42 ppm background TOC







CONCLUSIONS



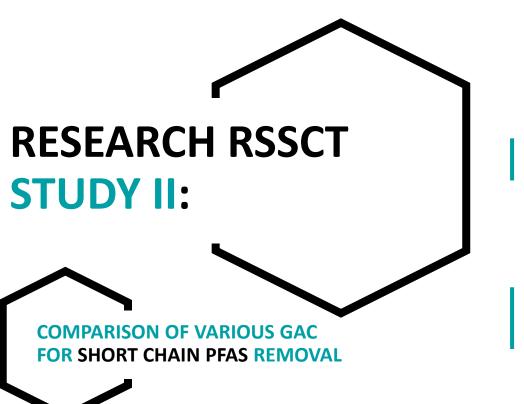
BOTH PFOS & PFOA ARE REMOVED BY GAC

- PFOS > PFOA
 - Molecular weight
 - Functional group

REAGGLOMERATED BITUMINOUS COAL GAC GREATLY OUTPERFORMS COCONUT BASED GAC

- Both virgin & reactivated GAC can be viable treatment options
- Filtrasorb React > Filtrasorb Virgin > Coconut 12x40 > Coconut 8x30





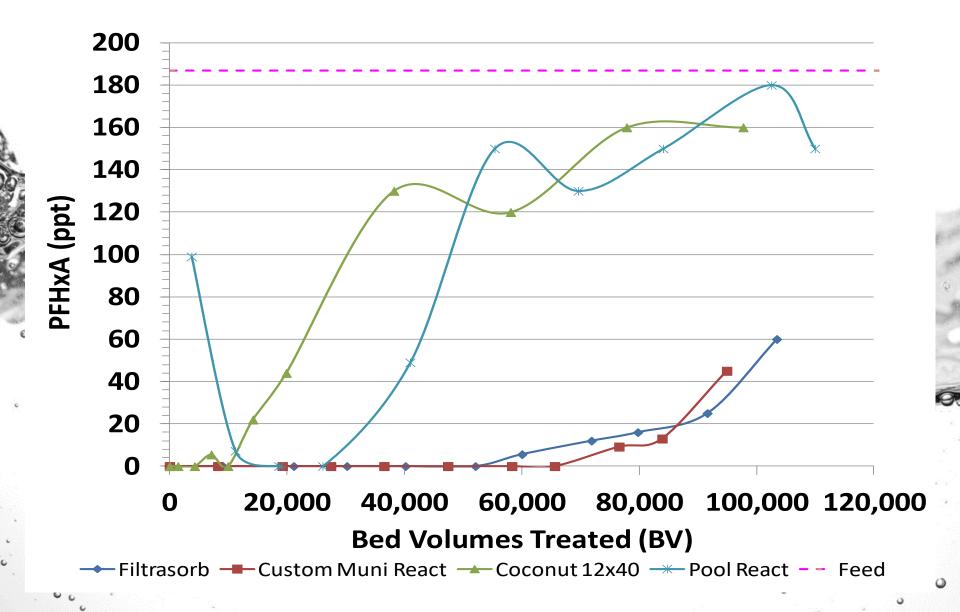
Multiple PFAS, variety of chain lengths

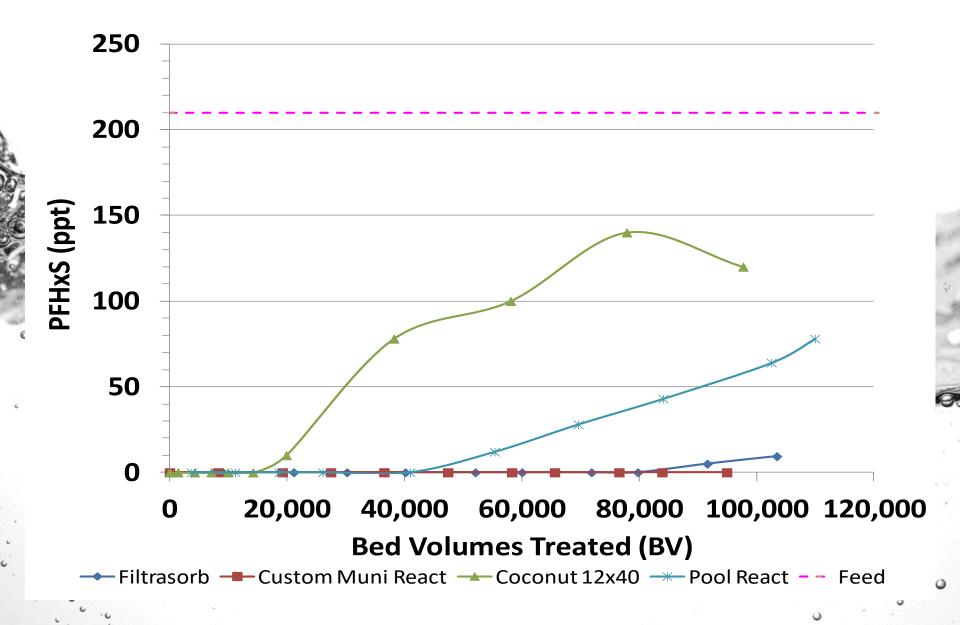
 Each compounds spiked to approximately 200 ppt

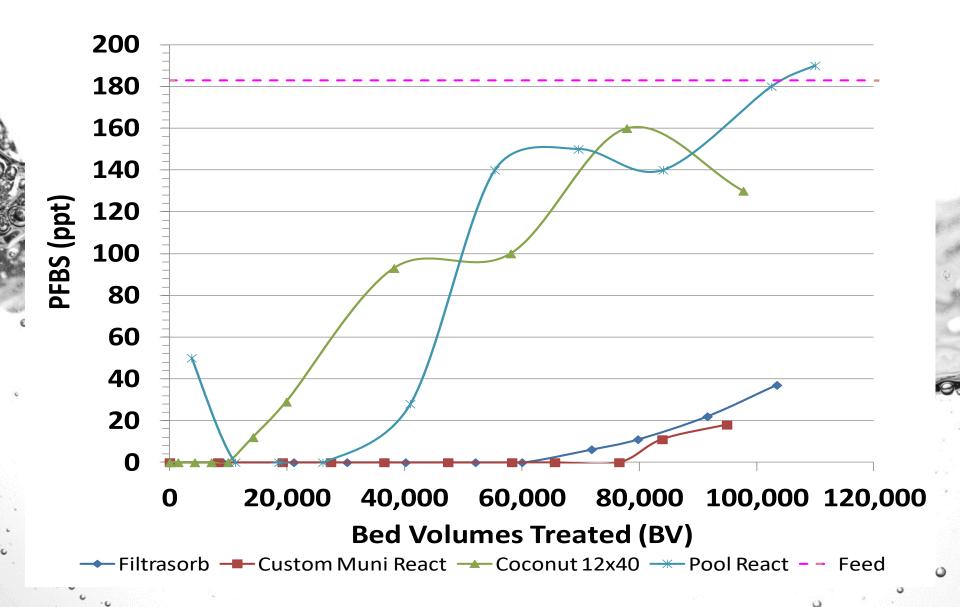
Background TOC – 0.16 ppm Simulated EBCT – 10 minutes

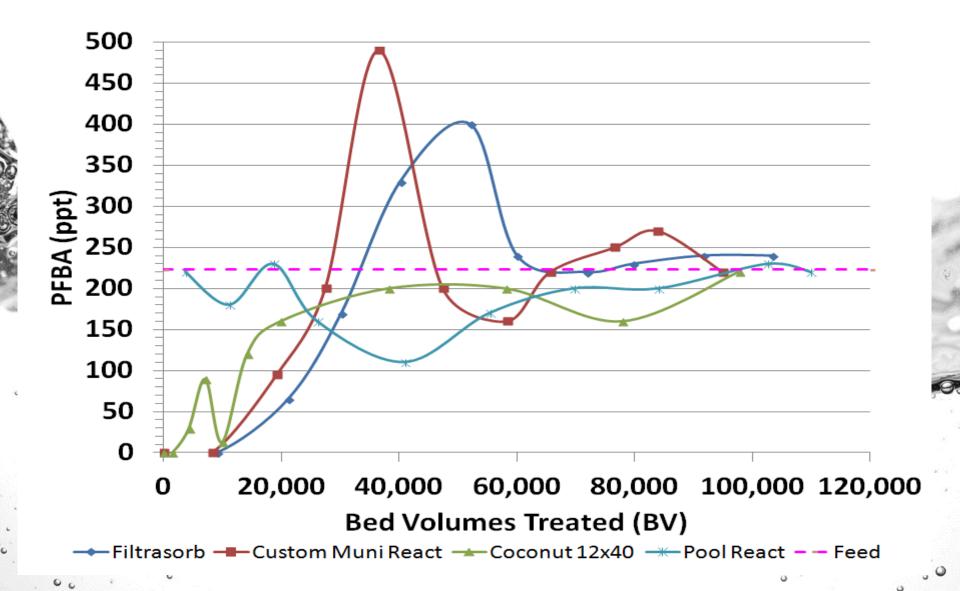
Name	Abbreviation	CAS Number	Carbon Chain Length	Molecular Weight (g/mol)
Perfluoro octanesulfonic acid	PFOS	1763-23-1	C8	500.13
Perfluoro octanioc acid	PFOA	335-67-1	C8	414.07
Perfluorohexanesulfonic acid	PFHxS	355-46-4	C6	400.11
Perfluoro hexanoic acid	PFHxA	307-24-4	C6	314.05
Perfluoro butanesulfonic acid	PFBS	375-73-5	C4	300.1
Perfluoro butanoic acid	PFBA	375-22-4	C4	214.04











CONCLUSIONS



ALL PFAS ARE REMOVED BY GAC TREATMENT

- Lower molecular weight PFAS exhibit lower loadings and earlier breakthrough times
- PFBA << PFHxA < PFBS < PFOA < PFHxS < PFOS

REAGGLOMERATED BITUMINOUS COAL GAC OUTPERFORMS COCONUT BASED GAC

Both virgin & reactivated GAC can be viable treatment options



RESEARCH RSSCT STUDY III:

Four Ion Exchange products marketed for PFOA/PFOS treatment were evaluated under identical operating conditions and influent water quality

The study looked at one GAC as well

COMPARISON OF ION EXCHANGE RESINS AND GAC

Carbon	Description	
CalRes 2109	Calgon Carbon Resin	
Purolite 120	Purolite Resin	
APR-1	Evoqua Resin	
PSR2+	Evoqua Resin	
Filtrasorb 400	Bituminous Reagglomerated Coal 12x40 mesh	



IX COMPARISON BACKGROUND



WIDEFIELD, CO

- Elevated nitrate in groundwater made GAC a challenge
- Footprint issues a concern
- No backwash handling



Empty Bed Contact Time (EBCT)

<u>Definition</u>: the amount of time required for a volume of water equivalent to the volume occupied by the media to pass through the vessel.

--Expressed in units of time (minutes)

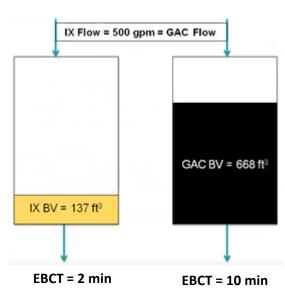
Adsorption is NOT instantaneous

--The portion of the bed in which adsorption is occurring is called the Mass Transfer Zone (MTZ)

IX EBCT < GAC EBCT

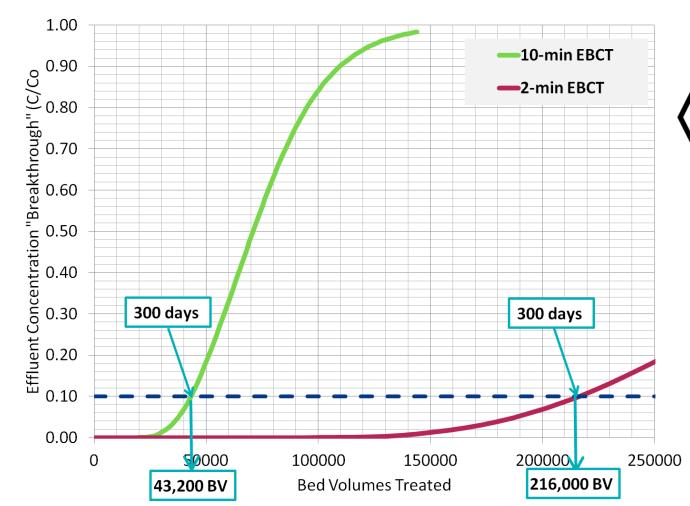
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IX Bed Volume < GAC Bed Volume





REFRESHER: READING BREAKTHROUGH CURVES

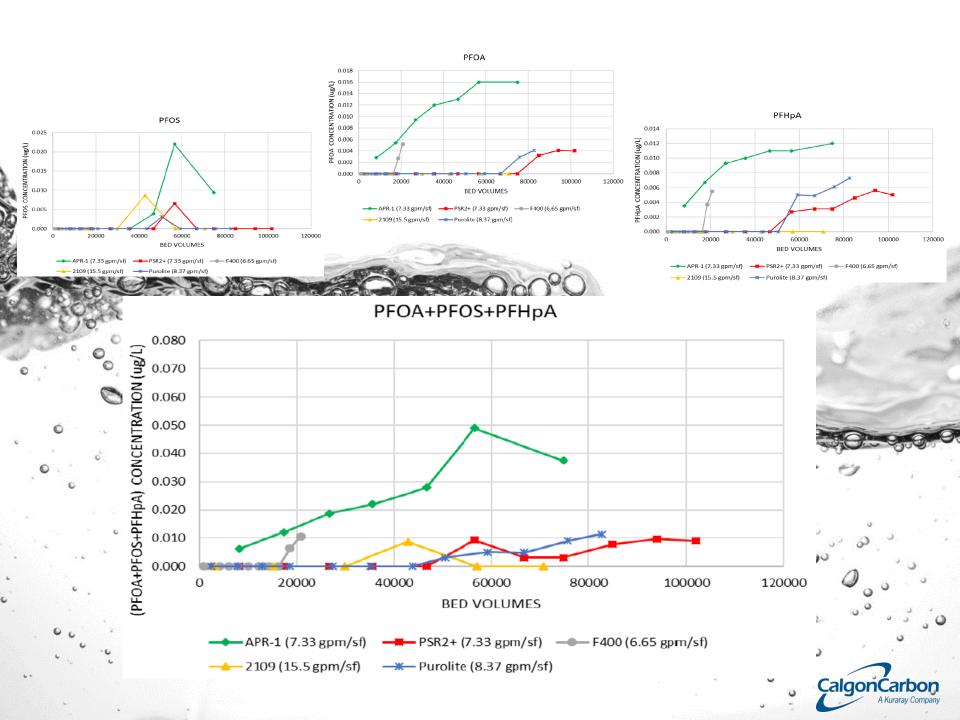




REMEMBER

 "Bed Volumes" does not equal actual run time.





FULL SCALE PILOT

May 2017 - January 2019 126,000 Bed Volumes



25% Sample Port: PFHpA – 22 ppt, PFOA – 23 ppt

50% Sample Port: PFHpA – 19 ppt, PFOA – 14 ppt

75% Sample Port : PFHpA – 5.3 ppt

Effluent: PFHpA – 5.8 ppt

PSR2-Plus:

25% Sample Port: PFBS – 2.2 ppt, PFHpA – 15 ppt, PFOA – 25 ppt

50% Sample Port: PFHpA – 12 ppt, PFOA – 15 ppt

75% Sample Port: PFHpA – 4.4 ppt, PFOA – 12 ppt

Effluent: PFHpA – 6 ppt, PFOA – 4.9 ppt





PFAS REMOVAL GAC vs IX

- 1. Preliminary System Design (based on flow rate and WQ data)
 - "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



COMPARATIVE COST ANALYSIS



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		
		2
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)	\$	2,963,000
Lifecycle Cost (10 year NPV)	\$	3,949,000

Hypothetical #2 - G/	١.	
Hypothetical #2 - G/	10	
51 (1405)		
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)	\$	2,828,000
Lifecycle Cost (10 year NPV)	\$	4,248,000

1X 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)	\$	2,963,000
Lifecycle Cost (10 year NPV)	\$	3,949,000

Hypothetical #2 - GAC		
Flour (MACD)	2	
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)	\$ 2,529,000	
Lifecycle Cost (10 year NPV)	\$ 3,949,000	

GAC & IX
Equivalent lifecycle costs



CONCLUSIONS



KEEP IN MIND

- IX resin tends to cost 3-5x more than GAC per unit volume, but requires fewer vessels
- RSSCT Testing on GAC can provide guidance on which technology is preferable
- Generally, GAC will provide the most economical approach over 15-20 years

RULES OF THUMB

- Groundwater with elevated nitrate may make IX a good solution
- Due to lower EBCT requirements, IX systems require a lower footprint and may be favorable when space is limited

EVERY CASE IS UNIQUE

 Testing <u>both</u> technologies is the only way to know for sure which is the best for a given water source



Wait, there's more ??



PFAS: The Next Generation - GenX

- •PFAS Precursors can they be removed too?
- •What about other types of GAC Lignite, Enhanced Coconut?



FINAL TAKEAWAYS

GAC AND IX ARE EFFECTIVE AND PROVEN FOR REMOVAL OF PFAS

- Long and short chain
- Precursor and replacement compounds

NOT ALL PRODUCTS ARE CREATED EQUAL

- GAC Base Material influences performance
- Different IX resins perform differently
- Water quality influences performance

TESTING REQUIRED TO ACCURATELY PREDICT SERVICE LIFE

- Column > Isotherm
- Performance influences economics

