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Experienced. Proven. Reliable.

The Basic Principles of Water Treatment Media Pilot Trial Design and Evaluation

PFAS Removal Solutions: Current industry standards for removing PFAS with life cycle costs

+++ High ++ Medium + Low

	Description	PFAS Removal Effectiveness	Relative Cost		Other Considerations
Granular Activated Carbon (GAC)	**Due to its highly porous nature and large surface area, GAC absorbs contaminants at the interface between liquid and solids phases.**	Up to 99% effective depending on the chain length, GAC works best on longer-chain	++	GAC is cheaper unit cost but higher volumes are needed to remove the same amount of PFAS	Lower hydraulic loading rates When water has multiple different total organic carbons (TOC) GAC may remove TOC over the PFAS, decreasing effectiveness
Ion Exchange Resins (IX)	**Positively charged anion exchange resins attract PFAS and hold the contaminate from moving through the water. Can come in both gel (standard water treatment with higher capacity) or macroporous (best for elevated organic content) resin types**	Up to 99% effective for all chain lengths PFAS but also effective for long chain	++	10-15% cheaper than GAC on a TOTEX basis but 50% cheaper than RO systems	IX is growing in market share compared to other technologies due to its lower cost IX has a lifespan of 6-18 months depending on PFAS concentration Most resins used are non-regenerable Does not need a large footprint for operations making it a better option for limited space
Specialty Media	Proprietary adsorptive medias that work like resins but have the relative cost of carbons	Effectiveness depending on chain Only suitable for low flow	++	Priced between IIX and GAC proprietary medias have benefit of both	New to emerging contaminants with long history in other remediation applications Performs similar to both resins and GAC Treats full spectrum of PFAS contaminants without being effected by co contaminates in the waste stream

Market Share: High → Low

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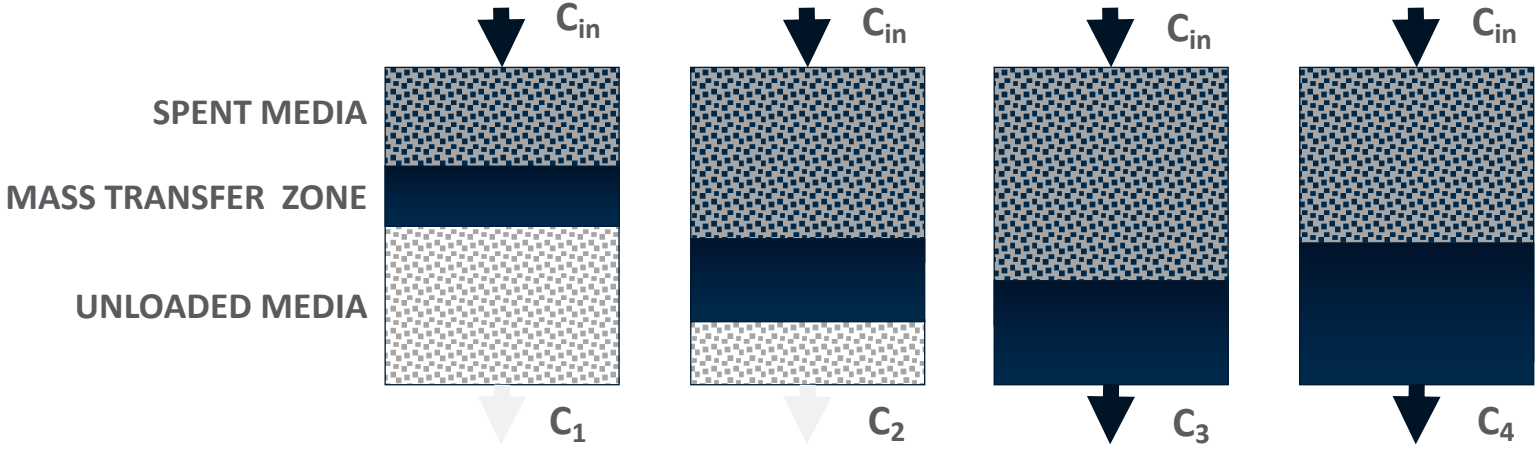
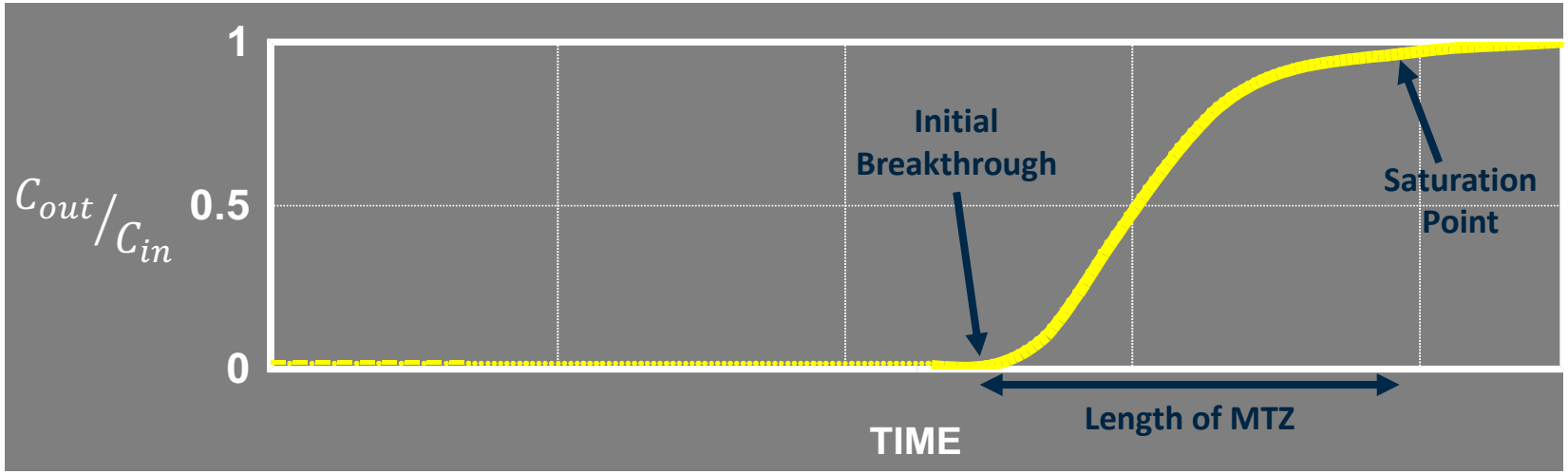
Source: Amane analysis | Expert interviews | EPA | Dupont | Westech | AWWA

How Do These Treatment Systems Work?

Media loading and design criteria is determined by the contact time with the water and the hydraulic loading.





System Design Criteria: Empty Bed Contact Time (EBCT)

Empty Bed Contact Time is a measurement of media volume and water flow rate.

~~$EBCT = Weight\ (lbs)$~~

$$EBCT\ (min) = \frac{Carbon\ Volume\ (ft^3)}{Flow\ Rate\ (ft^3/min)}$$

$$Example: 7.5\ minutes\ EBCT\ at\ 1,000\ gpm$$

$$Carbon\ Volume\ (ft^3) = EBCT\ (min)\ x\ Flow\ Rate\ (ft^3/min) =$$

$$7.5 \text{min}\ x \frac{1,000}{7.48}\ ft^3/min = 1,003\ ft^3$$

Referring to any Media manufacturer's performance guarantee, it is always referenced in Bed Volumes which is also a measurement of the volume of media being supplied.

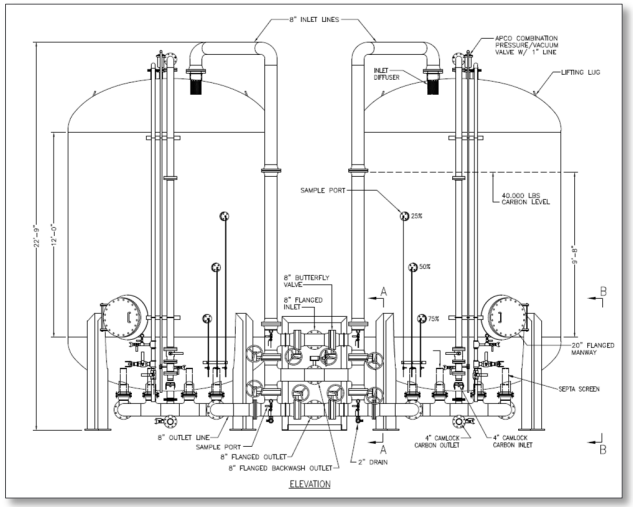
BVs x total CF x 7.48 gal/cf = total gallons treated

PFAS Treatment Options: GAC Media

Granular Activated Carbon is being used throughout the nation for the removal of organic contaminates in the water.

GAC – Granular Activated Carbon

- **>**10 min empty bed contact time per vessel
  - **A volumetric based calculation, not weight**
- Hydraulic loading rate: 2> X <10 gpm/ft^2 to prevent channeling
  - 12 ft. diameter vessel maximum flow rate → 1,000-1,100 gpm
- Height 22’-9” with a volume of 1,337 cu ft. of carbon per vessel
- ~12-13 psi DP including carbon @ 1,000 gpm
- Removes the target organics in the water
  - Can be good if you need to treat all organics
  - Higher levels of TOC limit the carbon bed life
- PFAS Removal: Bituminous Coal Carbon
  - Direct activated
  - Re-agglomerated bituminous
- PFAS Removal: Lignite Carbon
  - Lighter apparent density than bituminous coal carbon

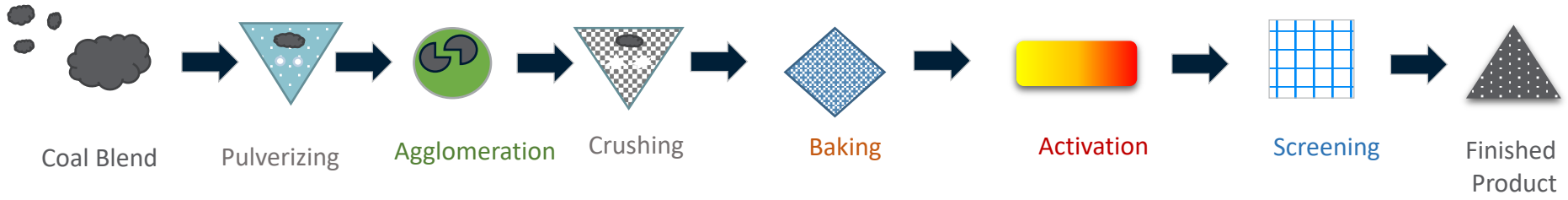


GAC: Direct Activation vs. Re-agglomeration

There are different ways to manufacture a granular activated finished product.

- Not all Coals Can be Direct Activated
  - Need a minimum volatile matter content and show sufficient agglomerating characteristics
- Lower Rank (Low Volatile) Bituminous Coals Cannot be Direct Activated
  - Volatile matter plays a factor in the ignition and flame stability, the reactivity and burnout of chars, and the amount of unburned carbon in the fly ash
- For Re-agglomerated carbons, a binder (Coal Tar Pitch) must be added to help artificially produce a coal with a higher volatile matter content

Re-agglomeration



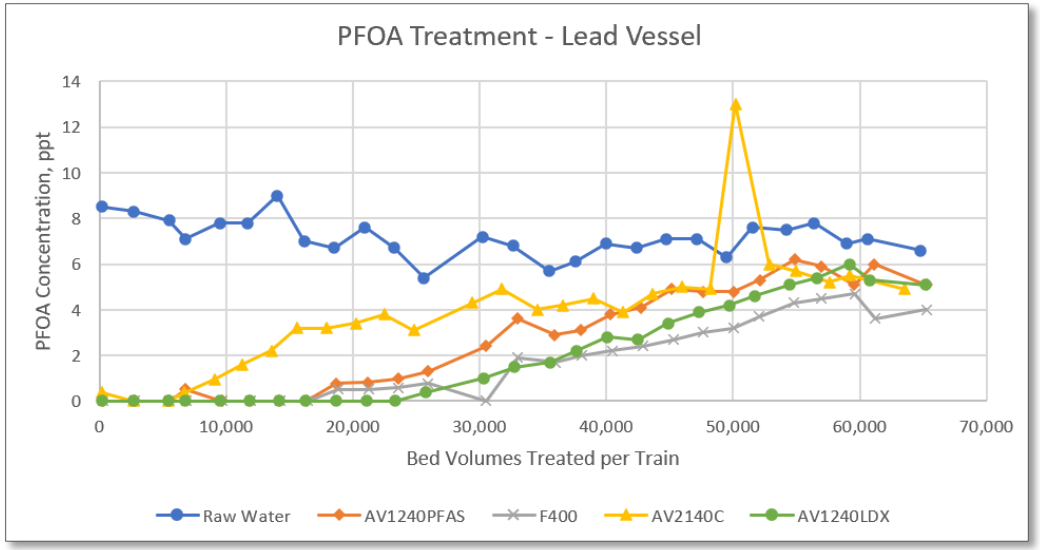
Direct Activation

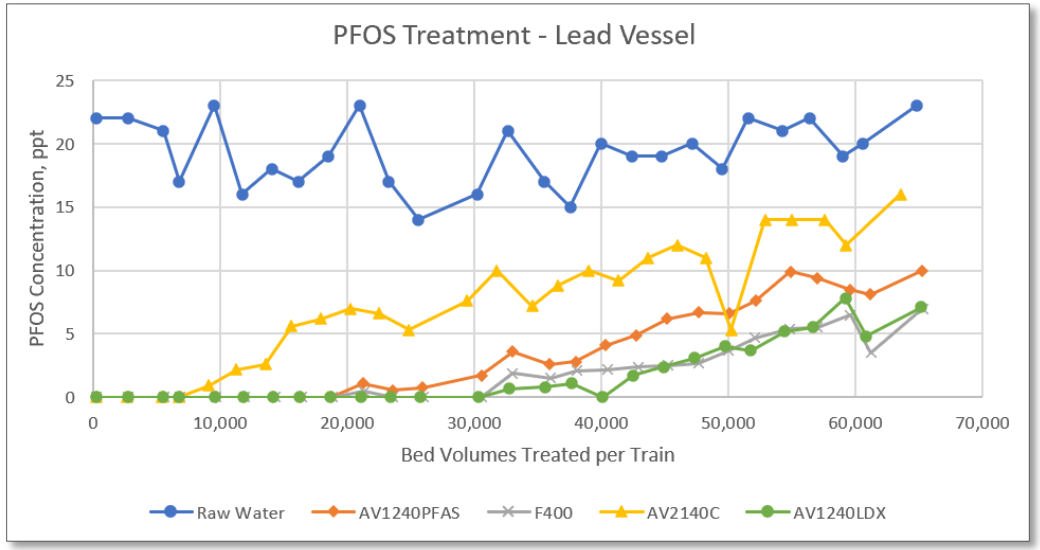
GAC Pilot Study Ventura County, CA

They were only testing GAC because they needed to remove both 123-TCP and PFAS Compounds.

Design Criteria	
EBCT	5 minutes*
Hydraulic Loading	8.2 gpm/ft2
Influent Water Quality	
PFOA	7.2 ppt
PFOS	18.9 ppt
TOC	0.29 ppm Avg.

*The pilot was run with lead-lag configuration. EBCT per column. Lag Columns did not breakthrough.





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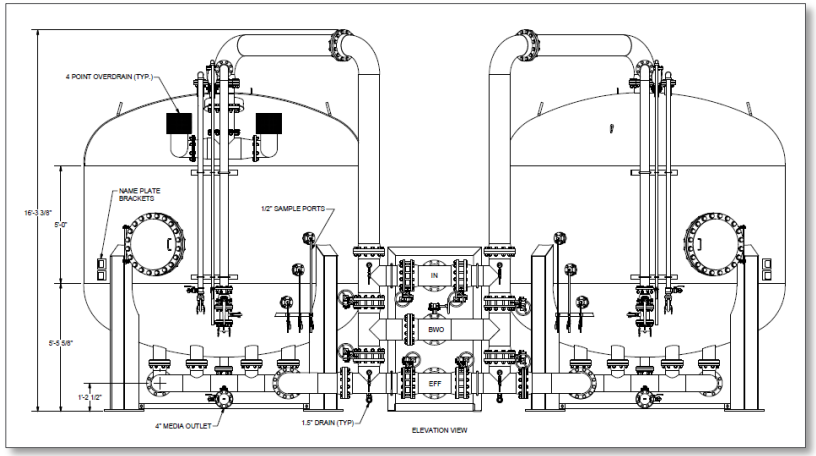
PFAS Treatment Options: IX Single Pass Resin

IX – Ion Exchange

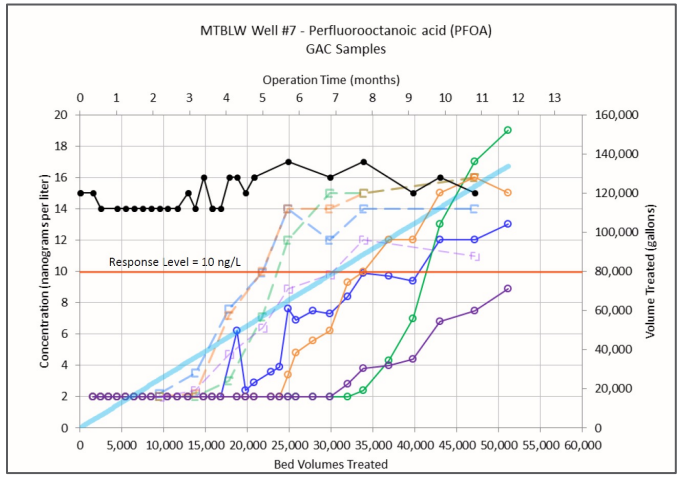
- >1.6 min empty bed contact time, typically 2-3 minutes per vessel
- Hydraulic Loading Rate 6 > X < 18 gpm/ft^2
  - 12 ft. dia. vessel max. flow rate → 2,000 gpm
- 25-28 psi DP with 535 cu. ft resin per vessel
- Overall System Height 16’-4”
- 4-point inlet distributor
- PFAS or Perchlorate Selective Resin
  - Competing anion concentrations (SO_4, NO_3, HCO_3, Cl, TOC) allow us to predict resin bed life
  - Background anions affect resin bed life



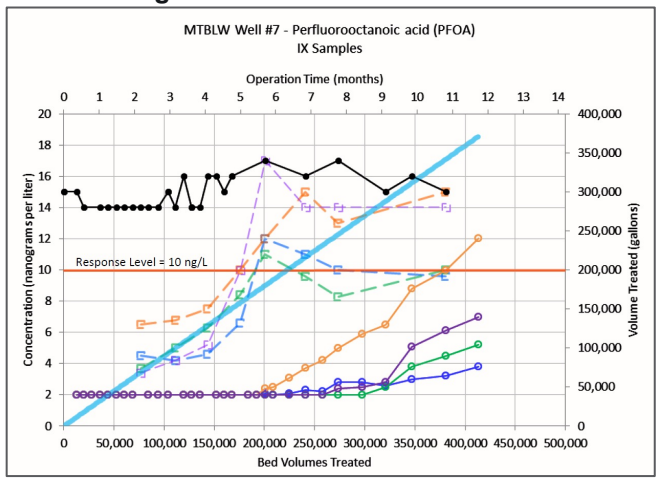
Pilot Data – Los Angeles County, CA #1– IX Resin and GAC

This was a comparison between GAC and IX Resin for both PFOA and PFOS.

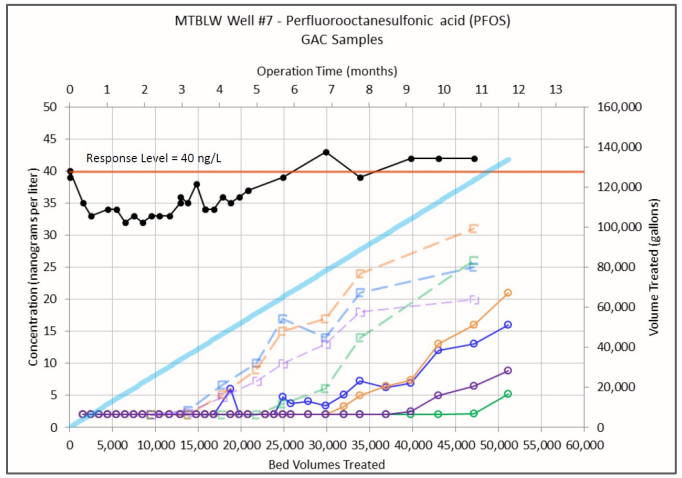
GAC: PFOA Removal



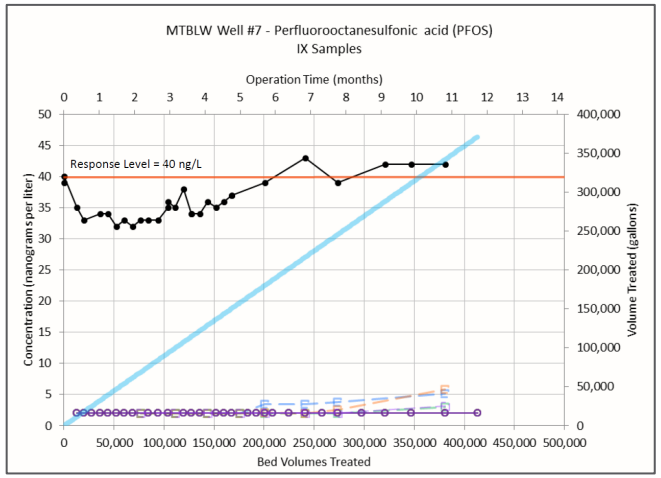
Ion Exchange Resin : PFOA Removal



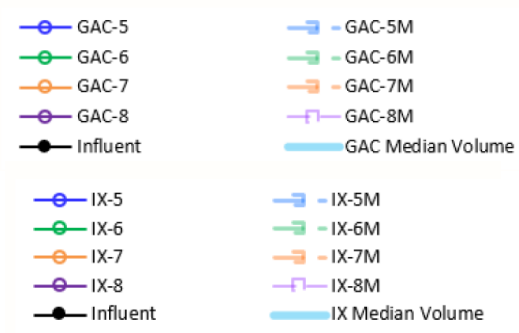
GAC: PFOS Removal



Ion Exchange Resin: PFOS Removal



GAC Design Criteria	
EBCT	10 minutes
Hydraulic Loading	8.2 gpm/ft2
Ion Exchange Resin Design Criteria	
EBCT	1.2 minutes
Hydraulic Loading	16 gpm/ft2
Influent Water Quality	
PFOA	11-17 ppt
PFOS	29-37 ppt
TOC	0.68 ppm Avg.



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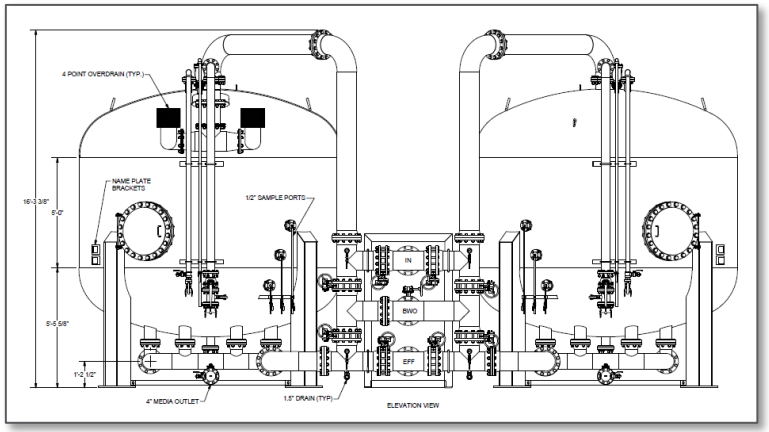
Treatment Options: CETCO FLUORO-SORB®

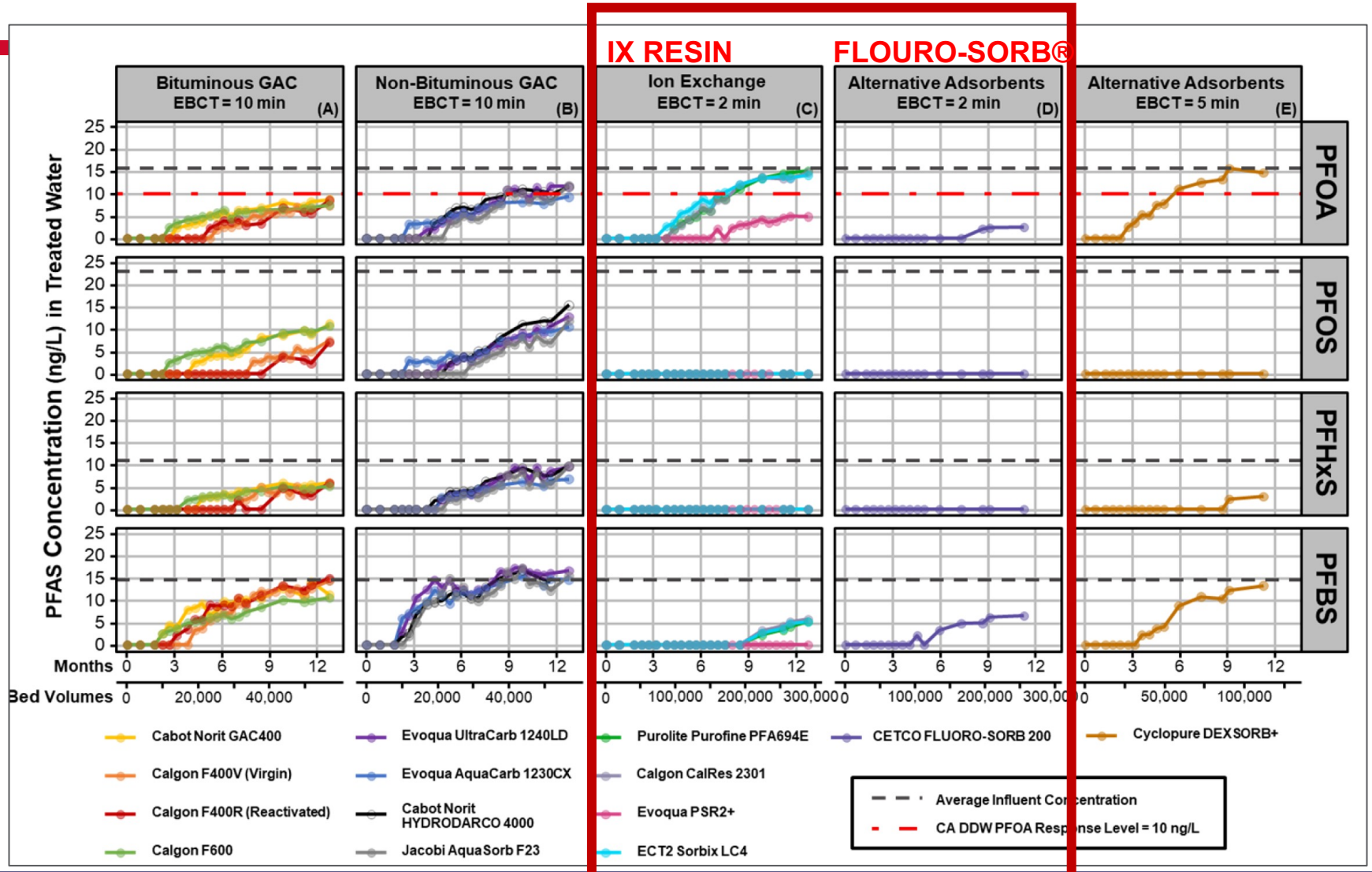
A new media showing to perform as well as ion exchange resin.

Municipal applications: FLUORO-SORB® 200

- Adsorbent that is proprietary
- >2 min empty bed contact time
  - Example: SJW is using 2.5 minutes
- Hydraulic Loading Rate < 14 gpm/ft^2
  - 12 ft. dia. vessel max. flow rate → 1,600 gpm
  - Testing for max capability
- Overall System Height < 15 ft. (LowPro™)
- Apparent Density 49.9 lb/ft^3
- Requires Backwashing
- Works well with long and short-chain PFAS compounds
- Currently no other compounds that significantly affect or shorten the bed life



Orange County Water District PFAS Pilot Study



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