PFAS Treatment with Ion Exchange: Worldwide Compliance and Everchanging Regulations

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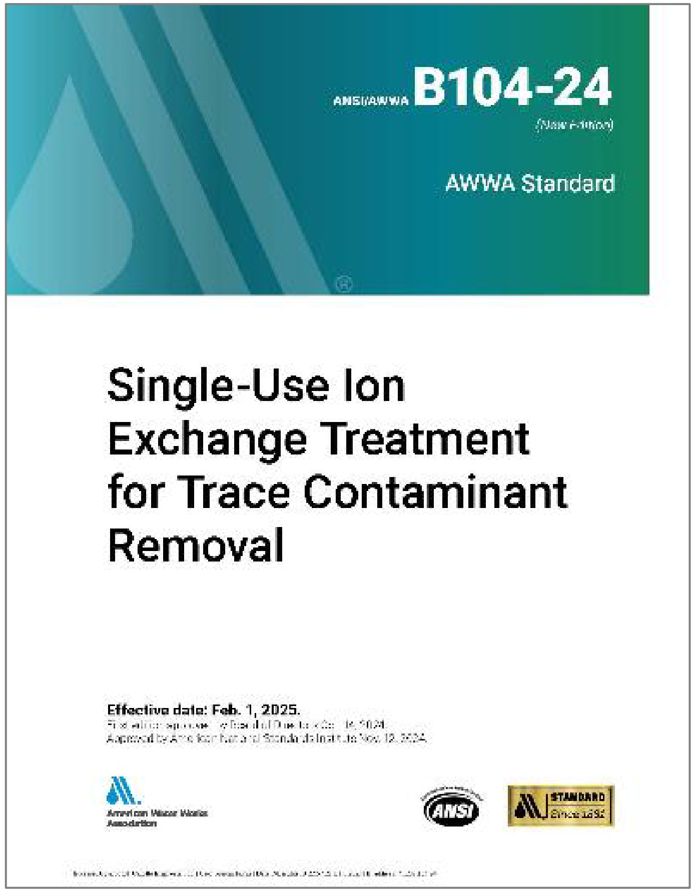
ANSI/AWWA B104-24
(New Edition)
AWWA Standard
Single-Use Ion Exchange Treatment for Trace Contaminant Removal
Effective date: Feb. 1, 2025.
American Water Works Association
ANSI
STANDARD

- ~ 20 years in ion exchange treatment for micropollutants such as chromate, perchlorate, nitrate, arsenic, uranium, PFAS systems, and more.
- Vice Chair of the AWWA Ion Exchange Committee Meeting
  - Co-chair of its Standards Subcommittee
    - AWWA B104-24 Single-Use Ion Exchange Treatment for Trace Contaminant Removal published Feb 1, 2025.
    - Regenerable resin standard 2026
  - CA-NV AWWA PFAS Subcommittee Secretary
- Past Chair of the Los Angeles Water For People Committee
- Chair of the California Nevada AWWA PFAS Workgroup

- BS in Chem E at Northwestern University
- MBA from UNC Chapel Hill

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Trace Contaminants / Micropollutants

Ion Exchange Resin is Used to Treat:

- Low level contamination in:
  - Drinking water
  - Groundwater
  - Surface water
  - Stormwater
  - Industrial discharge of PFAS
- Typical users:
  - Drinking Water Purveyors
  - OEMs
  - Consultants and Engineers
  - Remediation sites
- Includes:
  - PFAS
  - Perchlorate
  - Nitrate
  - Chrome VI
  - Disinfection byproducts / TOC
  - Arsenic
  - Uranium
  - Boron
  - Barium/Radium/Strontium/Iron/Manganese
  - Softening when used for these types of clients
  - Metals

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US Federal Regulations and Timeline

NATIONAL ARCHIVES

FEDERAL REGISTER

The Daily Journal of the United States Government

Compound	Final MCLG	Final MCL	PQL
PFOA	0	4.0 ng/L	4 ng/L
PFOS	0	4.0 ng/L	4 ng/L
PFHxS	10 ng/L	10 ng/L	3 ng/L
PFNA	10 ng/L	10 ng/L	4 ng/L
HFPO-DA (GenX)	10 ng/L	10 ng/L	5 ng/L
PFBS	--	--	3 ng/L
Hazard Index (HI)	1.0	1.0	--

$$HI = \frac{[PFHxS]}{10\ ng/L} + \frac{[PFNA]}{10\ ng/L} + \frac{[GenX]}{10\ ng/L} + \frac{[PFBS]}{2{,}000\ ng/L}$$

- Compliance will be determined by running annual averages (RAAs) at each distribution system entry point.
- Zero is used to calculate the compliance data when PFAS concentrations are less than the practical quantification levels (PQLs).

2024 Rule Finalization

2027 Initial Monitoring

2029 MCL Compliance

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2024 Rule Finalization

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2031

2029 MCL Compliance ?

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European Union

Drinking Water Directive (DWD)

- Limits levels of 20 individual PFAS to 0.1 µg/L or 100 ppt
- Total PFAS in drinking water is limited to 0.5 µg/l or 500 ppt
- Compliance for testing by 12 January 2026.

PFAS listed in paragraph 3 of Part B of Annex III to the Directive that are to be analysed for the reporting of the parametric value of '*Sum of PFAS*' (* Abbreviation not mentioned in the Directive)

Carbon chain length	Perfluoroalkyl carboxylic acids (PFCAs)	Perfluoroalkyl sulfonic acids (PFSAs)
4	Perfluorobutanoic acid (PFBA)	Perfluorobutane sulfonic acid (PFBS)
5	Perfluoropentanoic acid (PFPA)	Perfluoropentane sulfonic acid (PFPS)
6	Perfluorohexanoic acid (PFHxA)	Perfluorohexane sulfonic acid (PFHxS)
7	Perfluoroheptanoic acid (PFHpA)	Perfluoroheptane sulfonic acid (PFHpS)
8	Perfluorooctanoic acid (PFOA)	Perfluorooctane sulfonic acid (PFOS)
9	Perfluorononanoic acid (PFNA)	Perfluorononane sulfonic acid (PFNS)
10	Perfluorodecanoic acid (PFDA)	Perfluorodecane sulfonic acid (PFDS)
11	Perfluoroundecanoic acid (PFUnDA)	Perfluoroundecane sulfonic acid (PFUnDS)*
12	Perfluorododecanoic acid (PFDoDA)	Perfluorododecane sulfonic acid (PFDoDS)*
13	Perfluorotridecanoic acid (PFTrDA)	Perfluorotridecane sulfonic acid (PFTrDS)*

Source: https://environment.ec.europa.eu/topics/water/drinking-water_en

European Union

Drinking Water Directive (DWD)

- Ion Exchange has excellent bed life for the green highlighted PFAS.
- Often, the *Sum of PFAS* can be reduced below the DWD with removal of the green highlighted PFAS.
- The green highlighted PFAS are associated with the higher toxicity.

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7		Perfluoroheptanoic acid (PFHpA)	Perfluoroheptane sulfonic acid (PFHpS)
8	Long Bed Life	Perfluorooctanoic acid (PFOA)	Perfluorooctane sulfonic acid (PFOS)
9		Perfluorononanoic acid (PFNA)	Perfluorononane sulfonic acid (PFNS)
10		Perfluorodecanoic acid (PFDA)	Perfluorodecane sulfonic acid (PFDS)
11		Perfluoroundecanoic acid (PFUnDA)	Perfluoroundecane sulfonic acid (PFUnDS)*
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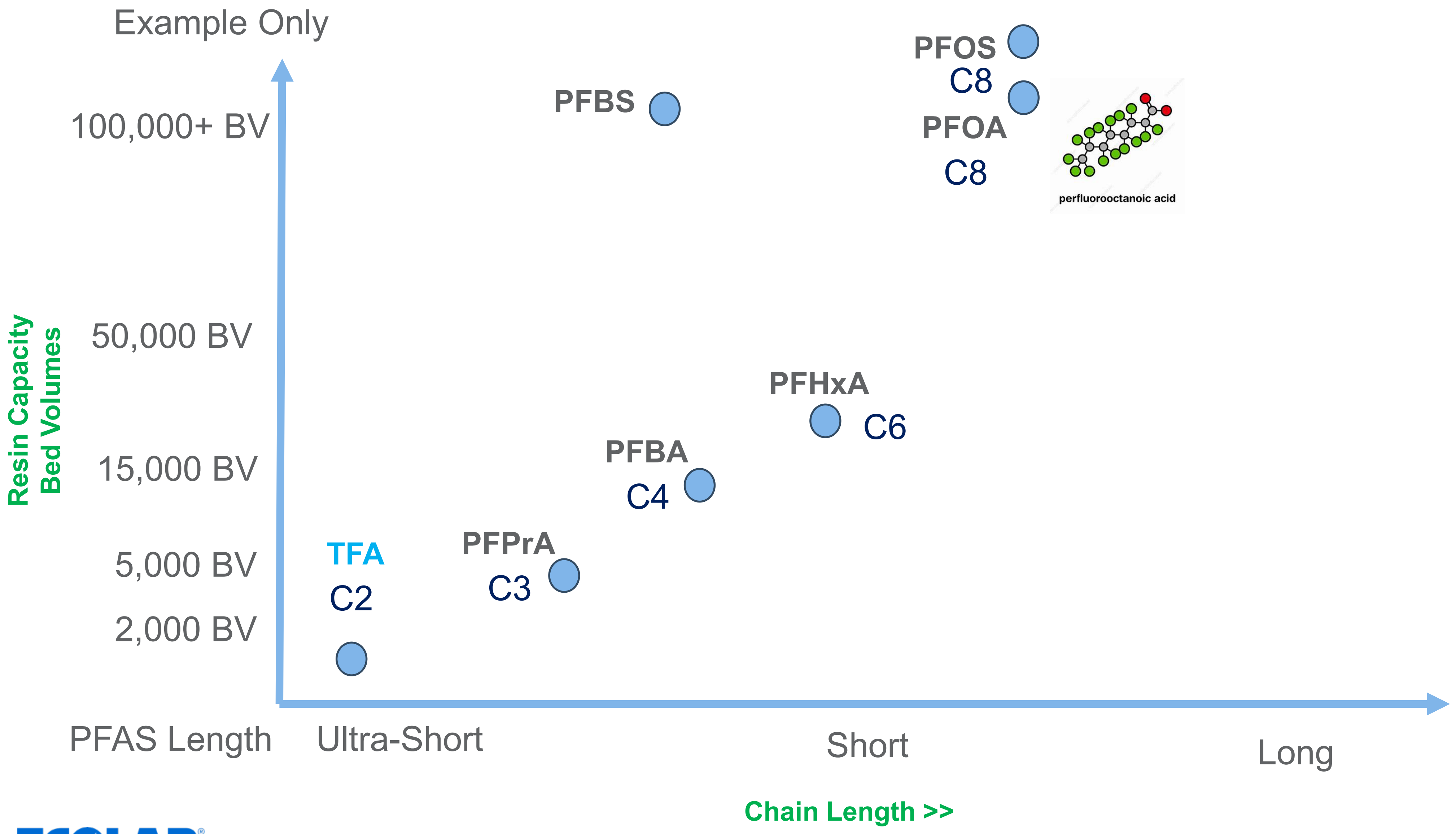
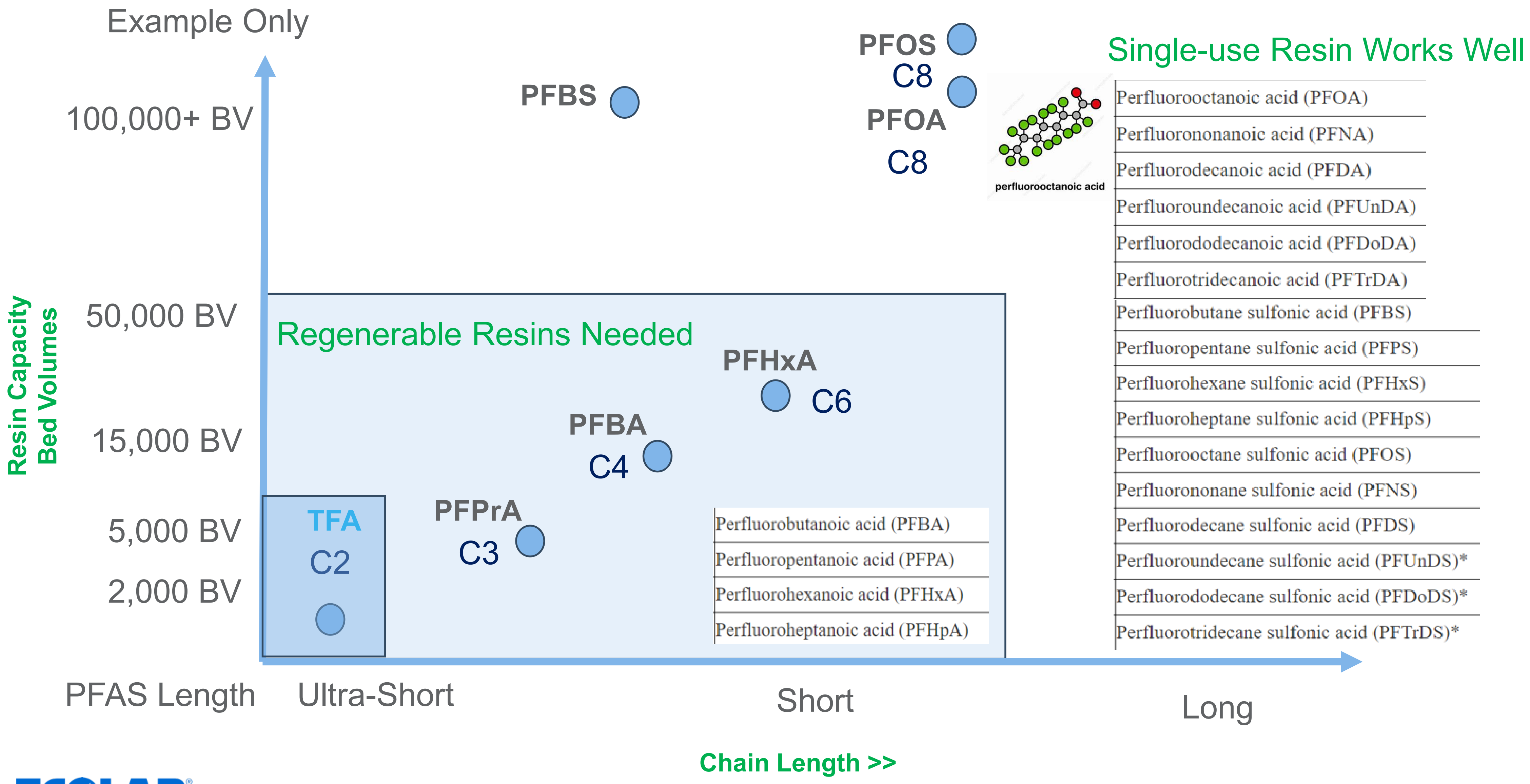
Capacity vs PFAS chain length



Capacity vs PFAS chain length



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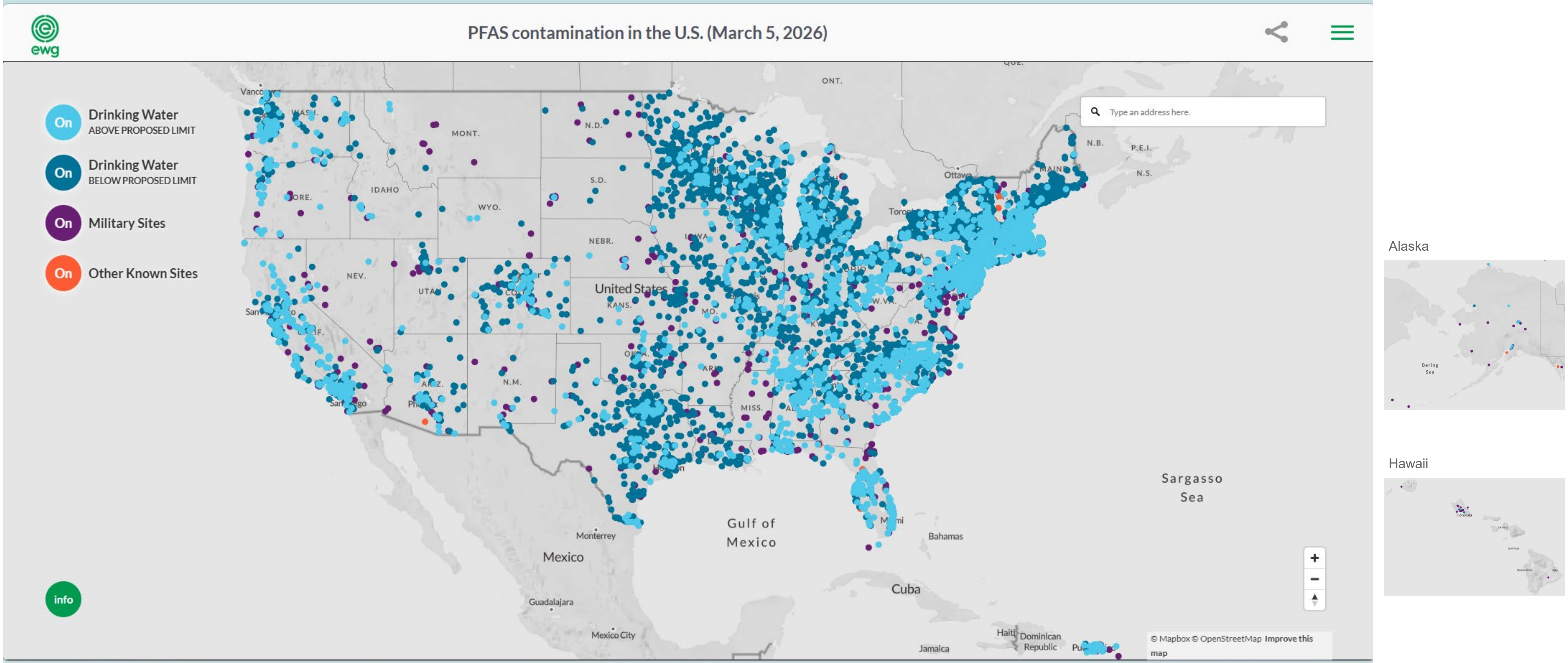
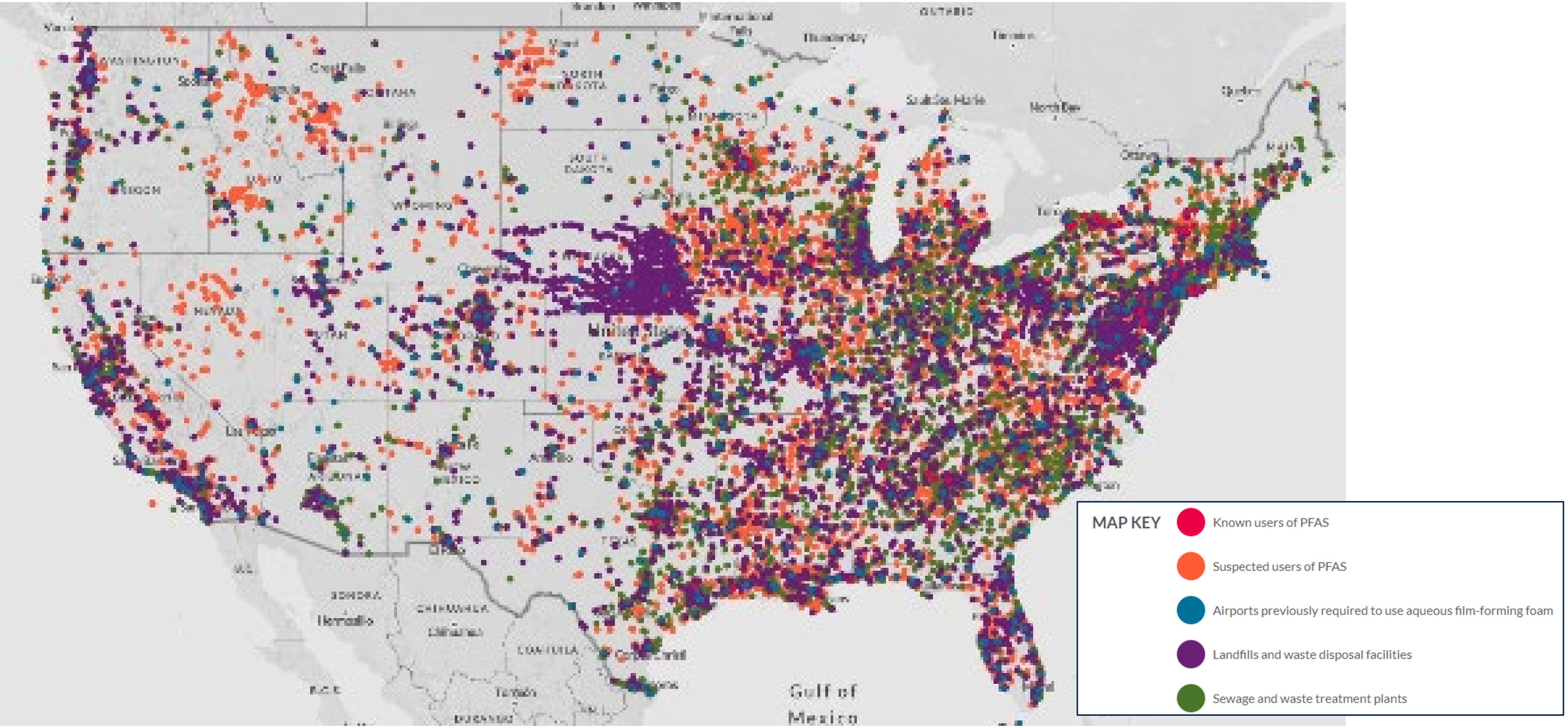
Drinking Water - US

Source: https://www.ewg.org/interactive-maps/pfas_contamination/map/



Suspected Industrial Discharges of PFAS

[Interactive Map: Suspected industrial discharges of PFAS (ewg.org)]



Industries identified as potential commercial or industrial users of PFAS

Electroplating, plating, polishing, anodizing and coloring

Petroleum bulk stations and terminals

All other miscellaneous chemical product and preparation manufacturing

All other miscellaneous fabricated metal product manufacturing

Commercial printing (except screen and books)

Plastics material and resin manufacturing

Paint and coating manufacturing

Semiconductor and related device manufacturing

Other chemical and allied products merchant wholesalers

Other electronic component manufacturing

Other airport operations

Gold ore mining

Petroleum lubricating oil and grease manufacturing

Polish and other sanitation good manufacturing

Car washes

Unlaminated plastics film and sheet (except packaging) manufacturing

Soap and other detergent manufacturing

All other miscellaneous electrical equipment and component manufacturing

Petroleum refineries

Paper bag and coated and treated paper manufacturing

Other paperboard container manufacturing

Textile and fabric finishing mills

Paper (except newsprint) mills

Fabric coating mills

Other industrial machinery manufacturing

Paperboard mills

Printing ink manufacturing

Fire protection

Broadwoven fabric mills

All other miscellaneous textile product mills

Other communication and energy wire manufacturing

Photographic film, paper, plate and chemical manufacturing

Carpet and rug mills

Nonwoven fabric mills

Leather and hide tanning and finishing

Support activities for printing

Uranium-radium-vanadium ore mining

All other leather good and allied product manufacturing

Narrow fabric mills and schiffli machine embroidery

Carpet and upholstery cleaning services

Knit fabric mills

Gold ores

Uranium-radium-vanadium ores

Carpets and rugs

Coated fabrics, not rubberized

Paperboard mills

Coated and laminated paper, not elsewhere classified

Plastics materials, synthetic and resins, and non-vulcanizable elastomers

Specialty cleaning, polishing and sanitation preparations

Paints, varnishes, lacquers, enamels and allied products

Unsupported plastics film and sheet

Leather goods, not elsewhere classified

Electroplating, plating, polishing, anodizing and coloring

Semiconductors and related devices

Carpet and upholstery cleaning

Fire protection

Finishers of broadwoven fabrics of cotton

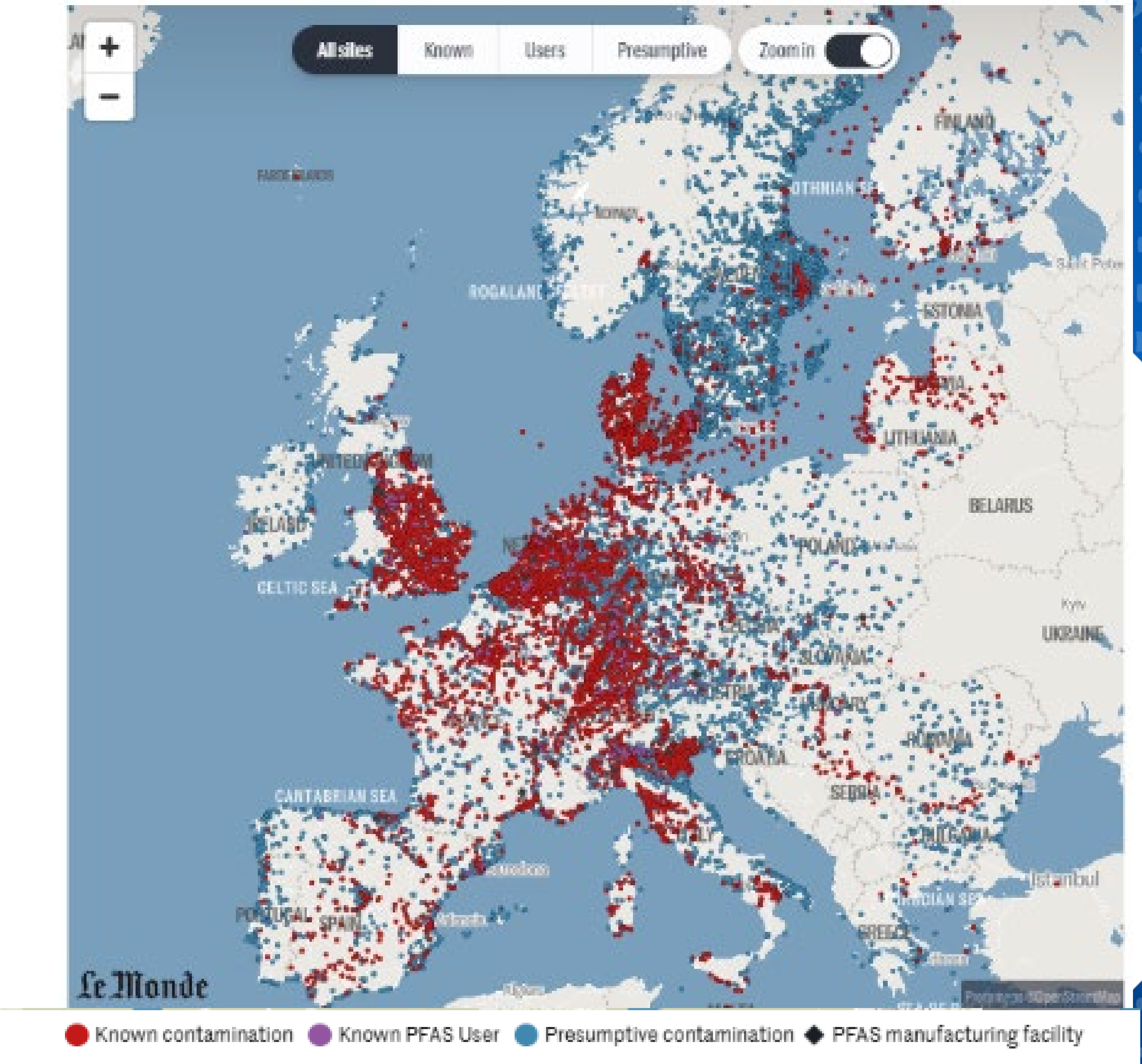
Finishers of broadwoven fabrics of manmade fiber and silk

Finishers of textiles, not elsewhere classified (linen fabric finishing)

Interactive Map: Suspected industrial discharges of PFAS (ewg.org)

The Map of Forever Pollution by Le Monde

- 23,000 contaminated sites
- Source: https://foreverpollution.eu/map/



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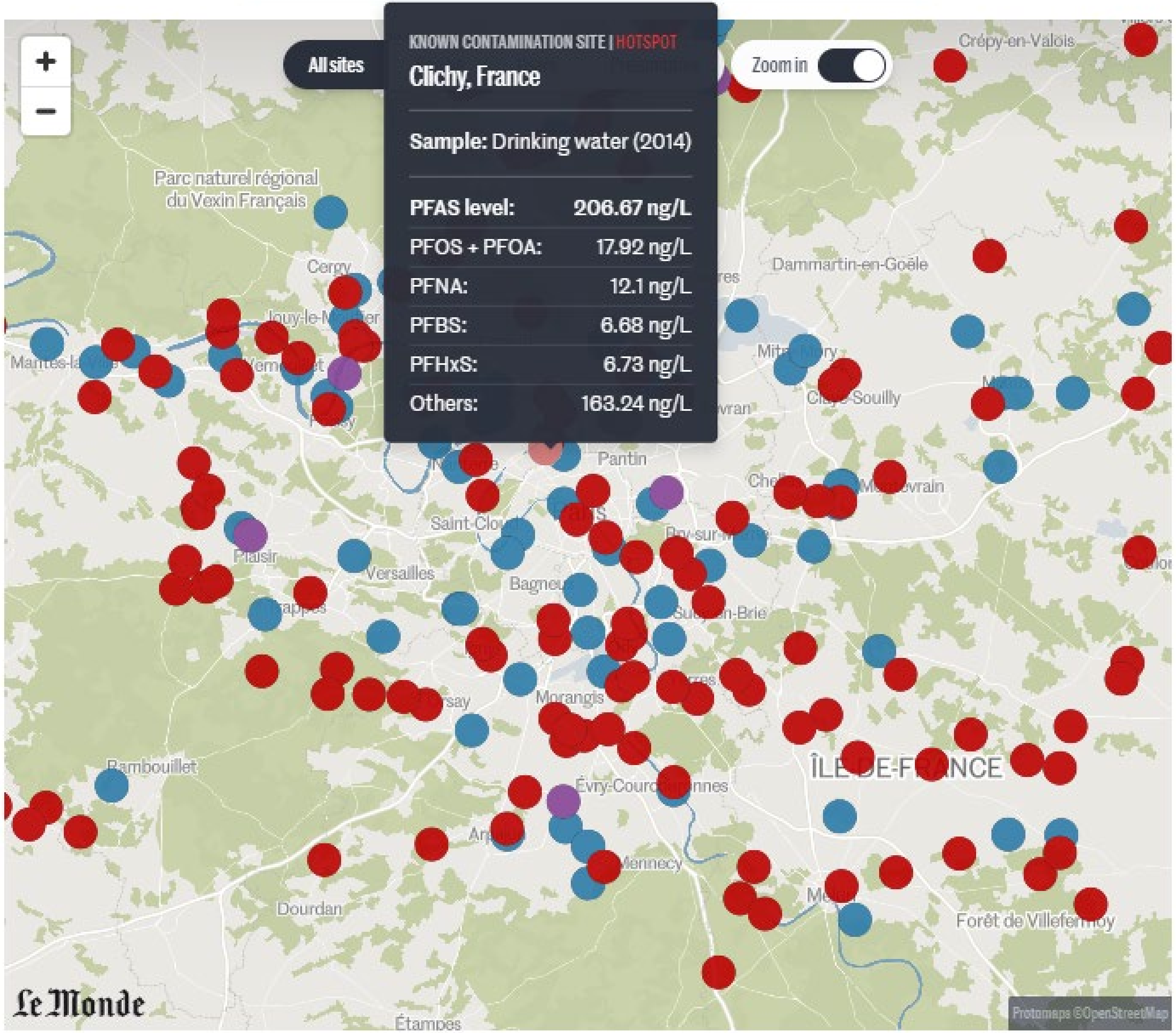
Zoom in Paris

The Map of Forever Pollution by Le Monde

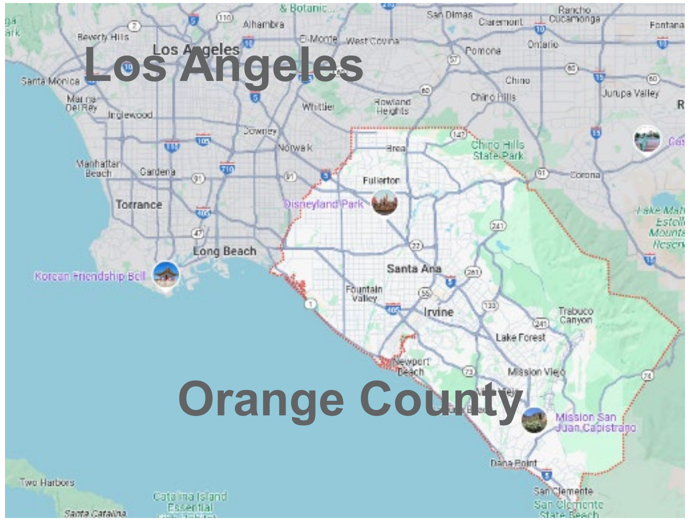
- Many of the sites are amenable to Single-Use PFAS Resin Treatment
- Typical contaminant list includes:
  - PFOA
  - PFOS
  - Lots of "Other"
- Source: https://foreverpollution.eu/map/

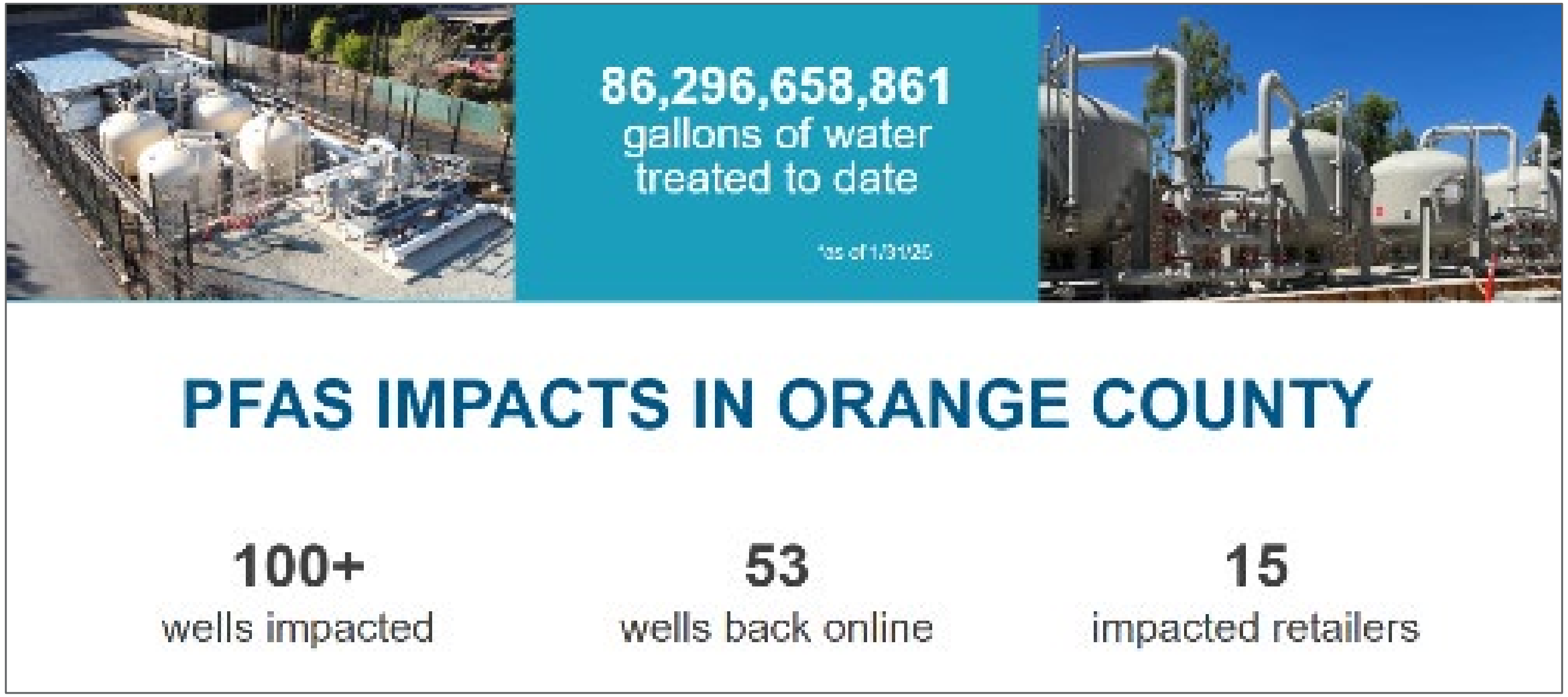


Known contamination · Known PFAS User · Presumptive contamination · ◆ PFAS manufacturing facility

PFAS

Orange County Water District





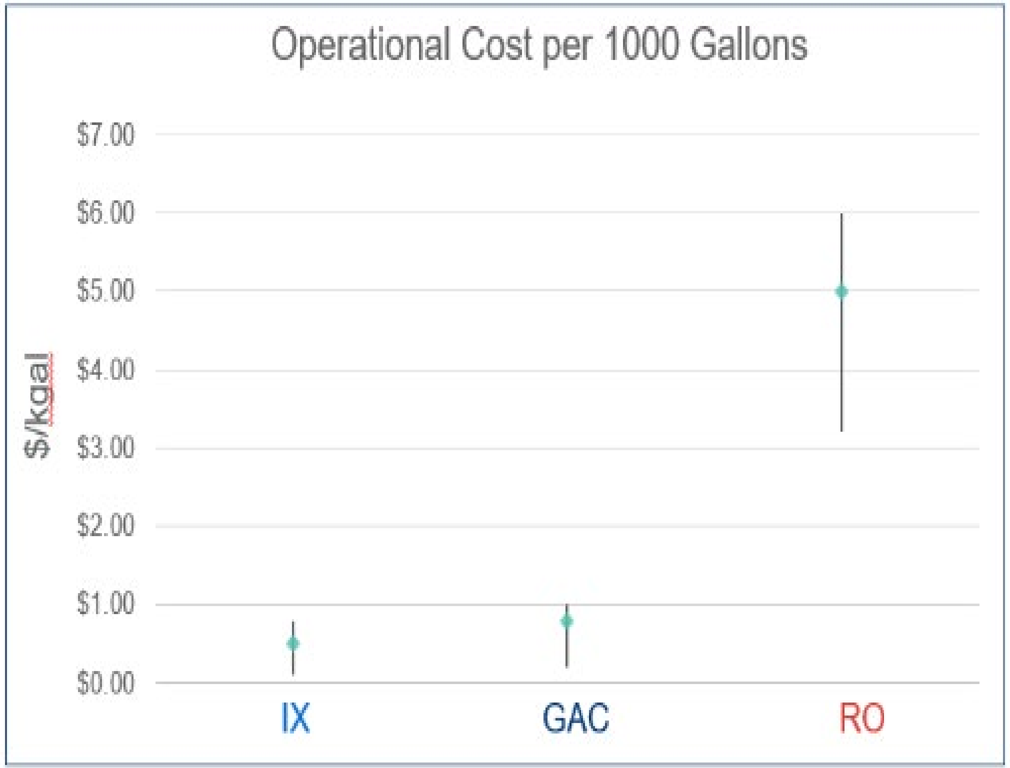
[Source: Quarterly PFAS Update Winter 2026]

- Over 326,668,389 m^3 treated with ion exchange since ~2022 as of Jan 31, 2026.
- Estimate over 85,000m^3 per hour, or 375,000 gallons per minute, were treated in the US with single-use PFAS selective resin in 2024.

PFAS Treatment Options

- Treatment follows regulations
- Regulations have focused on drinking water and highly contaminated sites
- **Currently, EPA has 3 Best Available Technologies:**
  - Single-Use PFAS Selective Ion Exchange
  - Granular Activated Carbon
  - Reverse Osmosis

- **Single-use PFAS-Selective IX is generally:**
  - Smaller footprint
  - Longer lasting
  - Lower lifecycle costs for CAPEX and OPEX.
  - Least waste
  - Simple and clean to operate



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Why has the US Embraced Single-Use IX Technology?

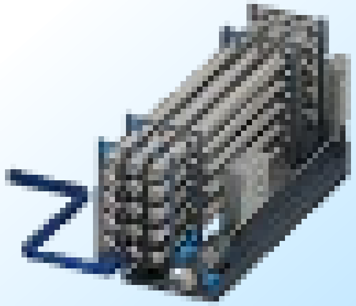
PFAS-Selective IX Resin Provides the Following Advantages

Property		Effect		Benefit
Fast Kinetics	→	Smaller footprint	→	Lower Capital Cost
High Selectivity	→	Longer bed life	→	Lower Operating Cost
Higher Selectivity	→	Excellent retention of PFAS	→	Robust performance
Less Media used for Longer Periods	→	Less waste generation	→	Lower Operating Cost More Sustainable

Industrial Processes Concentrate PFAS

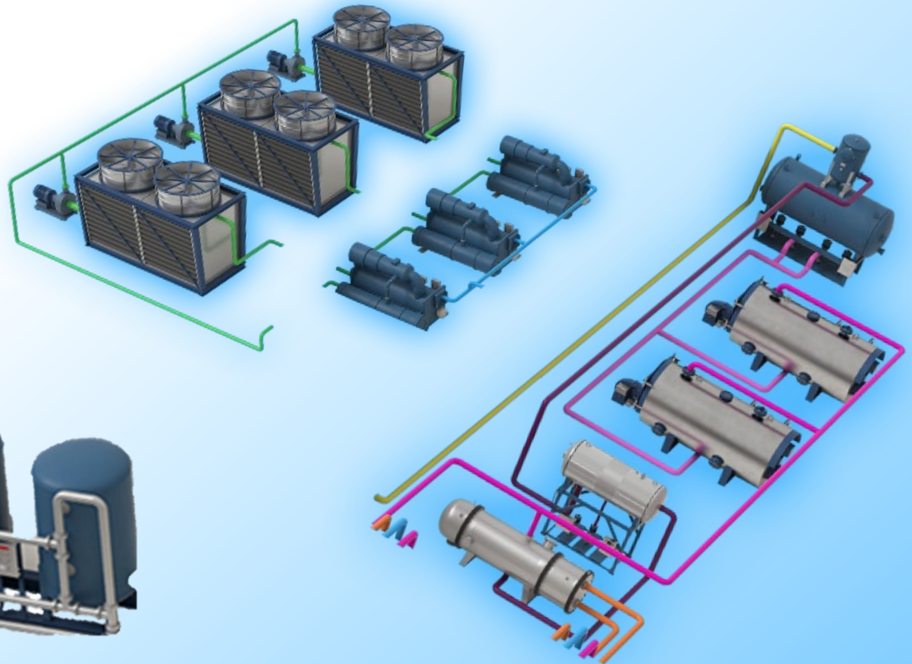
Any industrial influent water has a significant chance of having PFAS

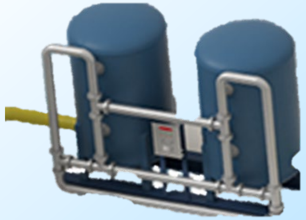
- Even if PFAS are not at detectable levels, PFAS are concentrated up in many industrial processes
- Pre-cursor PFAS may get changed into PFAS during operations
- Much easier to clean PFAS on the influent streams



Industrial Processes that Concentrate Influent Water:

- Boilers
- Cooling Towers
- Anion Ion Exchange Resin (Demin Systems)
- Reverse Osmosis
- Crystallizers
- Sludge Processing





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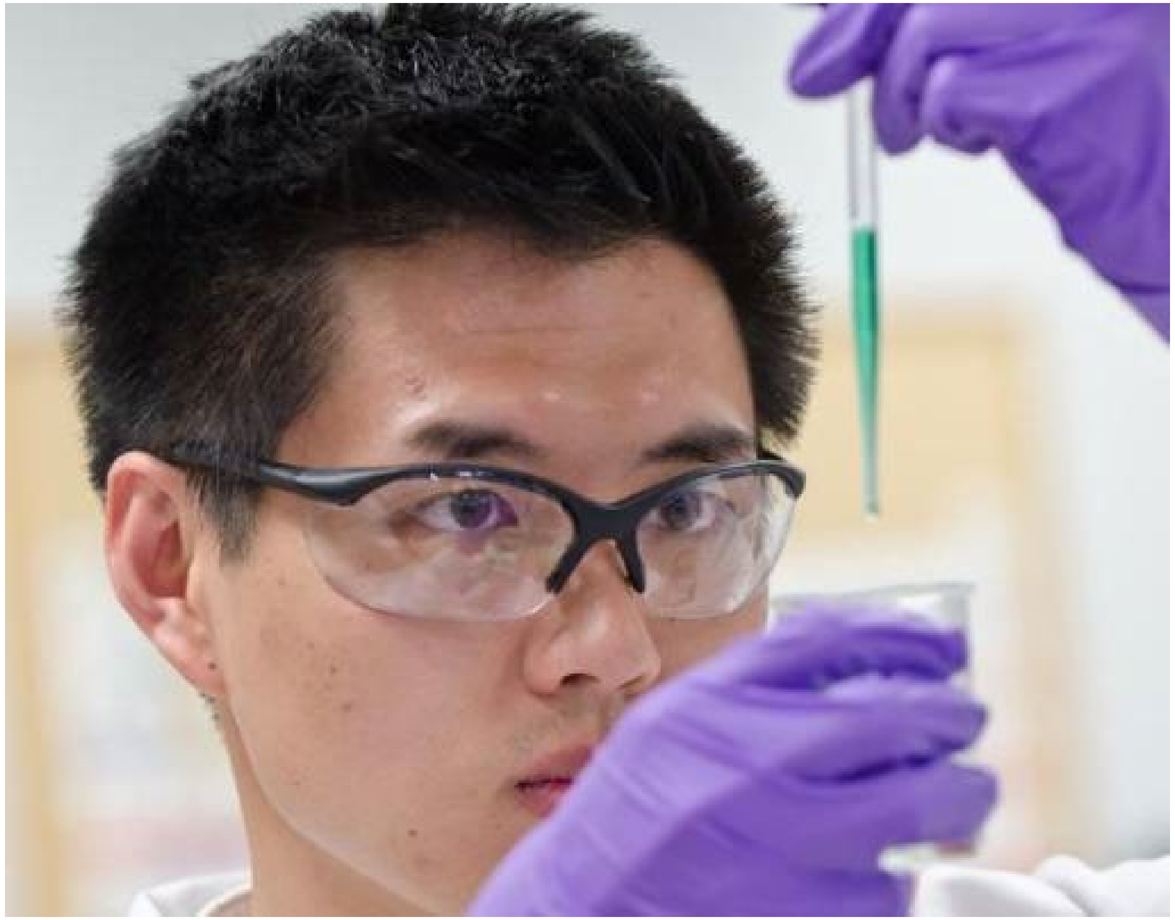
Water Chemistry

- Need a complete and balanced water chemistry to figure out beforehand what the issues will be.
- Changes in water chemistry will affect the resin longevity.



Inlet Water to Plant

- Background WQ will help determine operational treatment costs
- Modeling or piloting will confirm

Description	Units
Operational Flow Rate	gpm
Operational Schedule	hour/day
Daily Volume (average)	Gallons
Sulfate	mg/L
Nitrate (as N)	mg/L as N
Nitrate (as NO3)	mg/L as NO3
Alkalinity (as $CaCO_3$)	mg/L
Chloride	mg/L
Fluoride	mg/L
Perchlorate	ppb
Arsenic	ppb
Hexavalent chromium	ppb
Uranium	ppb
Calcium (as $CaCO_3$)	mg/L
Magnesium (as $CaCO_3$)	mg/L
Sodium	mg/L
Potassium	mg/L
Iron	mg/L
Manganese	mg/L

pH		
ORP		
TDS		mg/L
Suspended Solids		mg/L
Oil & Grease		mg/L
Total Organic Carbon	TOC	mg/L
Perfluorobutanoic acid	PFBA	ng/L (ppt)
Perfluoropentanoic acid	PFPeA	ng/L (ppt)
Perfluorohexanoic acid	PFHxA	ng/L (ppt)
Perfluoroheptanoic acid	PFHpA	ng/L (ppt)
Perfluorooctanoic acid	PFOA	ng/L (ppt)
Perfluorononanoic acid	PFNA	ng/L (ppt)
Perfluorododecanoic acid	PFDoDA	ng/L (ppt)
Perfluorotetradecanoic acid	PFTeA	ng/L (ppt)
Perfluorobutanesulfonic acid	PFBS	ng/L (ppt)
Perfluorohexanesulfonic acid	PFHxS	ng/L (ppt)
Perfluoroheptanesulfonic acid	PFHpS	ng/L (ppt)
Perfluorooctanesulfonic acid	PFOS	ng/L (ppt)
4:2 FTS (fluorotelomer sulfonate)	4:2 FTS	ng/L (ppt)
6:2 FTS (fluorotelomer sulfonate)	6:2 FTS	ng/L (ppt)
8:2 FTS (fluorotelomer sulfonate)	8:2 FTS	ng/L (ppt)
GenX	GenX	ng/L (ppt)
VOC	VOC	ppb

Inlet Water to Plant

Single-use PFAS-selective ion exchange resin

Characteristics

- Typically, low PFAS levels
- Low TDS

Solution

- Lead/lag configuration
- Single-use PFAS-selective ion exchange resin

Source: AqueoUS Vets

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PFAS Selective Resin Choices

Single-Use Choices

- Strong base anion resin with nitrate selectivity (no nitrate sloughing)
- > 99.99% removal to < 2 ppt PFOA, PFOS, and others
- Long treatment life
- General-purpose anion resins are not suitable for PFAS < ~ 90% reduction, but do pick up PFAS
- PFAS capacity depends heavily on competing anions in the water
    - SO4, NO3, HCO3, Cl, TOC
- Standard, Buffered, and Industrial grades
    - Buffered resin allows for a neutral effluent providing corrosion potential control

Purolite™ Purofine™ PFA694E

Polystyrenic Gel, Potable Water Grade

Purolite™ Purofine™ PFA694EBF

Polystyrenic Gel, Buffered Resin, Potable Water Grade

Purolite™ Purofine™ PFA694

Polystyrenic Gel

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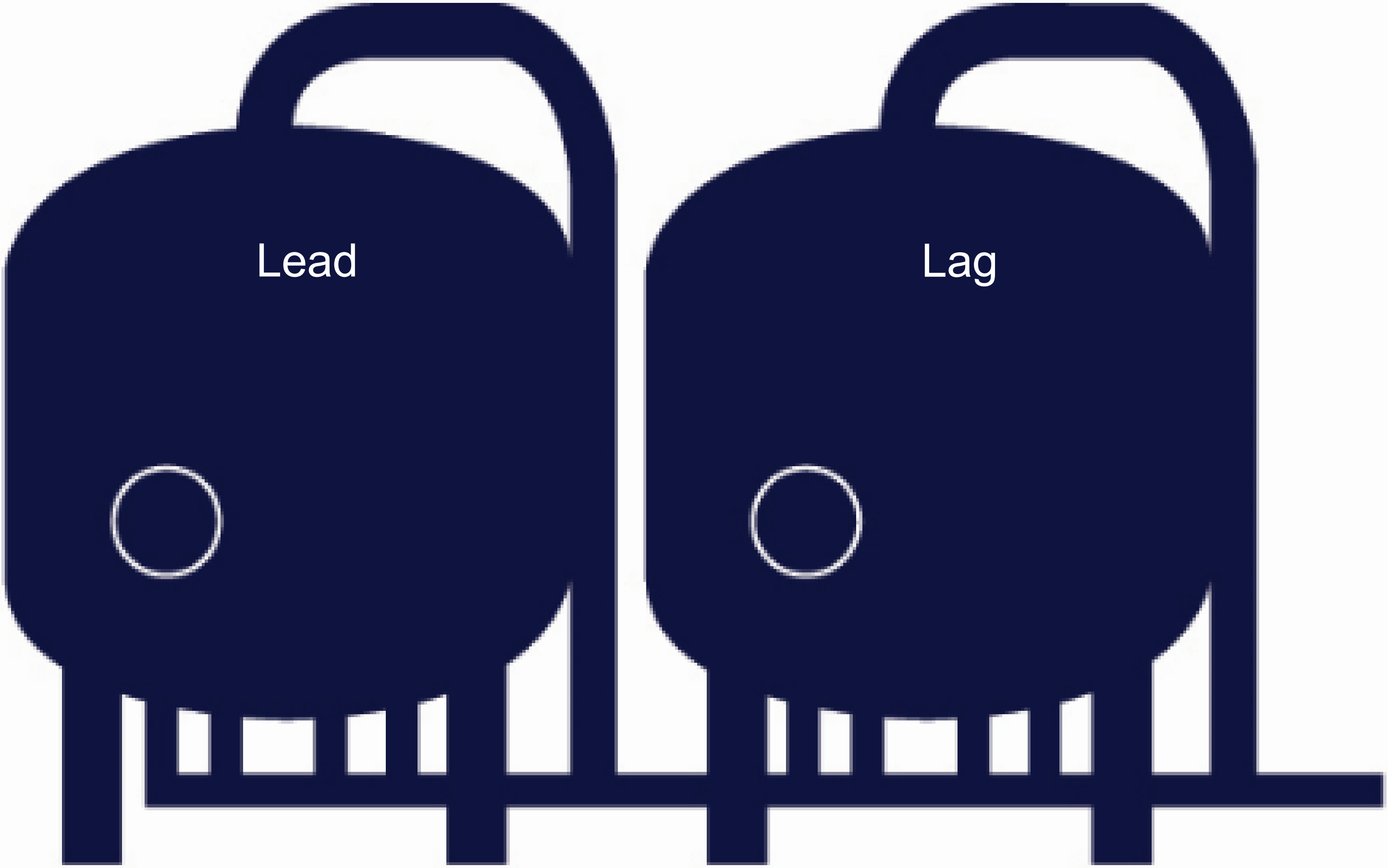
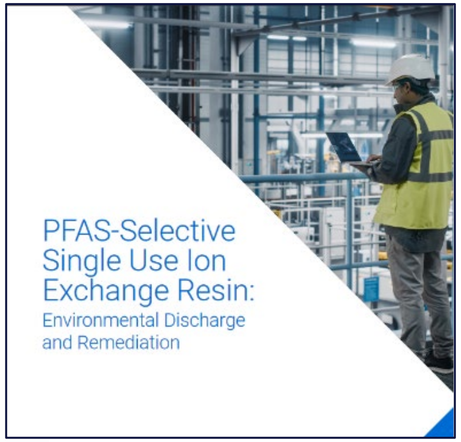
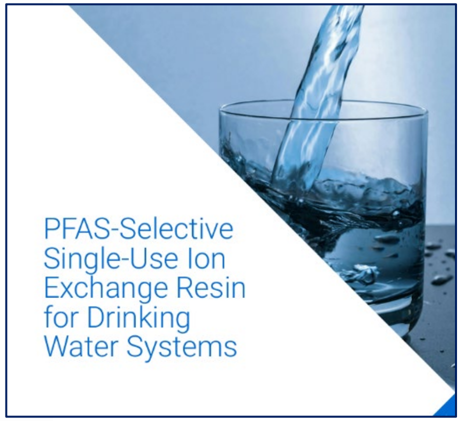
Design Guidelines: Single-Use IX



Industrial Discharge Guide



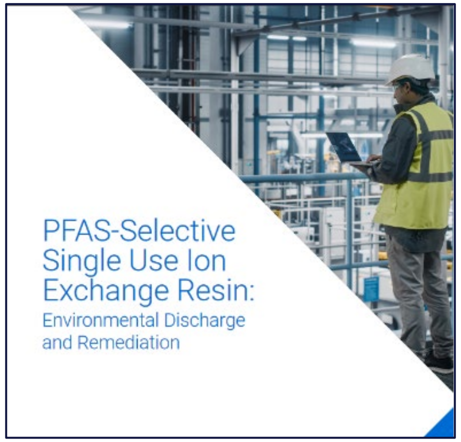
Drinking Water Guide



Design Guidelines: Single-Use IX

Parameter	Design Goal
Linear Velocity (LV)	6 to 18 gpm/ft^2 (15 to 45 m/h)
Bed Depth for LV <= 12 gpm/ft^2 (30 m/h)	3 ft (0.91m) minimum
Bed Depth for LV > 12 gpm/ft^2 (30 m/h)	3.7 ft (1.1 m) minimum
Specific Flowrate	1 to 5 gpm/ft^3 (8 to 40 BV/h)
Empty Bed Contact Time (EBCT)	2 min for typical city water 3 min for higher concentrations

Industrial Discharge Guide



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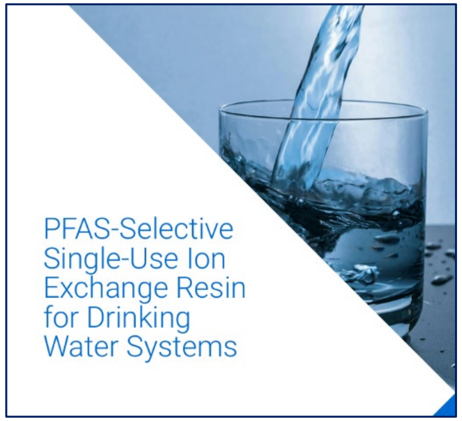

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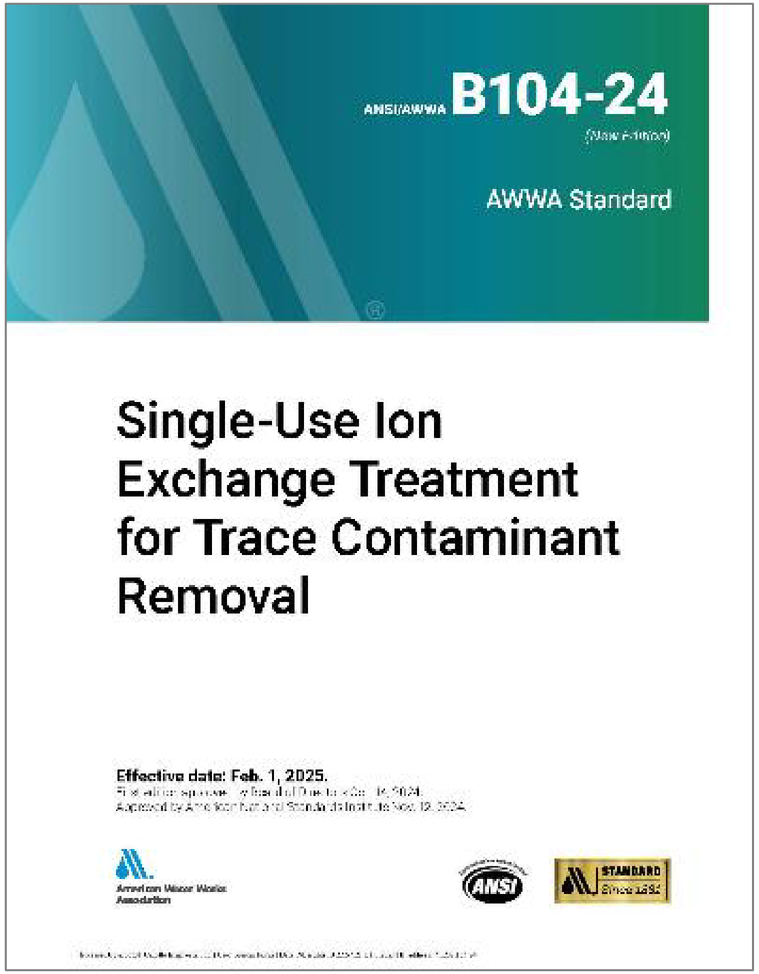
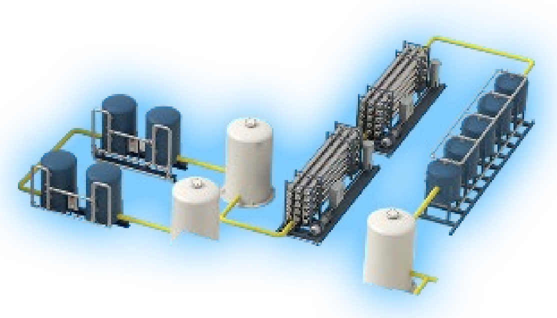
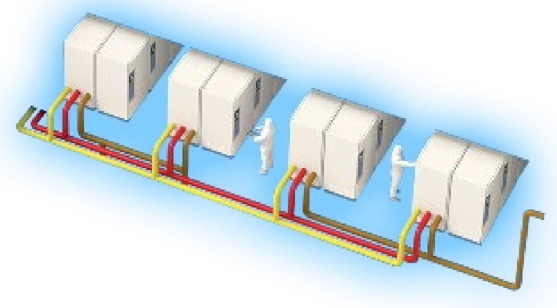


Anion Resins in Mixed Beds or Other Purification Steps

- If the RO is first, the permeate goes to the mixed bed, no PFAS is being adsorbed by the resin.
- If there are any upstream anion exchange processes from the RO, that anion resin will allow PFAS breakthrough.
- Be aware that any anion resin will adsorb PFAS.
- Long-chain PFAS will display a break normal breakthrough on the resin, even if regenerated. Typical salt regen is not enough to displace the long-chain PFAS.

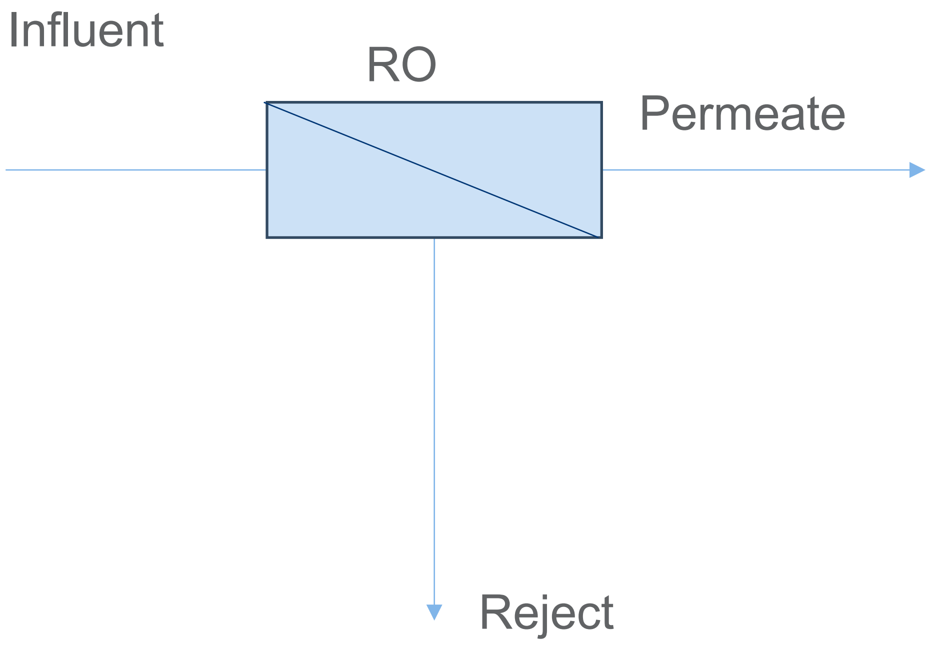




Reverse Osmosis

With Single Use PFAS Selective Resin

- RO will reject PFAS, but then you need to be concerned about treatment of the reject stream
- PFAS are concentrated up, but so are the sulfate, nitrate, chlorides… TDS
- We can model both scenarios:
  - Treating PFAS in the RO reject
    - Throughput will be much less due to anion competition, but treatment stream will also be much lower flow
  - Treating PFAS in the influent
    - Bed life will be longer, but flow rate is higher
  - It all comes down to cost



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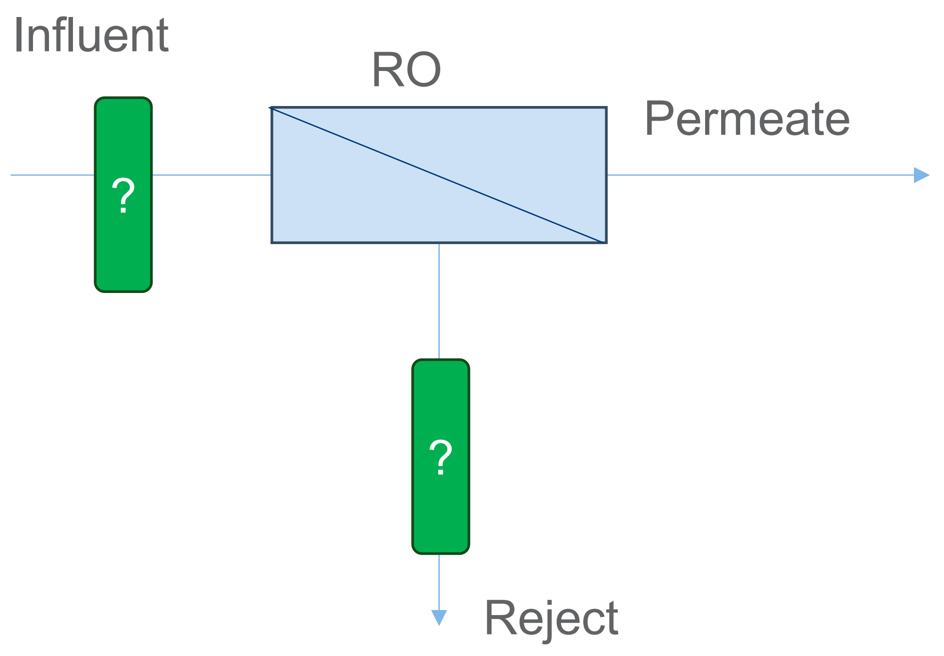

Regenerable PFAS Removal Needs

- Regenerable PFAS resins are being evaluated at sites where:
  - Short chain PFAS levels are extremely high
  - Regulations are more restrictive (Europe, Canada)
  - Influent streams that are difficult to treat, i.e. high short chain, high TDS, high PFAS levels, high TOC.
  - It's often paired with a PFAS destruction technology.

How do we treat these?

PFAS listed in paragraph 3 of Part B of Annex III to the
reporting of the parametric value of '*Sum of PFAS*' (* Abb

Carbon chain length		Perfluoroalkyl carboxylic acids (PFCAs)
4		Perfluorobutanoic acid (PFBA)
5	Short Bed Life	Perfluoropentanoic acid (PFPA)
6		Perfluorohexanoic acid (PFHxA)
7		Perfluoroheptanoic acid (PFHpA)

PFAS Waste Management

Landfill Incineration Reactivation (GAC)	**Currently Commercial**
Supercritical Water Oxidation Mechanochemical Electrochemical	**Promising Technologies**
Chemical Biological Plasma Sonolysis Ebeam UV	**Technologies Also Being Developed**
Deep Well injection Sorption / stabilization Land application	**Sometimes only option**

PFAS Waste Management

Treatment of Solid Waste	Landfill Incineration Reactivation (GAC)	**Currently Commercial**
	Supercritical Water Oxidation	
Treatment of Liquid Waste for PFAS Destruction	Mechanochemical Electrochemical	**Promising Technologies**
	Chemical Biological Plasma Sonolysis Ebeam UV	**Technologies Also Being Developed**
	Deep Well injection Sorption / stabilization Land application	**Sometimes only option**

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PFAS Waste Management

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Treatment of Liquid Waste for PFAS Destruction	Mechanochemical Electrochemical	**Promising Technologies**
	Chemical Biological Plasma Sonolysis Ebeam UV	**Technologies Also Being Developed**
	Deep Well injection Sorption / stabilization Land application	**Sometimes only option**

Regenerable resin ideal for liquid waste

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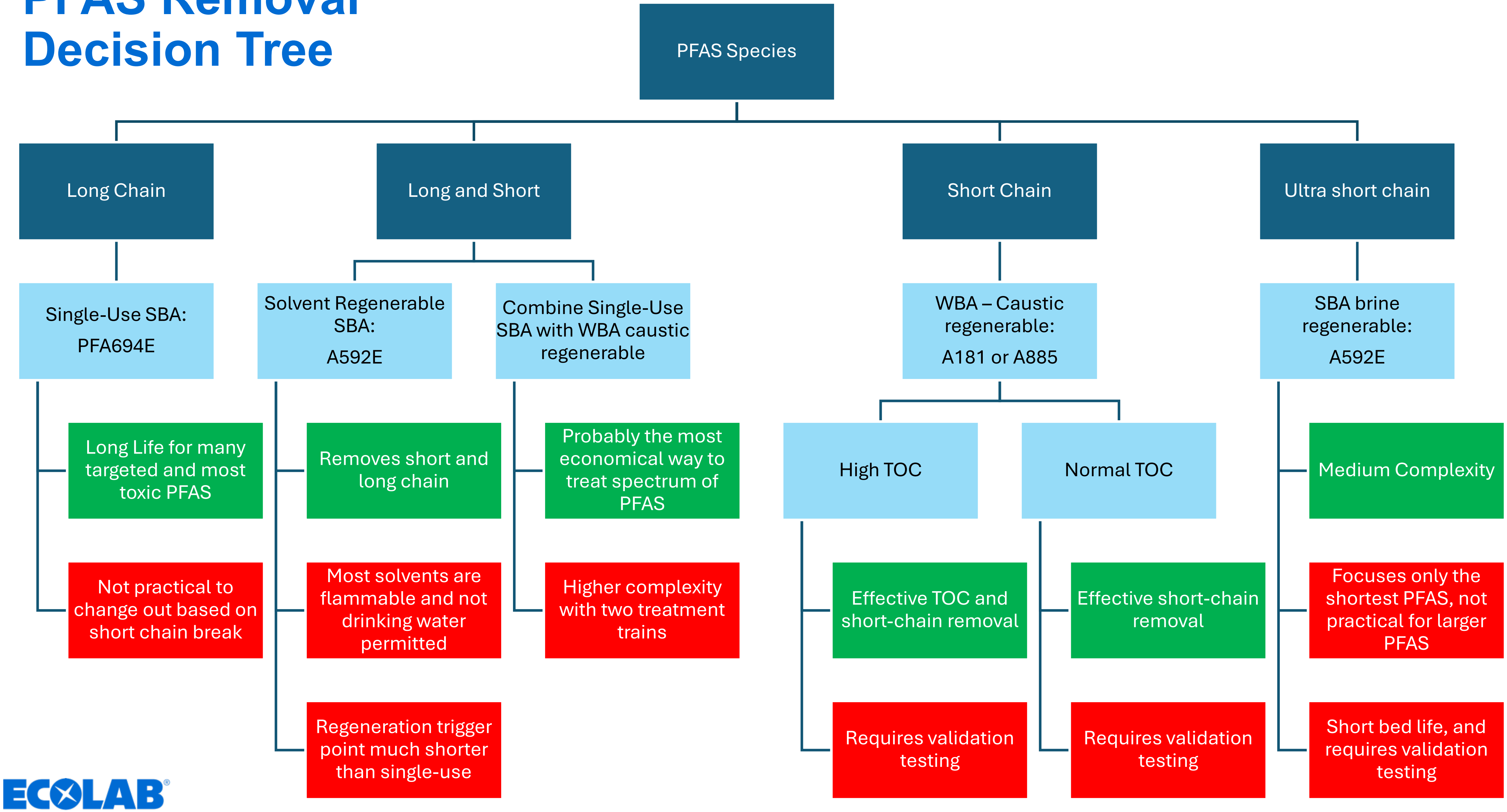
Regenerable Resin Solution Options

- PFAS-Selective resins developed for single-use are being regenerated with solvent and brine.
  - Will remove both long and short chain
- SBA specialty resin with brine regeneration to target TFA
- WBA specialty resins run at slightly acidic conditions, and regenerated with caustic, to target short chain PFAS

Depending on the targeted PFAS, the influent concentrations, and the effluent limitations, resins may be needed to use in combination.

PFAS Removal Decision Tree



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WBA Regeneration Process – Short Chain

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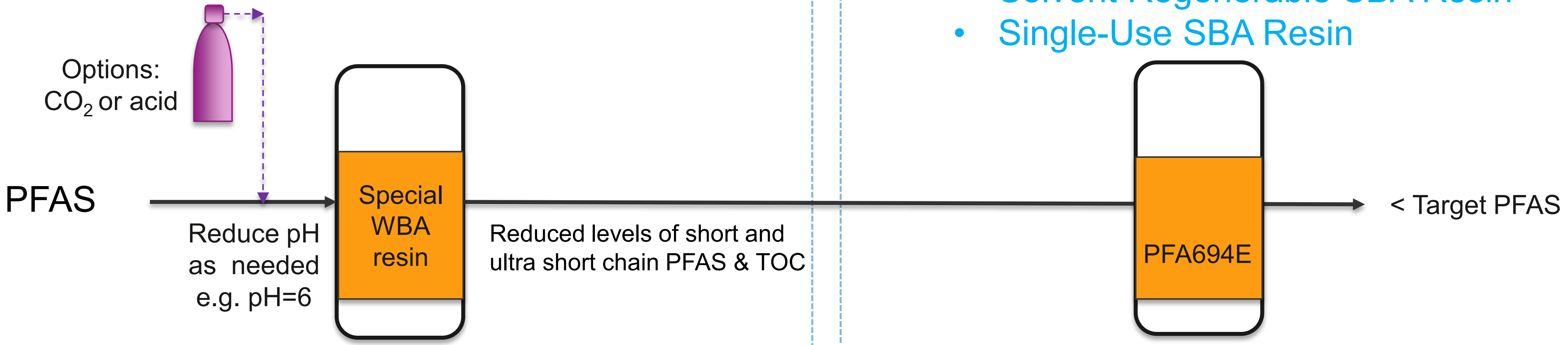
Service: Remove Short, Ultra-short PFAS and TOC. Remove long chain PFAS

Remove primarily ultra-short and short-chain PFAS + TOC

Caustic Regenerable WBA Resin

Remove residual long-chain PFAS

Options:
- Solvent Regenerable SBA Resin
- Single-Use SBA Resin



Example 1000 – 3000 BV

Example 15,000 BV to solvent regen
Example 100,000 – 300,000 BV for single-use

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Alternative Service: Remove Long-Chain PFAS then Short and Ultra-short

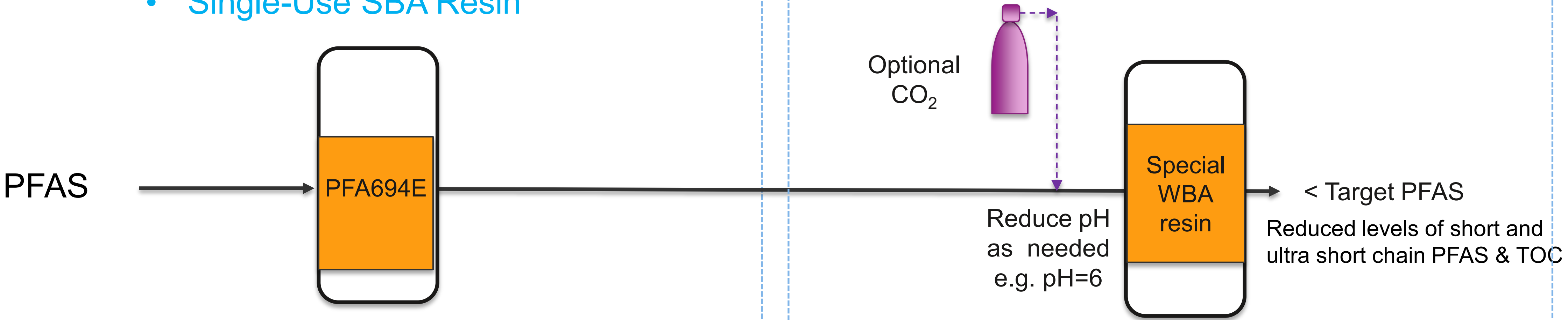
Remove residual long-chain PFAS

Options:

- Solvent Regenerable SBA Resin
- Single-Use SBA Resin

Remove primarily ultra-short and short-chain PFAS + TOC

Regenerable WBA Resin



Example 15,000 BV to solvent regen

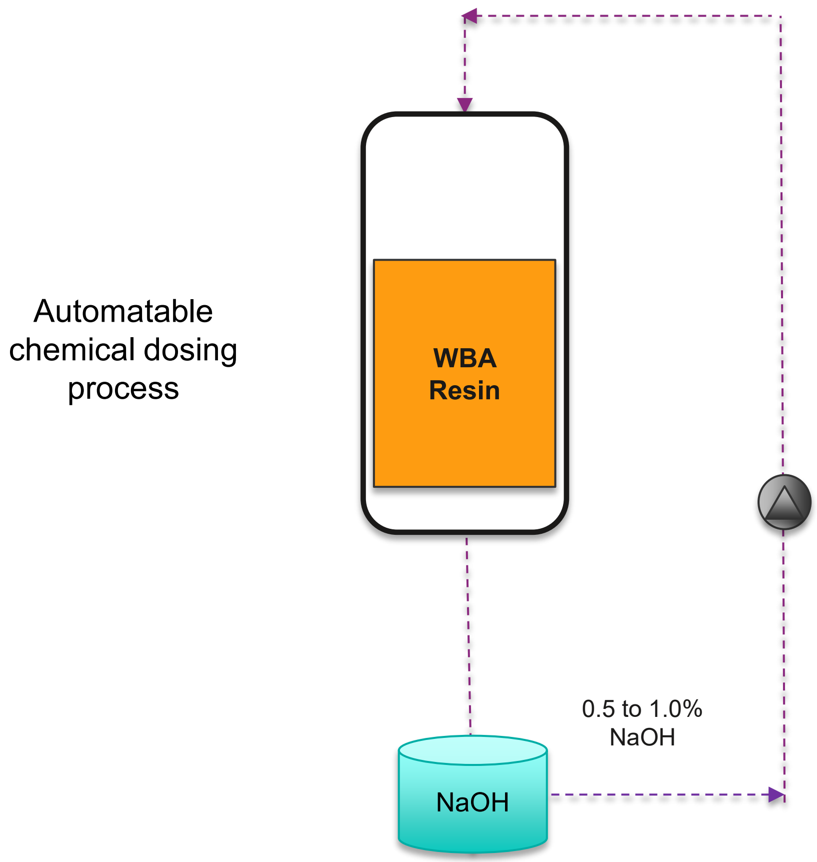
Example 100,000 – 300,000 BV for single-use

Example 1000 – 3000 BV

WBA Regeneration: Regenerant Injection

Dilute NaOH - Recirculated

Multiple Recovery/Reuse of Spent Regenerant

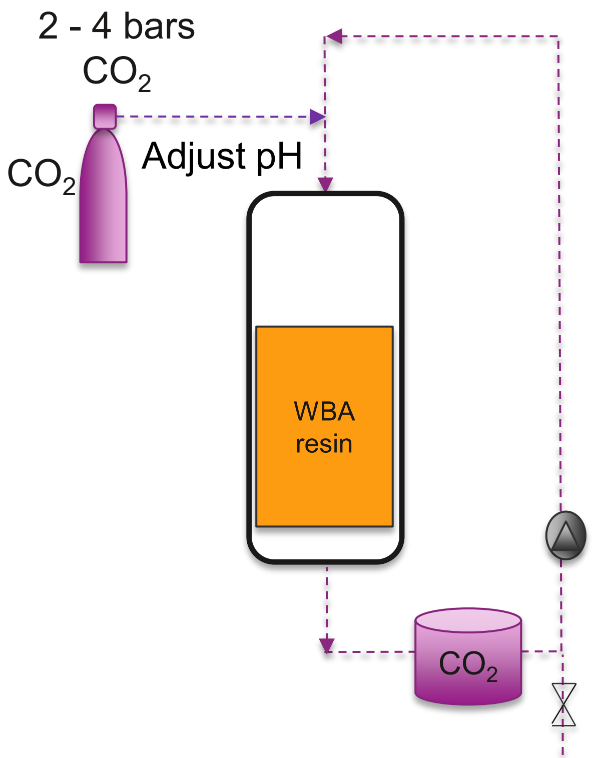


Very dilute NaOH regenerant (e.g. 0.5 to 1%) is recirculated & reused over multiple regenerations.

This is expected to elute largely the ultra-short and short chain, but also a small portion of the long chain PFAS.

WBA Regeneration: Rinse

Recirculate CO_2-infused rinse water to neutralize resin

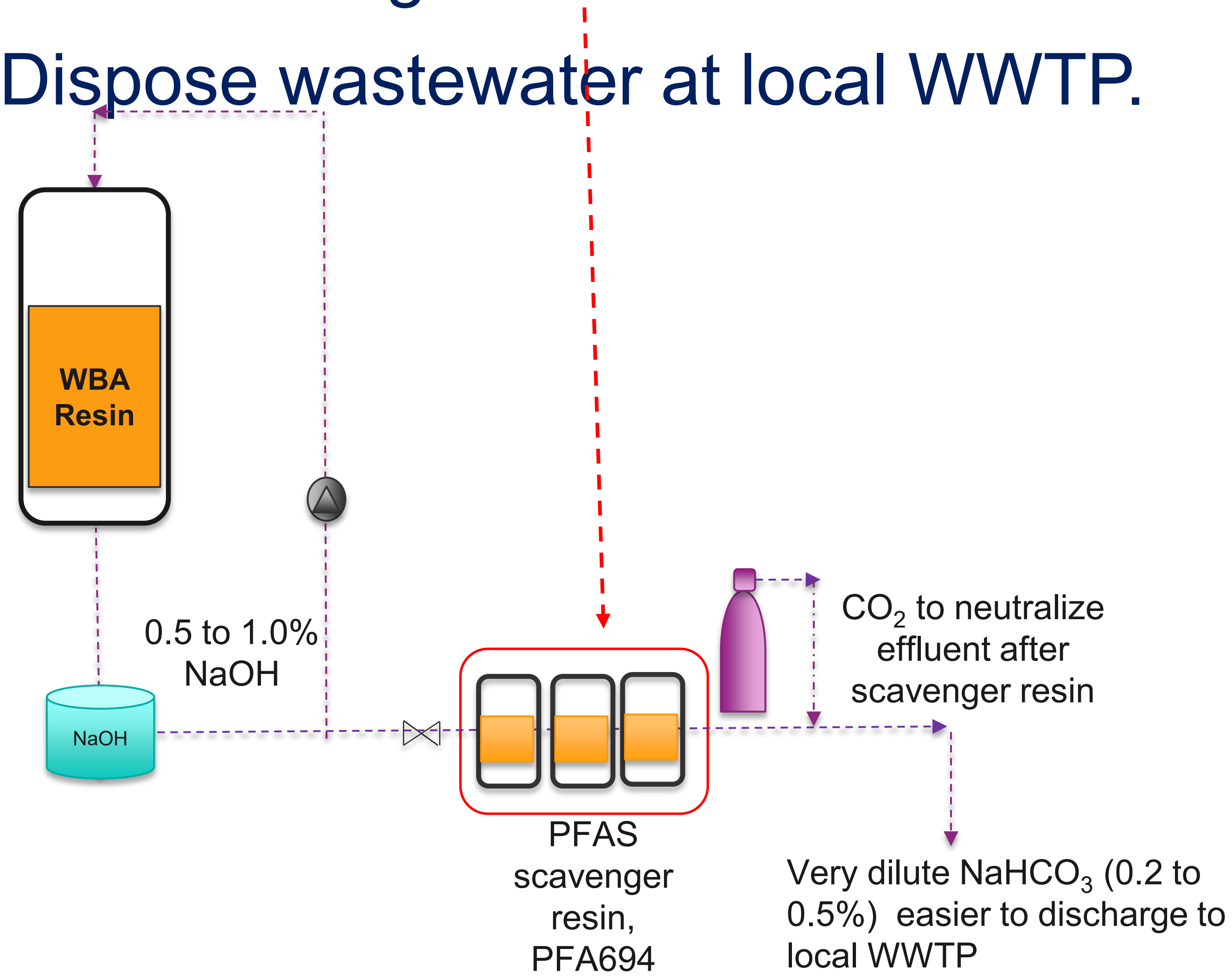


CO_2-infused rinse water is used to neutralize residual caustic and the rinse is recirculated & reused for multiple regenerations

WBA Regeneration: Wastewater Disposal Option

Use Scavenger IX to remove PFAS from spent regenerant.

Dispose wastewater at local WWTP.



- Use single-use PFA694 resin to remove PFAS from spent caustic regenerant.
- Use CO_2 downstream to neutralize NaOH before discharge
- The resulting dilute sodium bicarbonate (0.2 to 0.5%) is easily disposed at local wastewater plant (no expensive offsite brine hauling/disposal is needed)

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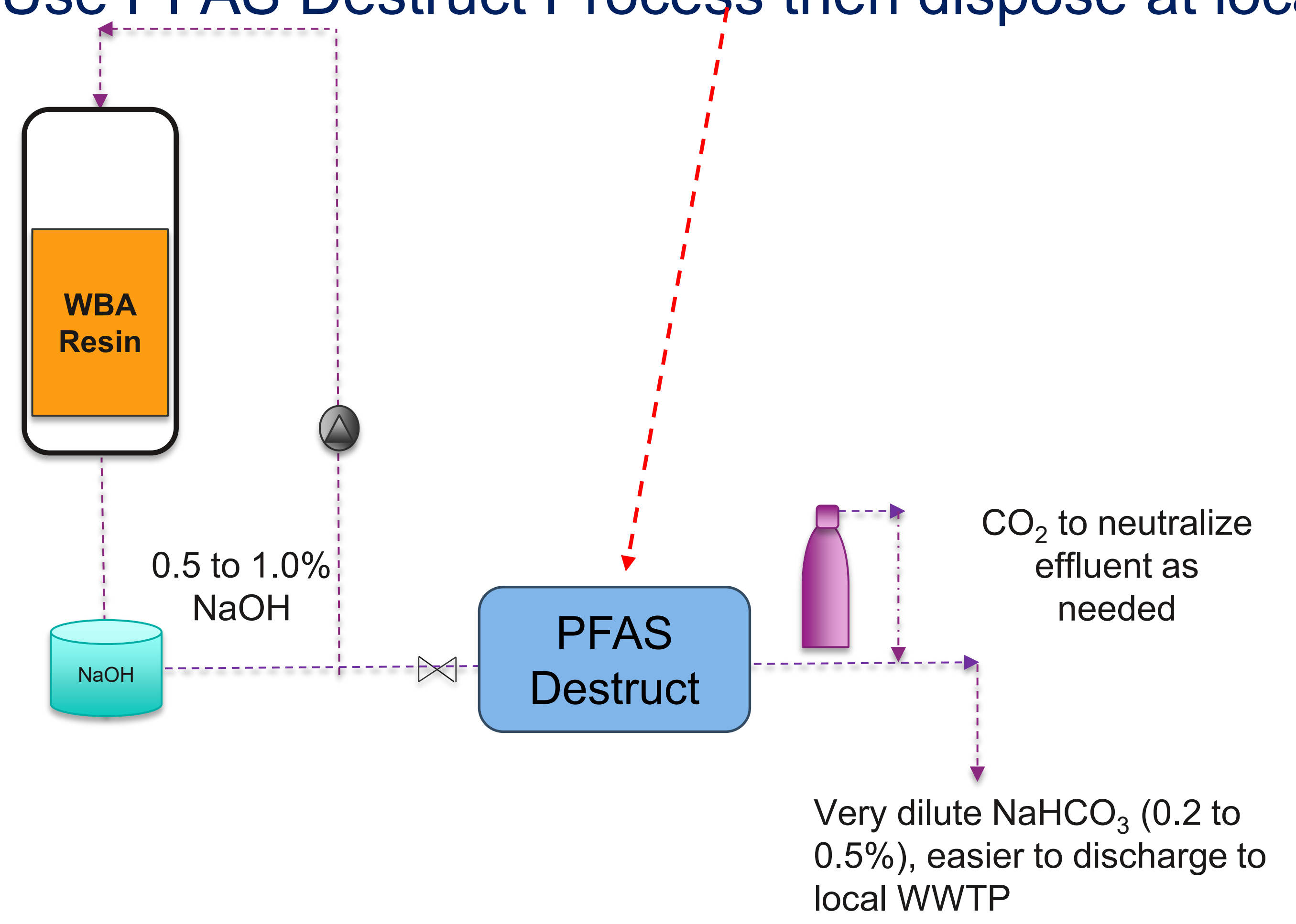
WBA Regeneration: Wastewater Disposal Option

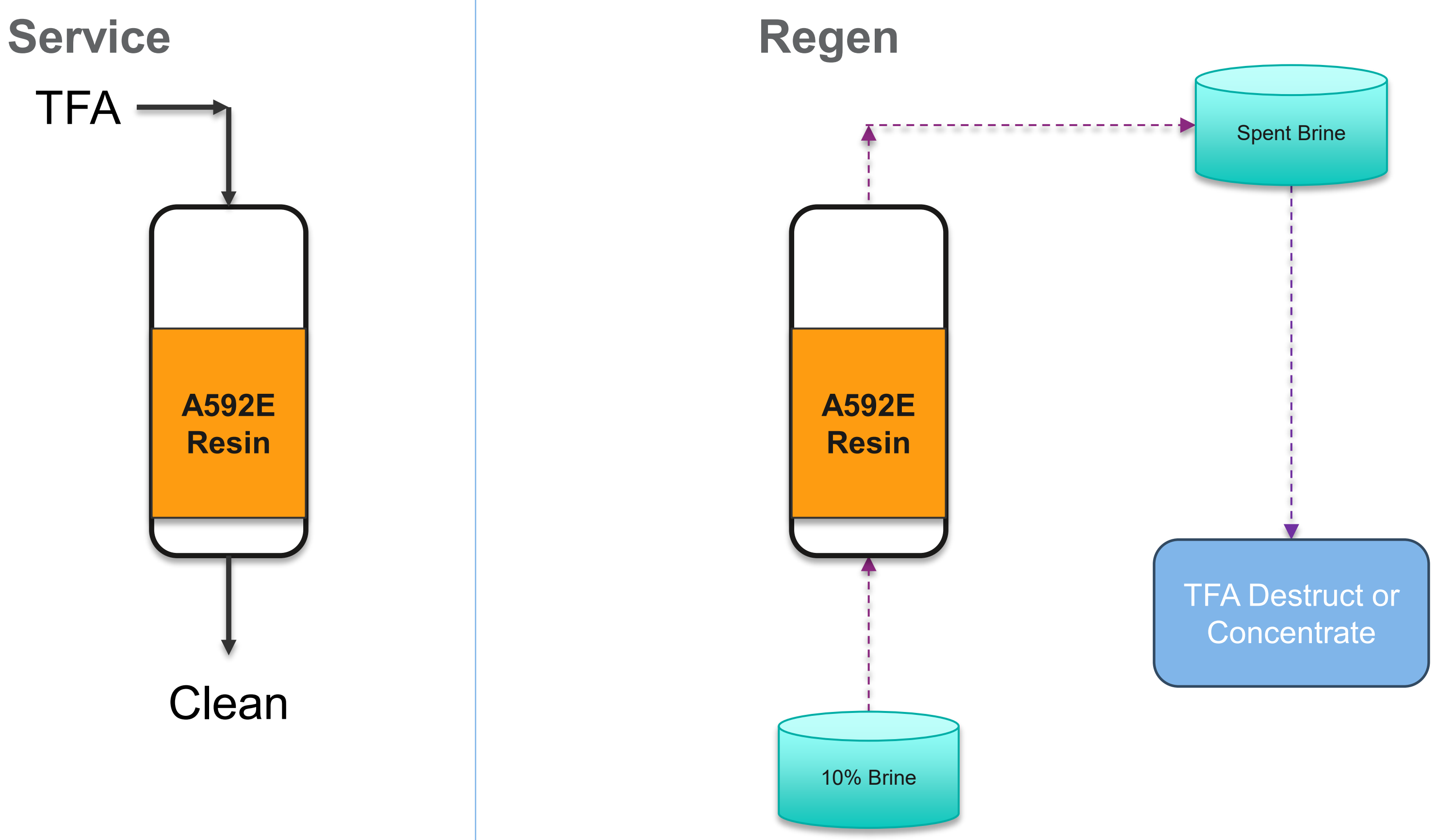
Use PFAS Destruct Process then dispose at local WWTP



- Use SCWO, Plasma, Electrochemical, or Sonochemical process to destroy PFAS
- Neutralize NaOH with CO2 as needed
- Easily dispose of the resulting dilute (0.2 to 0.5%) sodium bicarbonate to local wastewater plant (no expensive offsite brine haulage needed)

SBA Regeneration for TFA: Brine Injection

Use PFAS Destruct Process or Scavenger Resin on Concentrate

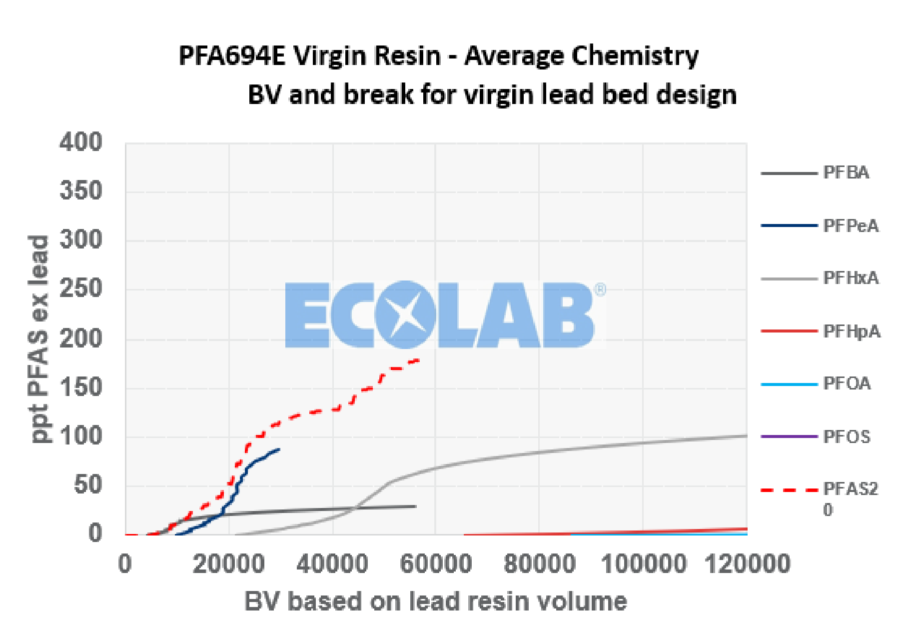


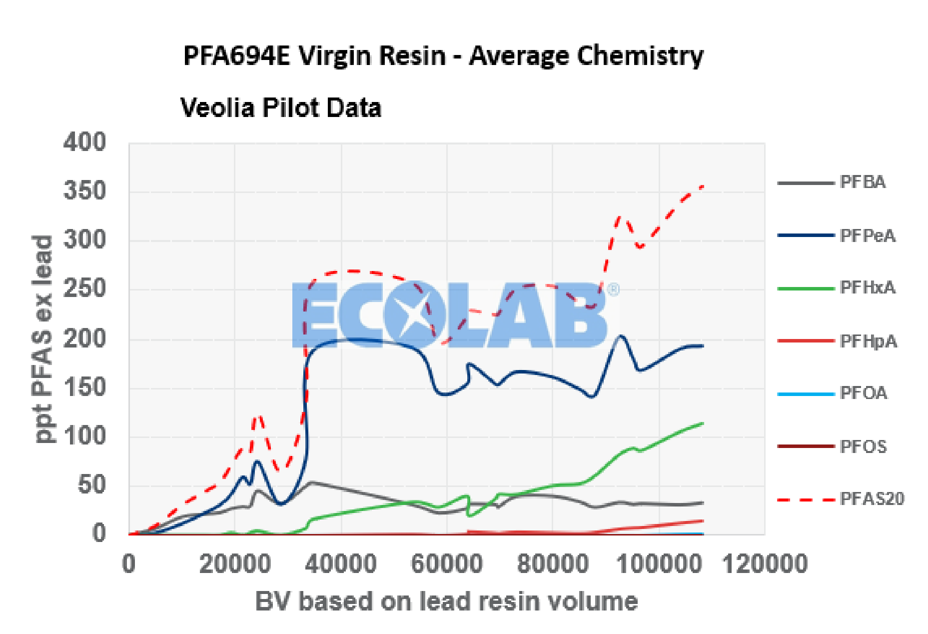
- Counterflow regeneration of service column
- Brine Injection of 5 BV of 10% NaCl

Case Histories: Local Waters

Single-Use: Predictions Match Actual

Veolia and Ecolab Collaboration: Surface Water in France



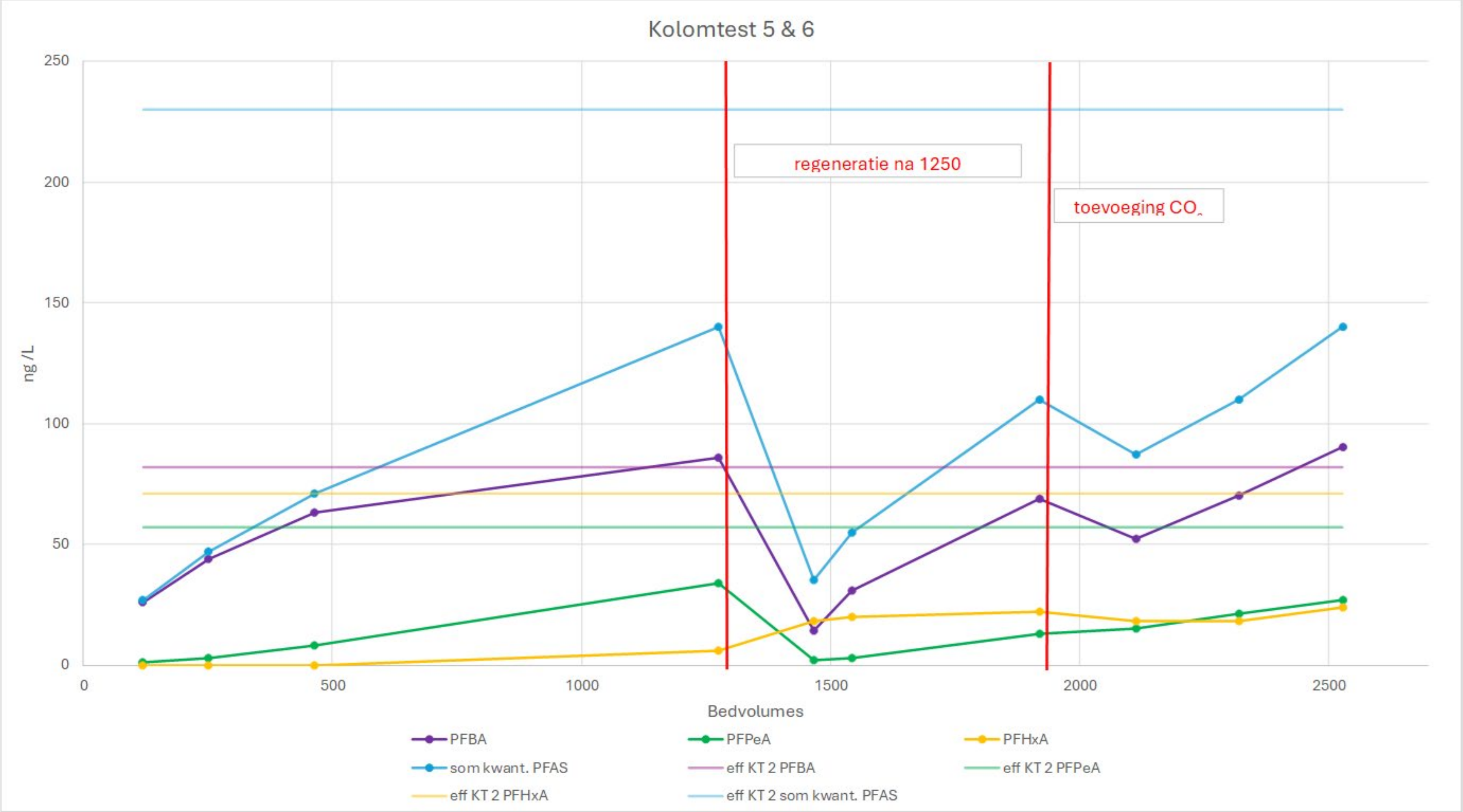


- Complex and variable water quality
- Variable influent leads to variable effluent
- Predictions match performance
- Short chain broke first, PFOA and PFOS still very low.
- 120,000 BV is already 6 months of run time for single-use resin.

WBA Data – Short Chain Regenerable

Belgium - Purolite A181

- High TDS Water
- Ran at pH of 7.7 initially
- 20 ng/l ∑ PFAS goal
- Regeneration more effective for PFBA and PFPeA than PFHxA
- Performance improved with the addition of CO2 to lower pH.



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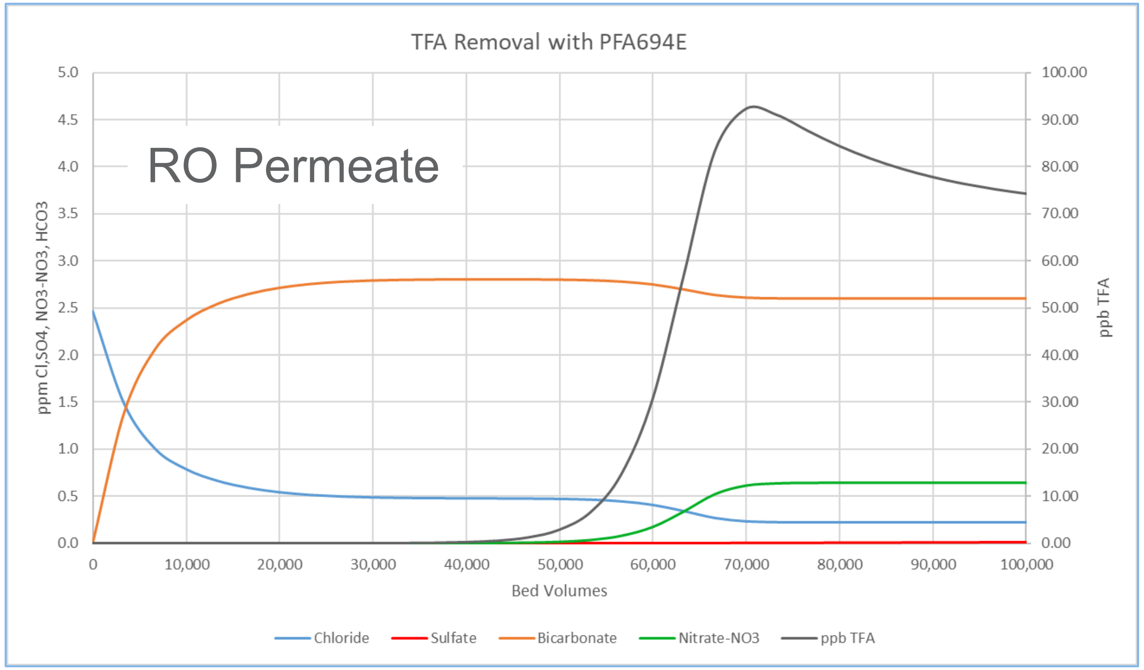
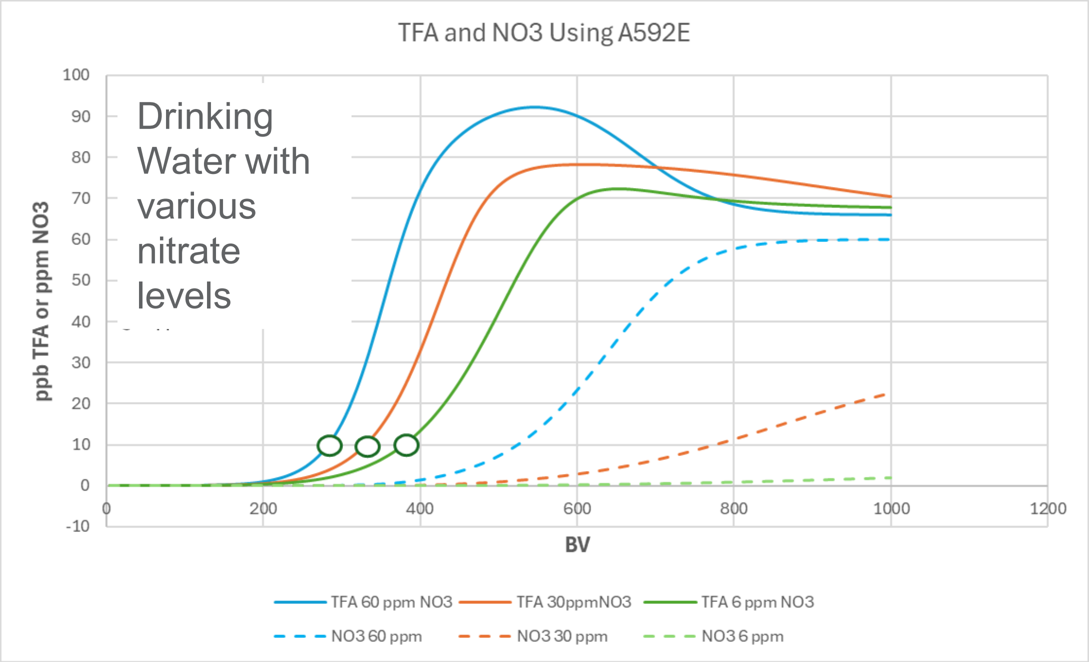
TFA Removal

Projections on Single-Use and Regenerable





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Case History:
Los Angeles, California site

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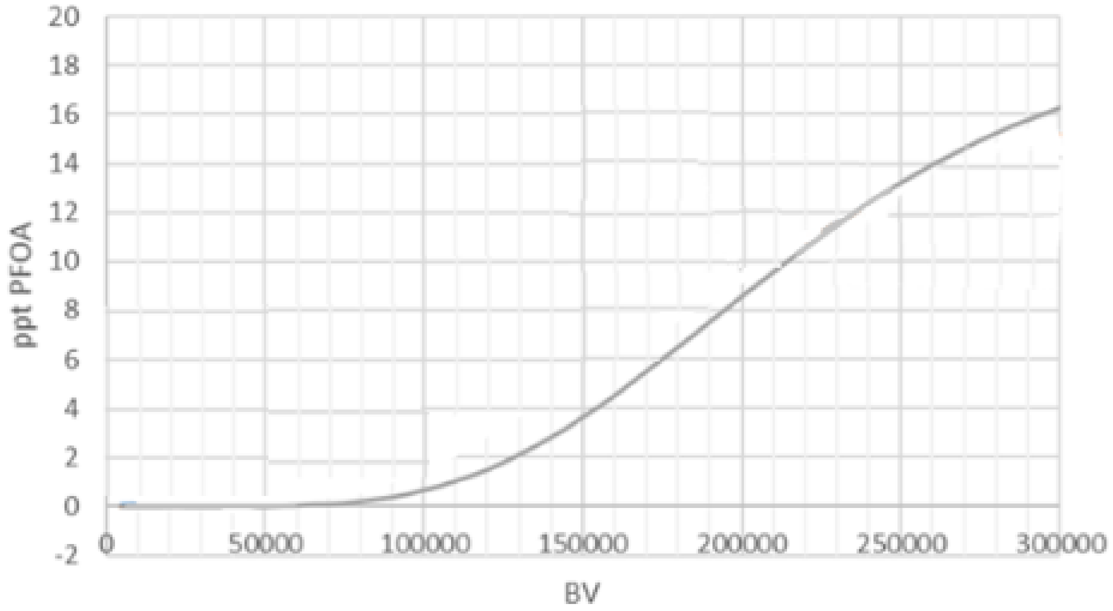
Started with Water Chemistry and Modeling

Los Angeles Drinking Water Design Example

Operational Flow Rate		gpm	1240
Operational Schedule		hour/day	
Daily Volume (average)		Gallons	1,785,485
Sulfate		mg/L	120.0
Nitrate (as N)		mg/L as N	2.5
Nitrate (as NO3)		mg/L as NO3	12.0
Alkalinity (as $CaCO_3$)		mg/L	180.0
Chloride		mg/L	76.0
Fluoride		mg/L	ND
Perchlorate		ppb	0.4
Arsenic		ppb	1.8
Hexavalent chromium		ppb	0.4
Uranium		pCi/l	1.7
Calcium		mg/L	90.2
Magnesium		mg/L	16.2
Sodium		mg/L	56.0
Potassium		mg/L	4.7
Iron		ug/l	11.0
Manganese		ug/l	5.1
pH			7.5
ORP			
TDS		mg/L	520.0
Suspended Solids		mg/L	Assume ND
Oil & Grease		mg/L	Assume ND
Total Organic Carbon	TOC	mg/L	0.52
Perfluorobutanoic acid	PFBA	ng/L (ppt)	
Perfluoropentanoic acid	PFPeA	ng/L (ppt)	
Perfluorohexanoic acid	PFHxA	ng/L (ppt)	5.6
Perfluoroheptanoic acid	PFHpA	ng/L (ppt)	3
Perfluorooctanoic acid	PFOA	ng/L (ppt)	12
Perfluorononanoic acid	PFNA	ng/L (ppt)	2.1
Perfluorododecanoic acid	PFDoDA	ng/L (ppt)	
Perfluorotetradecanoic acid	PFTeA	ng/L (ppt)	
Perfluorobutanesulfonic acid	PFBS	ng/L (ppt)	5.6
Perfluorohexanesulfonic acid	PFHxS	ng/L (ppt)	4
Perfluoroheptanesulfonic acid	PFHpS	ng/L (ppt)	
Perfluorooctanesulfonic acid	PFOS	ng/L (ppt)	22
4:2 FTS (fluorotelomer sulfonate)	4:2 FTS	ng/L (ppt)	
6:2 FTS (fluorotelomer sulfonate)	6:2 FTS	ng/L (ppt)	
8:2 FTS (fluorotelomer sulfonate)	8:2 FTS	ng/L (ppt)	
GenX	GenX	ng/L (ppt)	
VOC	VOC	ppb	

Throughput Simulation for PFOA

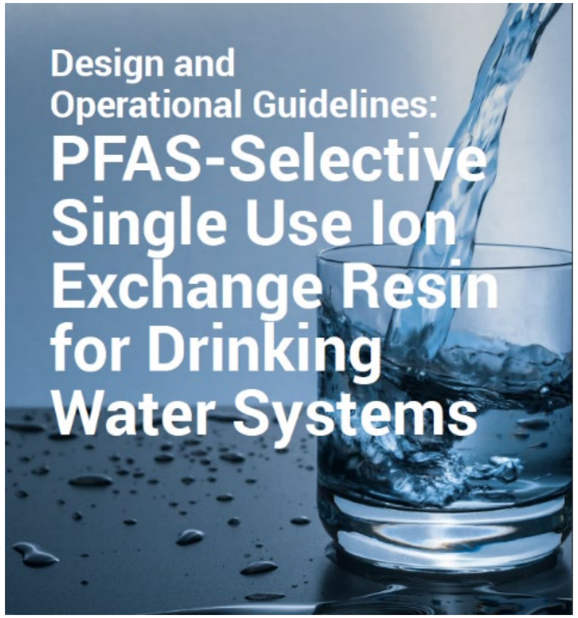


PFAS Total = 54.3 ppt, PFOA driver for throughput

Los Angeles Drinking Water Design Example

	Units	PFA694E Resin	GAC
Flow Rate	m^3/h	681	681
Vessel Diameter	mm	3500	3500
Number of Trains		2	4
Flow per Train	m^3/h	340.7	170.3
Total number of vessels onsite (lead+lag)		4	8
Media Volume per vessel	m^3	12	20
BV/hour		28.4	8.5
EBCT	min	2.1	7.0
Estimated throughput for lead vessel change out trigger	BV	273,550	27,300
Days between exchanges	days	401	134
Water treated per run	$1000m^3$	393,912	131,040
Change outs per year		0.9	2.7
Volume of Media consumed per year	m^3	21.8	218.6

Design Guidelines



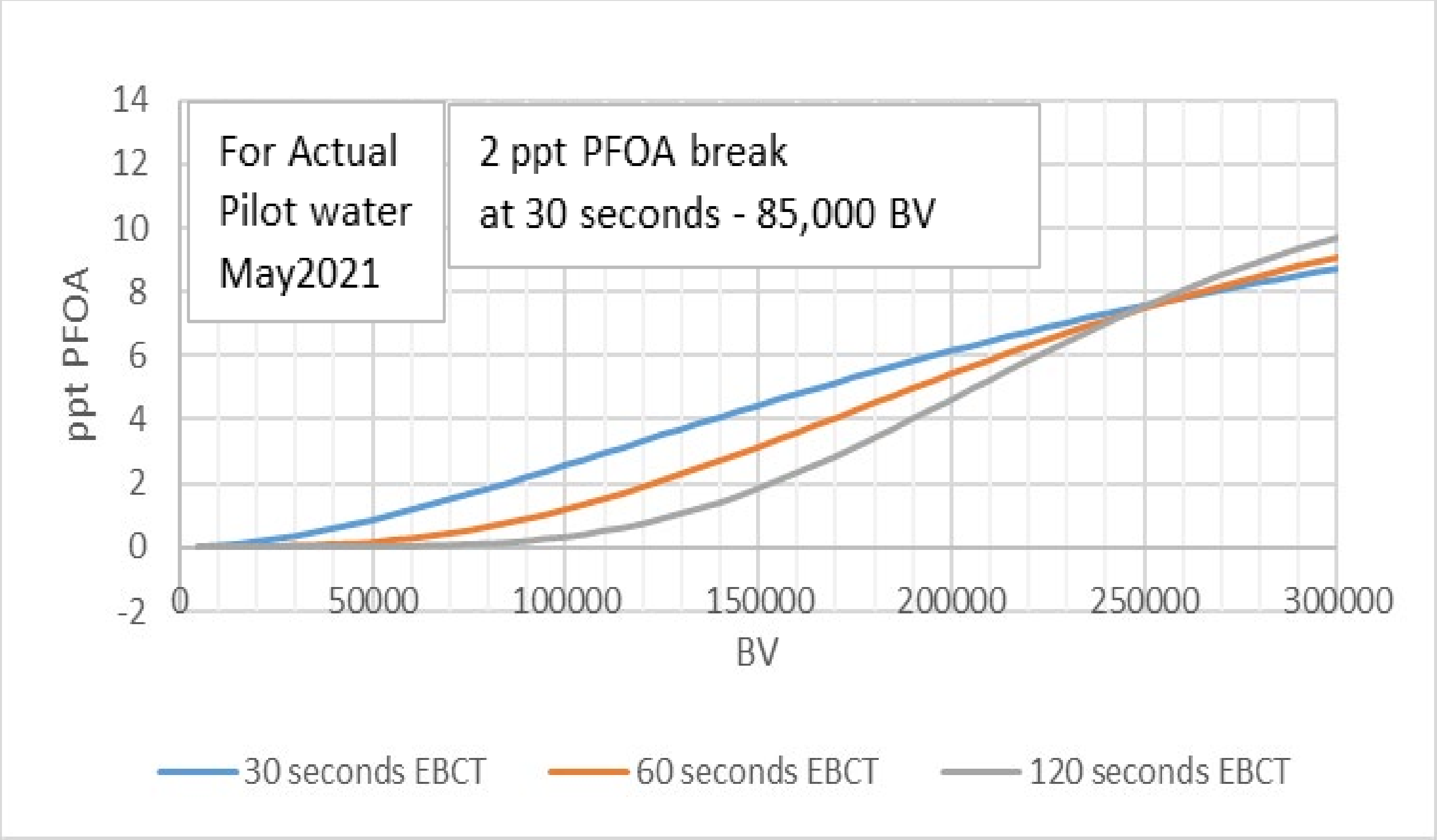
Vessel Parameter	Design Goal
Linear Velocity (LV)	15 to 45 m/h
Bed Depth for LV <= 30 m/h	0.91m minimum
Bed Depth for LV > 30 m/h	3.7 ft (1.1 m) minimum
Specific Flowrate	8 to 40 BV/h
Empty Bed Contact Time (EBCT)	2 min for drinking water 3 min for higher concentrations

Next step was validation…

- Ion Exchange: Accelerated Pilot
  - Segmented pilot for IX allowed sampling as the mass transfer zone moved down the bed.
  - Reduces the amount of time for piloting by 25%
  - Sharper breakthrough curves for shorter contact times
  - Sharper breakthrough = a more conservative capacity estimate vs the full-scale plant
  - With PFAS-selective resins, low error is expected and predictable in capacity at 30 vs 120 seconds EBCT
  - Allows much earlier decisions on full-scale treatment
  - Reduces analytical costs for piloting

- GAC: Rapid Small Scale Column Test (RSSCT)
  - Crush resin bed for faster results

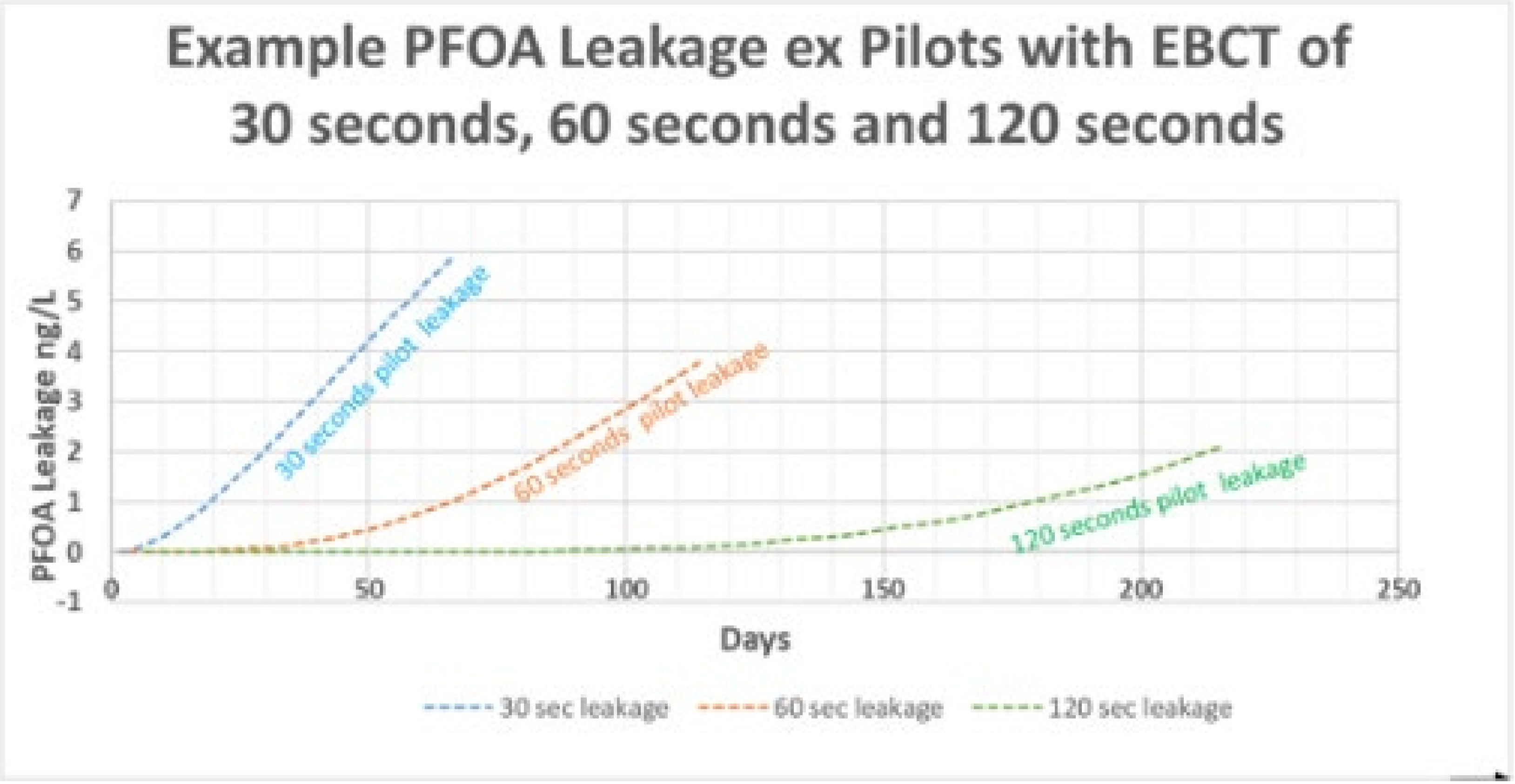
Accelerated Piloting Predictions:
BV to 2 ppt break at 30, 60, 120 seconds



Sharper break with shorter EBCTs

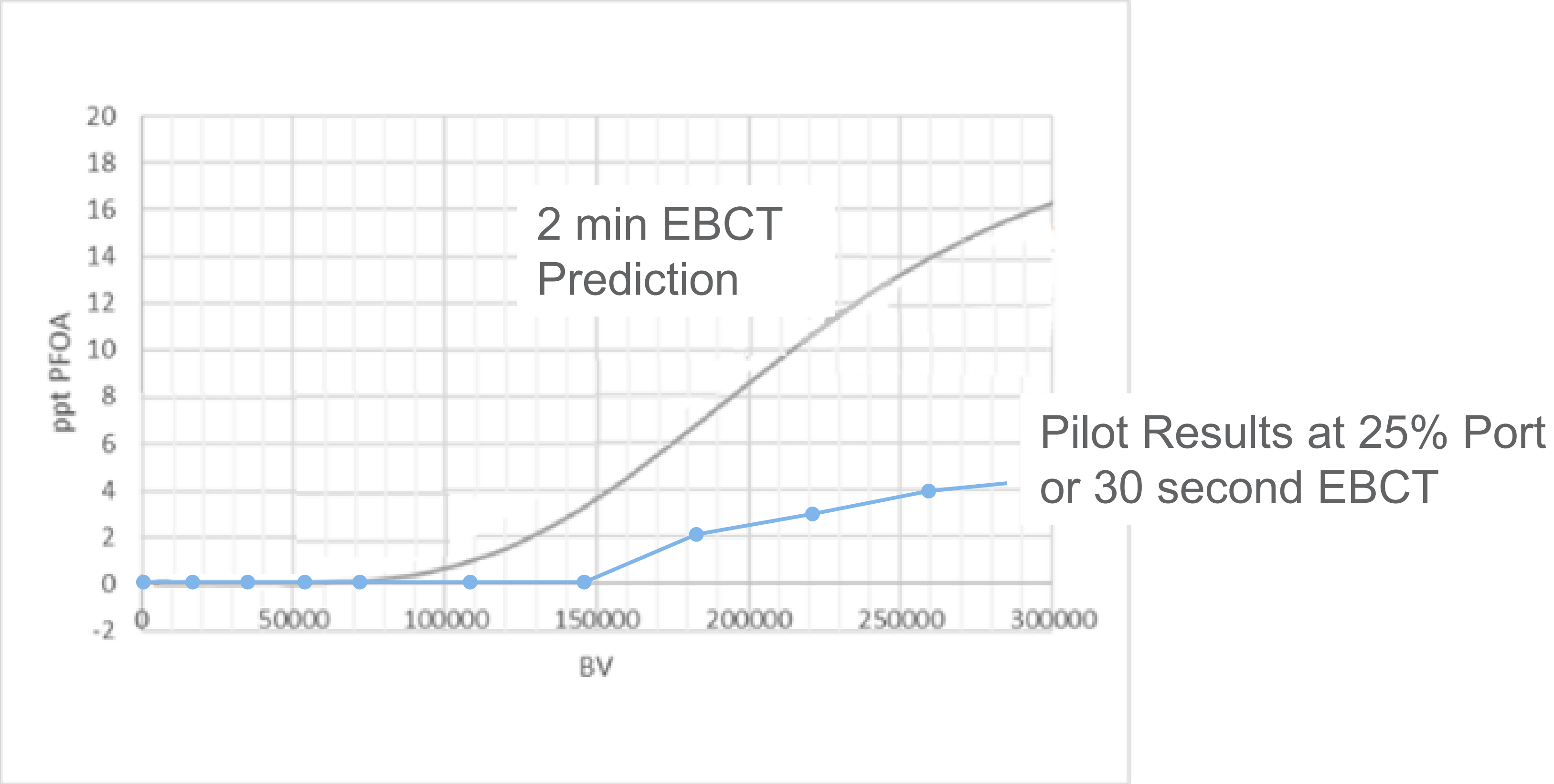
Predictable Error

With 30-seconds pilot completed in 1/4th the time of a full pilot



Modeling was Conservative and Accurate

Comparing Model to Pilot Results



Los Angeles Drinking Water Design Example

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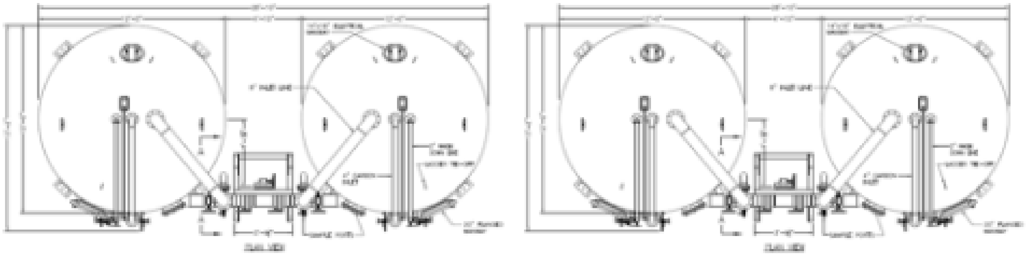
IX half the equipment

Los Angeles Site

Footprint Considerations

681 m^3/h Footprint: IX Resin with High Flow Vessels

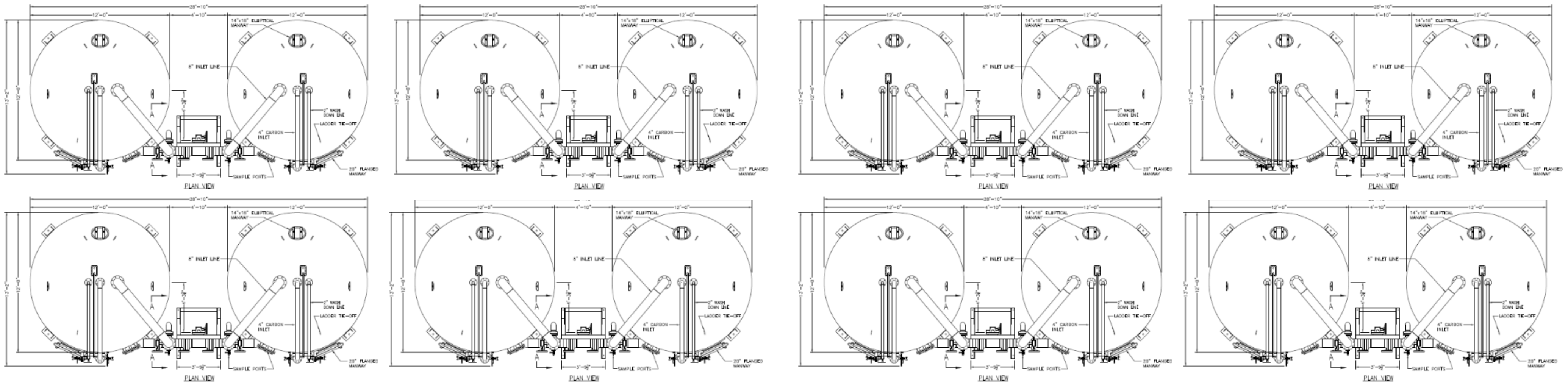


Drawings complements of Aqueous Vets

2 Systems

- 3500 mm Diameter

681 m^3/h Footprint: GAC "20,000 pounders"



8 Systems
- 3500 mm Diameter

GAC capital cost and footprint is ~ four times IX

Los Angeles Drinking Water Design Example

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IX 10 times the throughput

Los Angeles Drinking Water Design Example

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GAC
10 x more media consumed
10 x more waste

Los Angeles Drinking Water Design Example

Operational Costs Based on 2023 Data in the US

	IX	GAC
Media consumed per year	771	7721
Media Cost per pound		$ 2.00
Media Cost per cubic foot	$ 350	$ 67.20
Media Cost per year	**$ 269,680**	**$ 518,829**
Operating Cost - $/Kgal	**$ 0.17**	**$ 0.33**
OPEX per year $/AF	**$ 55.73**	**$ 107.22**

IX was ~ half the OPEX

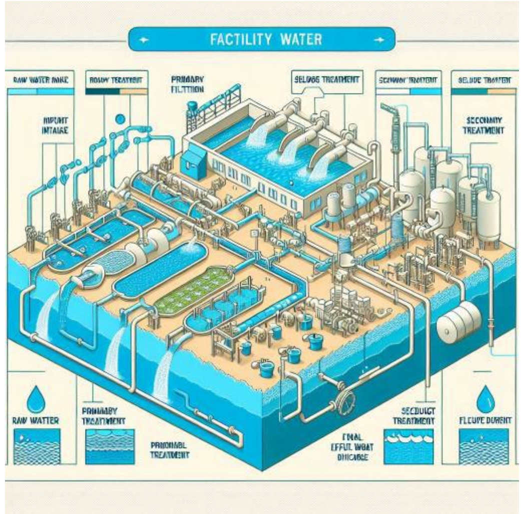
Los Angeles Drinking Water Design Example

In the end, ion exchange made much more sense.

Next Steps

Water Mapping

- Figure out what PFAS is coming in and what is being discharged
- When sampling for PFAS, also obtain samples for:
  - Balanced general chemistry analysis
    - i.e. nitrate, sulfate, chloride, alkalinity
  - pH
  - Total Organic Carbon (TOC)
  - Total Dissolved Solids (TDS)
  - Iron and manganese
- Request samples, resin recommendations, and testing protocols



Next Steps

Solution Development

- Modelling
- Feasibility Design

Validation

- Piloting

Solution Implementation

Ongoing PFAS Management

Why has the US Embraced Single-Use IX Technology?

PFAS-Selective IX Resin Provides the Following Advantages

Property		Effect		Benefit
Fast Kinetics	→	Smaller footprint	→	Lower Capital Cost
High Selectivity	→	Longer bed life	→	Lower Operating Cost
Higher Selectivity	→	No sloughing of nitrate	→	Robust performance
Less Media used for Longer Periods	→	Less waste generation	→	Lower Operating Cost More Sustainable

Questions?

Thank you!

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