The use of selective Lewatit® ion exchange resins for the removal of emerging contaminants: PFAS and beyond

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International PFAS Conference, June 5, 2024

Versatile specialists – comprehensive product portfolio provides advanced solutions

LANXESS
Energizing Chemistry

Products and brands

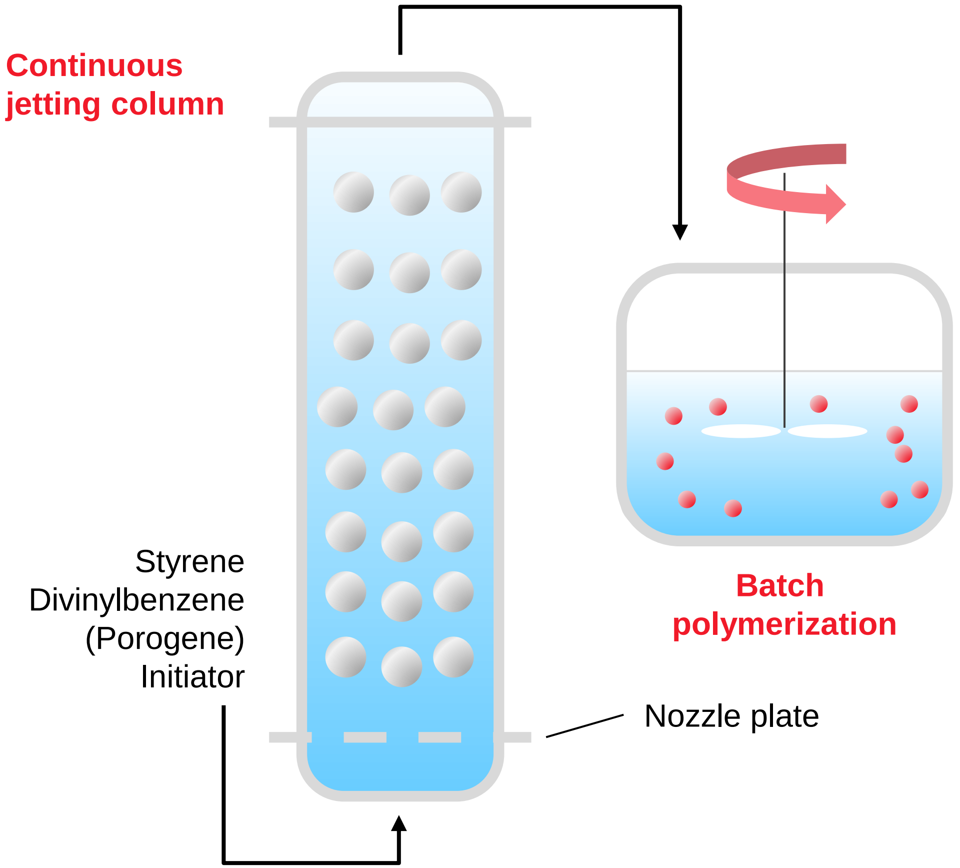
Lewatit® Lewatit® Scopeblue	▪ Ion exchange resins, adsorbers, and functional polymers for use in many industries and applications
Bayoxide®	▪ Granular iron oxide adsorbers for water treatment
LewaPlus®	▪ Software for designing and optimizing ion exchange resin plants

Customer industries

Monodisperse droplet generation by jetting process

Stable scaffolds for demanding metals processing applications!

Formation of monodisperse droplets



Description

- Continuous process
- Raw materials are fed through a nozzle plate at the bottom of the column
- The resulting monomer jet is chopped into droplets of the same size
- Particle size can be controlled by adjustment of the whole width of the nozzle plate
- The droplets formed at the bottom start to encapsulate as they proceed to the column head
- Polymerization of the monodisperse encapsulated droplets is completed afterwards

Overview of LANXESS resins and adsorbers for wastewater applications

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Portfolio of selected LANXESS products

Pollutant		Chelating resin		Strong base anion resin (SBA)		Weak base anion resin (WBA)	Ferric hydroxide adsorber	Polymer adsorber
		Lewatit® MonoPlus TP 207	Lewatit® MonoPlus TP 214	Lewatit® K 6362	Lewatit® TP 108 Lewatit® MonoPlus TP 109	Lewatit® MP 62 WS	Bayoxide® E IN 20 / E IN 30	Lewatit® VP OC 1064 MD PH
Heavy metals	HM	■						
Mercury	Hg^{2+}		■					
Molybdate, Vanadate	MoO_4^{2-} VO_4^{3-}			■		■		
PFAS					■	■		
Arsenic	AsO_4^{3-}						■	
Phosphate	PO_4^{3-}						■	
Micropollutants								■

Key design properties of selective Lewatit® TP 108 DW

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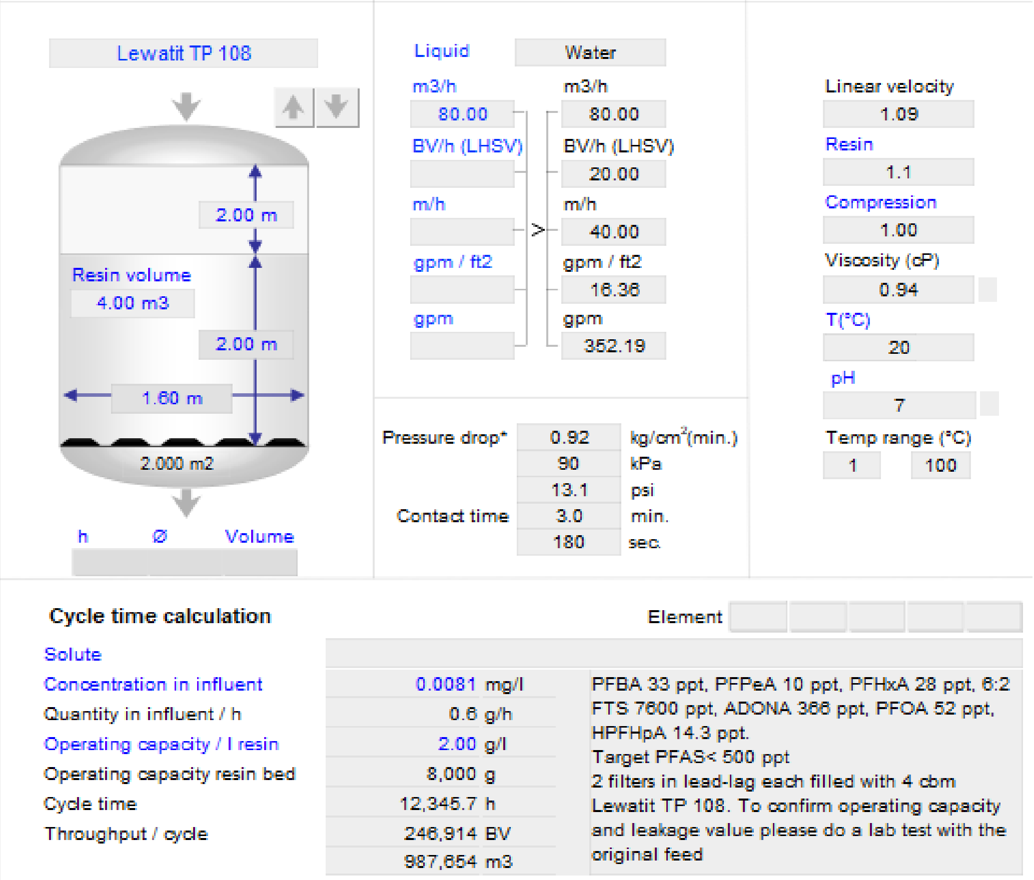
Precise control of resin parameters for critical separation challenges

- Functional group (Type of Amine)
- Polymer matrix (Styrenic or Acrylic)
- Morphology (Gel or Macroporous)
- Crosslinking
- Bead size
- Kinetics
- Resin swelling

Uniformity coefficient	1.7
Effective size	0.40-0.55
Fines	1
Total capacity (delivery form)	0.7
Delivery form	Cl^-
Functional group	quarternary ammonium
Matrix	styrenic
Structure	gel
Appearance	white, opaque



Chemical structures of most critical PFAS and their sources

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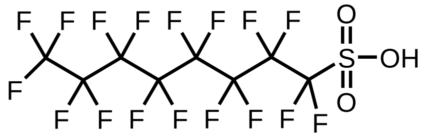
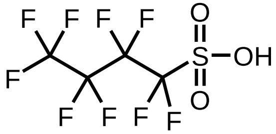
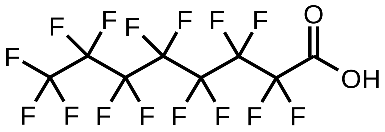
Highly efficient resin for the removal of toxic anions such as perchlorate, chlorate, and bromate



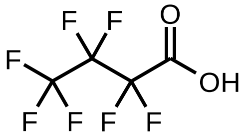
Perfluorooctanesulfonic acid (PFOS)
MW = 500 g/mol



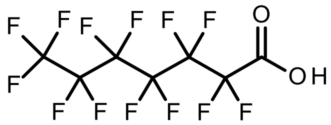
Perfluorobutanesulfonic acid (PFBS)
MW = 300 g/mol



Perfluorooctanoic acid (PFOA)
MW = 414 g/mol



Perfluorobutanoic acid (PFBA)
MW = 214 g/mol



Perfluoroheptanoic acid (PFHpA)
MW = 364 g/mol

A high-performance ion exchange resin required in order to remove mixture PFAS

US and EU State PFAS Regulations

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Selective States	State limits
Massachusette	**Drinking Water MCLs**: PFOS, PFOA, PFHxS, PFNA, PFHpA and PFDA (20ppt combined)
Illinois	**Health advisory levels**: PFOS (14ppt), PFOA (2ppt), PFHxA (560,000ppt), PFHxS (140ppt), PFBS (2100ppt).
Connecticut	**Drinking Water Action levels**: PFOA, PFOS, PFNA, PFHxS and PFHpA (70 ppt combined)
New Jersey	**Drinking Water MCLs and Groundwater Quality Standards**: PFOA (14 ppt), PFOS (13 ppt) and PFNA (13 ppt)
North Carolina	**Groundwater Quality Standard**: PFOA and PFOS (70 ppt combined) **Drinking Water Health Goal**: GenX (150 ppt)
Pennsylvania	**Proposing Drinking Water MCLs**: PFOA (14 ppt) and PFOS (18 ppt)
California	**Drinking Water Notification Levels**: PFOS (6.5 ppt), PFOA (5.1 ppt), PFBS (500 ppt) Drinking Water Response Levels: PFOS (40 ppt), PFOA (10 ppt), PFBS (5000 ppt)
Colorado	**Surface water/Groundwater Translation Levels**: PFOA, PFOS and PFNA (70 ppt combined), PFHxS (700 ppt) and PFBS (400,000 ppt).
Maine	**Interim Drinking Water MCLs**: PFOS, PFOA, PFHpA, PFNA, PFHxS and PFDA (20 ppt, combined)
Michigan	**Drinking Water MCLs**: PFNA (6ppt), PFOA (8 ppt), PFHxA (400,000 ppt), PFOS (16 ppt), PFHxS (51 ppt), PFBS (420 ppt), and hexafluoropropylene oxide dimer acid (HFPO-DA) (370 ppt).
Minnesota	**Health Advisory Levels**: PFOS (15 ppt), PFOA (35 ppt), PFHxS (47 ppt), PFBS (2,000 ppt), and PFBA (7,000 ppt).
New Hampshire	**Drinking Water MCLs and Groundwater Quality Standards**: PFOA (12 ppt), PFOS (15 ppt), PFNA (11 ppt), and PFHxS (18 ppt).
New York	**Drinking Water MCLs**: PFOA (10 ppt) and PFOS (10 ppt).
Ohio	**Drinking Water Action Levels**: PFOA and PFOS (70 ppt, combined), GenX (700 ppt), PFBS (140,000 ppt), PFHxS (140 ppt), and
Rhode Island	**MCLs standard:** 20 ppt individually or combined for six PFAS (PFOA, PFOS, PFHxS, PFNA, PFHpA, PFDA).
Vermont	**Drinking water MCLs:** PFOS, PFOA, PFHxS, PFNA, and PFHpA (20 ppt, combined).
Wisconsin	**Surface water MCLs**: PFOS (bioaccumulative, 8 ppt for all water), and PFOA (non-bioaccumulative, 20 ppt for public drinking water source and 95 ppt for all other waters)

State	State limits
EU	current- 2026 $PFAS_{total}$ 500ppt or $PFAS_{20}$ 100 ppt, from 2026 $PFAS_{20}$ 100 ppt, from 2028 $PFAS_4$ 20 ppt
Denmark	$PFAS_4$ 2 ppt
Sweden	$PFAS_4$ 4 ppt, $PFAS_{21}$ 100 ppt,

Options for treatment of PFAS

Ion exchange most efficient technology especially for short chain PFAS!

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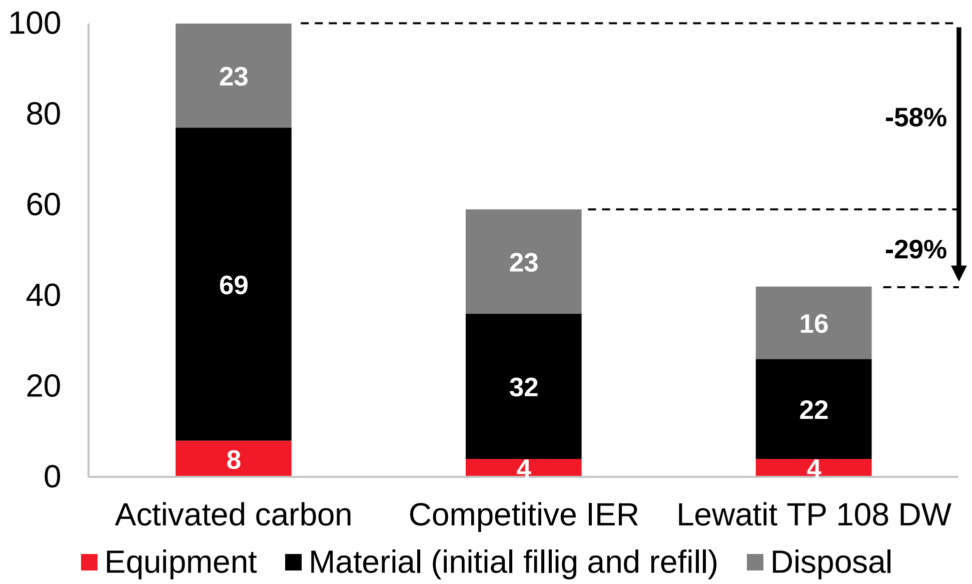
Reverse osmosis / nanofiltration	▪ Effectively removes even smaller chain PFAs ▪ Capex cost is high ▪ Operating cost and energy consumption is high ▪ Results in a relatively large waste stream
Granulated activated carbon	▪ Low-cost media difficult to change and expensive to reactivate ▪ Large footprint ▪ Low selectivity short chain PFAS results short cycles frequent exchanges
Ion exchange	▪ Fast kinetics, small vessels, ▪ Spent material is easy to be exchanged ▪ Very high selectivity, long cycles, low exchange rate

Cost calculation using Lewatit® TP 108 DW, a competitor ion exchange resin (IER), and activated carbon

Costs in %
Normalized to AC costs



Required resins and filter arrangements

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Wastewater leachates from hot spots
(PFAS influent: ppm-ppb)

1

- Activated carbon removal of natural organic matter
- Macroporous regenerable: Lewatit® MP 62 WS and Lewatit® MonoPlus TP 109 Regenerable working filter
- PFAS selective Lewatit® TP 108 and Lewatit® K 6362 polishing, especially short chain PFAS
- Purified water

2

- RO unit → Selective Lewatit® TP 108 Polishing
- concentrate
- Lewatit TP 108 single use or Lewatit® MonoPlus TP 109 Regenerable

Ground water
(PFAS influent: ppt)

- Activated carbon removal of natural organic matter
- Selective Lewatit® TP 108 Polishing, longest cycle time lowest leakage
- Purified water

Lewatit® PFAS resins

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Lewatit® TP 108 DW (NSF 61)	▪ **Very high selectivity to PFAS** ▪ Especially effective against short-chains, e.g., PFBA types ▪ Not recommended for regeneration ▪ NSF 61 Certified for drinking water application
Lewatit® MonoPlus TP 109 (**New**)	▪ **High selectivity to PFAS species** ▪ Macroporous structure for improved kinetics, **fouling resistance and easier regeneration** ▪ **Monodisperse resin bead size** for improved hydraulics ▪ Optimum functional group hydrocarbon chain length for balance PFAS removal and regeneration ▪ High regeneration efficiency 70% methanol + 1% NaCl[1]
Lewatit® MP 62 WS (**New**) **Lewatit® MP 62 WS Eco**	▪ Medium selectivity for PFAS species weak base anion exechange resin, short chains **regenerated NaOH** ▪ Suitable for highly PFAS-contaminated waters such as point sources or aquifers ▪ Macroporous structure for improved kinetics, fouling resistance and easier regeneration ▪ A high operating capacity and total capacity (≥1.7 eq/l), ideal as a pretreatment resin ▪ 24% greenhouse gas savings[2] due to usage of ISCC[2] Plus certified styrene in accordance with mass balance approach

[1] Deng et al. Water Research 2010, 44, 5188
[2] Compared to standard Lewatit® based on fossil monomer (acrylonitrile/styrene). ISCC refers to International Sustainability & Carbon Certification

Interactions of PFAS with anion exchange resins

Strongest interaction between Lewatit® TP 108 DW and long chain PFAS

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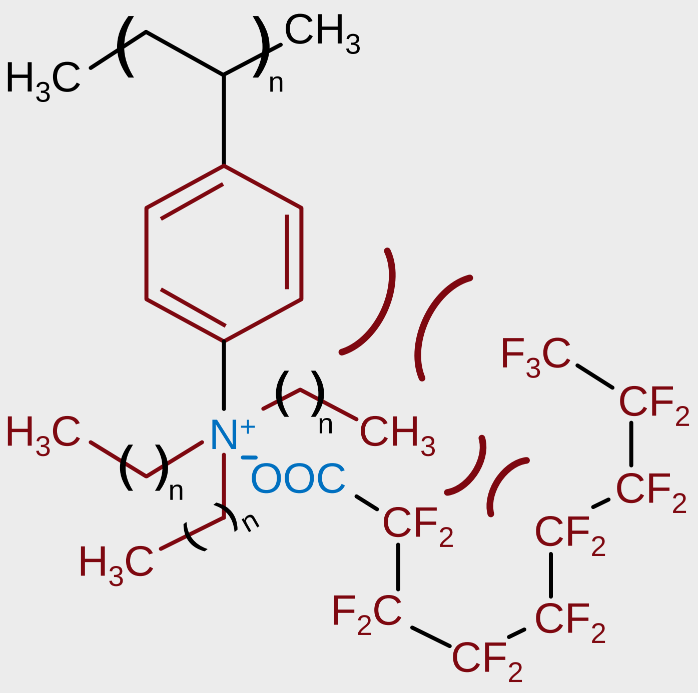
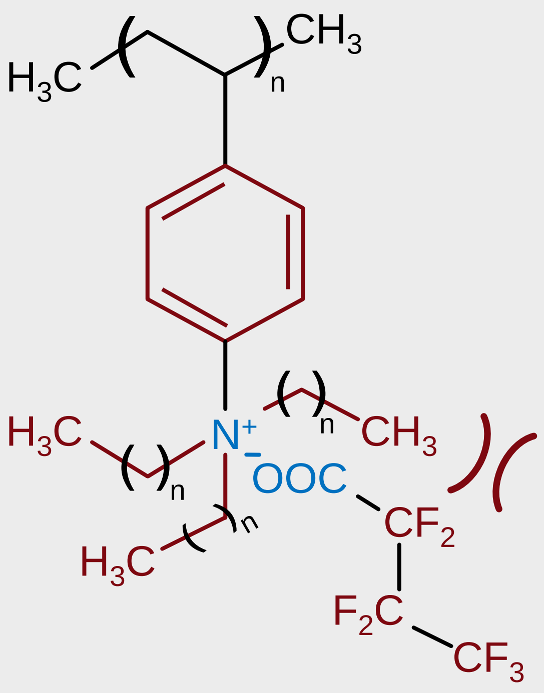
Strong interactions between Lewatit® TP 108 DW and PFNA



)(Hydrophobic interaction

Medium interactions between Lewatit® TP 108 DW and PFBA



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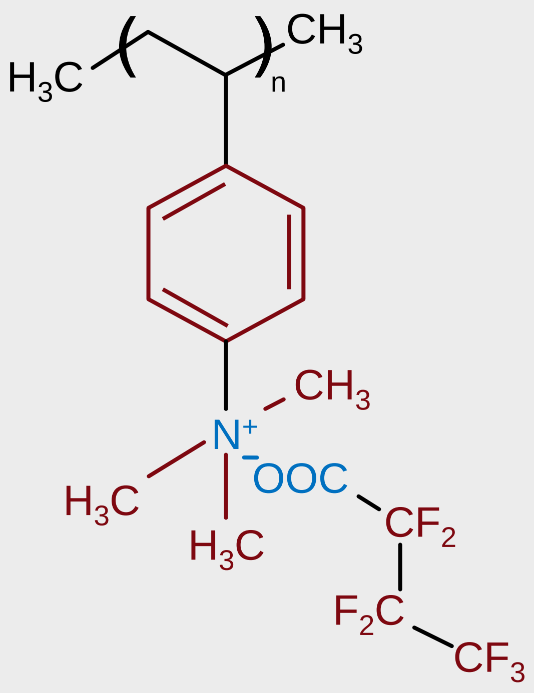
Weak interaction between Lewatit® K 6362 and PFBA



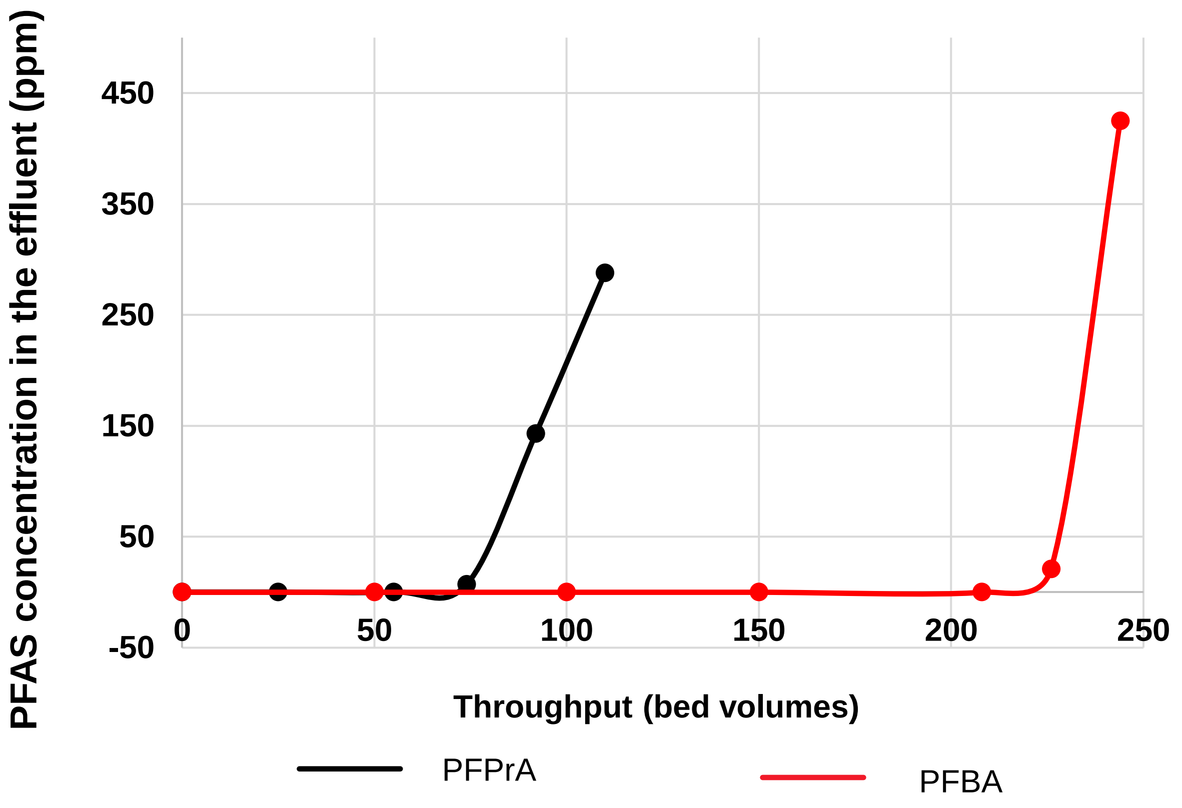
Ionic interaction

PFPrA[1)] and PFBA[2)] removal from process stream

Lewatit® MP 62 WS outperforms with high loading capacity and efficient regeneration using 4% NaOH

operating conditions	
applied form	free base form
$PFPrA_{feed}$	103 ppm
$PFPrA_{loading\ capacity}$	10.3 g/L
$PFBA_{feed}$	602 ppm
$PFBA_{loading\ capacity}$	145 g/L
Volume	900 L
pH	2
SV	2 BV/h
Reg.	4% NaOH, 3-4 BV
Configuration	merry-go-round

PFPrA and PFBA removal by Lewatit® MP 62 WS



Reliable and efficient PFAS removal for several years at waste water plant in Germany

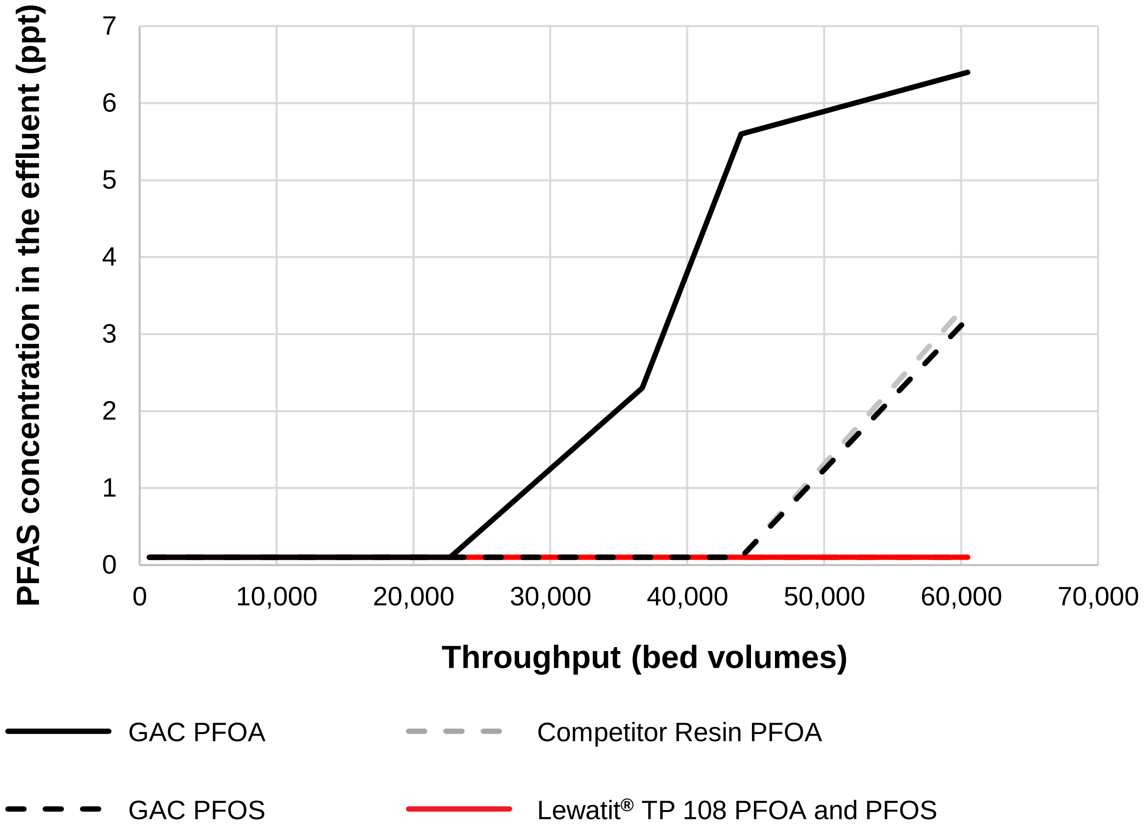
1) Perfluoropropanoic acid 2) Perfluorobutanoic acid

PFOA and PFOS removal from ground water

Lewatit® TP 108 DW offers longer lifetime than competitor resin and activated carbon

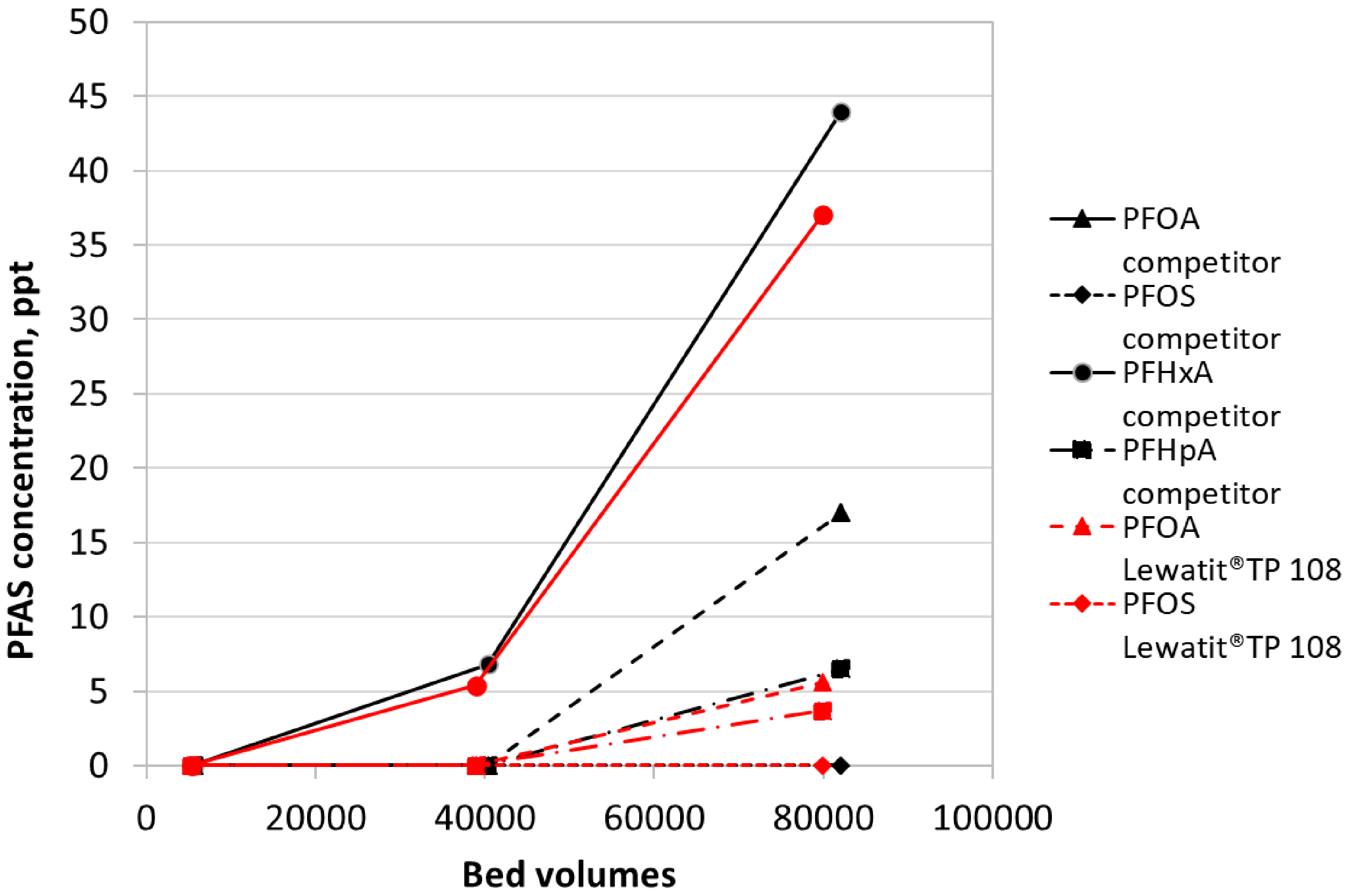
Operating Conditions	
Resin in Cl form	
PFOS	61 ppt
PFOA	44 ppt
Volume	75 L
pH	7
SV	15 BV/h
Temp	20°C
Breakthrough	> 1 ppt

PFOA and PFOS removal pilot in Italy



Pilot Comparative Results

Lewatit® TP 108 offers longer lifetime than competitor resin



1.5 L, PFOS 429 ppt, PFHxA 80 ppt, PFOA 174 ppt, PFHxS 110 ppt

Long lifetime of Lewatit® TP 108 DW even at high PFAS influent concentration

Pilot Trial in a River Water Project, USA

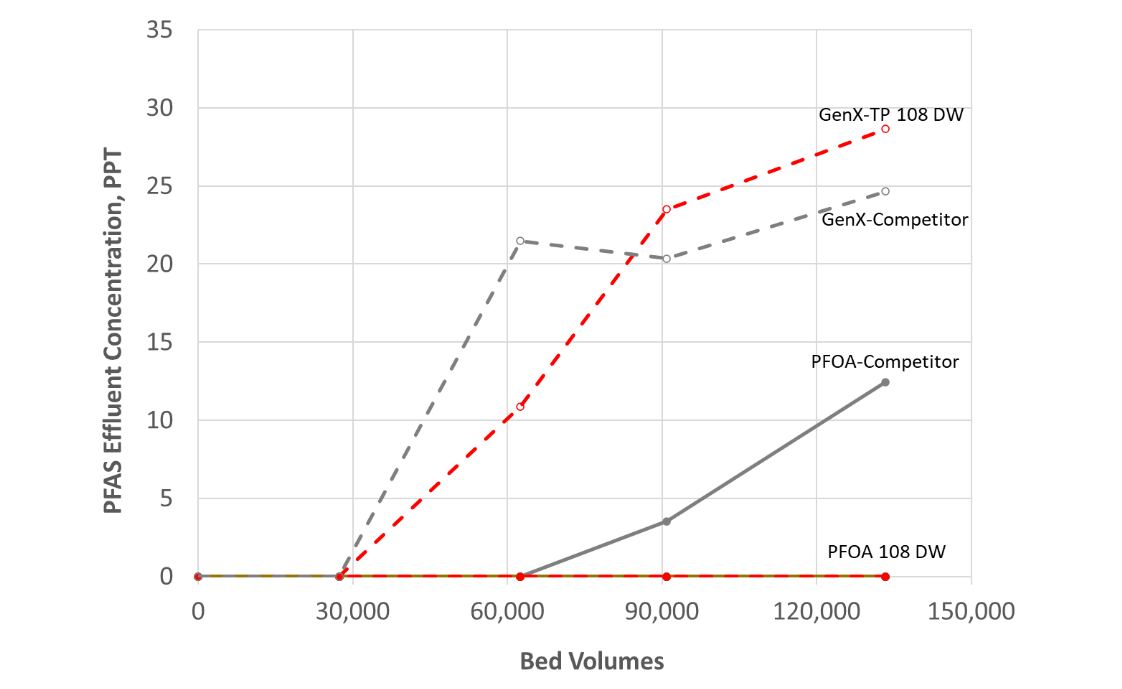
- 20 BV/Hour
- EBCT = 3 min
- Competitor resin is a gel type non-regenerable PFAS resin

IX Resins	Bed Volumes	PFOS, ppt	PFOA, ppt	PFBS, ppt	PFHxS, ppt	PFNA, ppt	GenX, ppt	PFHxA, ppt	PFHpA, ppt
	Raw Water	20.8	23.5	6.1	9.3	5.9	28.7	64.9	42.5
TP 108 DW	27,400	ND	ND	ND	ND	ND	ND	ND	ND
TP 108 DW	62,500	ND	ND	ND	ND	ND	10.9	7.8	ND
TP 108 DW	90,900	ND	ND	ND	ND	ND	23.5	37.0	6
TP 108 DW	133,400	ND	ND	ND	ND	ND	28.7	68.7	11.5
A Competitor Resin	27,400	ND	ND	ND	ND	ND	ND	ND	ND
A Competitor Resin	62,500	ND	ND	ND	ND	ND	21.5	16.9	2.5
A Competitor Resin	90,900	ND	3.5	ND	ND	ND	20.3	37.6	15.7
A Competitor Resin	133,400	ND	12.5	ND	ND	ND	24.6	50.6	26.3

ND: non-detect

PFOA and GenX Removal

- PFOA (feed) = 23.5 ppt; GenX (feed) = 28.7 ppt



Lewatit® TP 108 DW offers the highest capacity for most PFAS species found in drinking water sources

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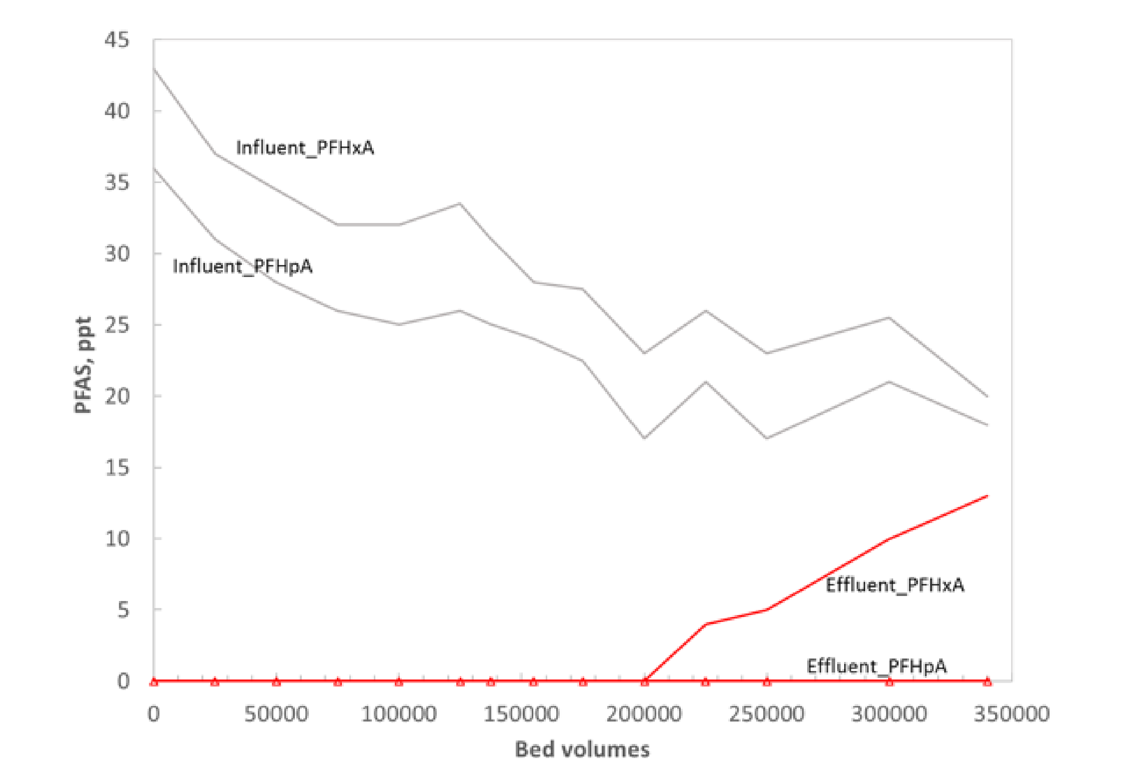
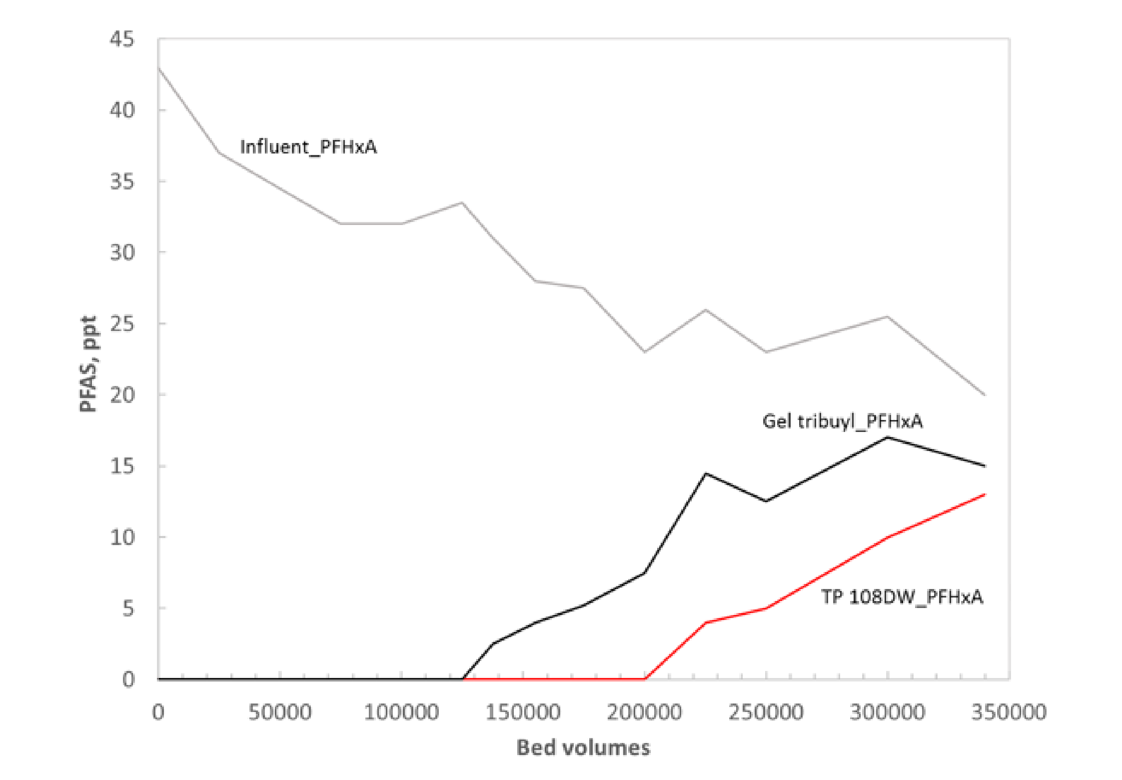
PFHxA and PFHpA breakthrough curves generated USA



PFHxA breakthrough curves generated USA



Resin performance for PFAS application

Fast access to breakthrough curves by Klinkenberg simulation

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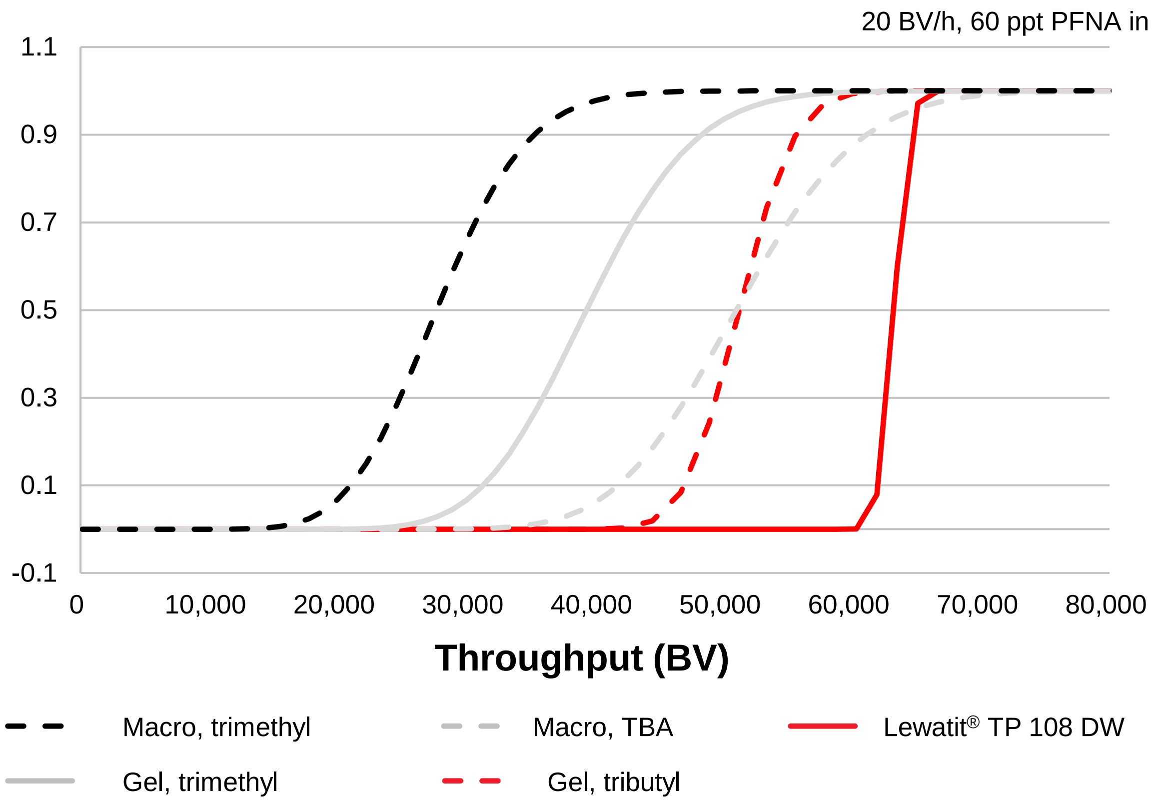
PFNA breakthrough curves



Conclusions

- Lewatit® TP 108 DW best resin to be used as single use polisher: longest cycle time and lowest leakage
- Macroporous resins, shorter cycle times and higher leakage values due to lower total capacity
- Technique established that yields fast access to breakthrough curves 2-3 weeks instead of 15 weeks for traditional method

$$\frac{C}{C_f} \approx \frac{1}{2}\left[1 + erf\left(\sqrt{\tau_1} - \sqrt{\xi} + \frac{1}{8\sqrt{\tau_1}} + \frac{1}{8\sqrt{\xi}}\right)\right]$$

$$\xi = \frac{kKu}{z}\left(\frac{1-\varepsilon}{\varepsilon}\right) \qquad \tau_1 = k\left(t - \frac{z}{u}\right)$$

Case study at fire training site Australia

One of the most successful PFAS water treatment plants

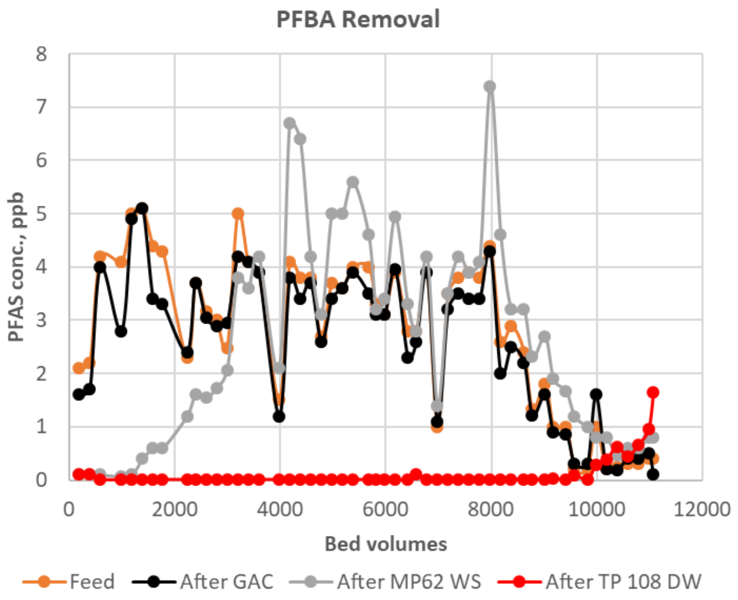
Containerized PFAS treatment plant

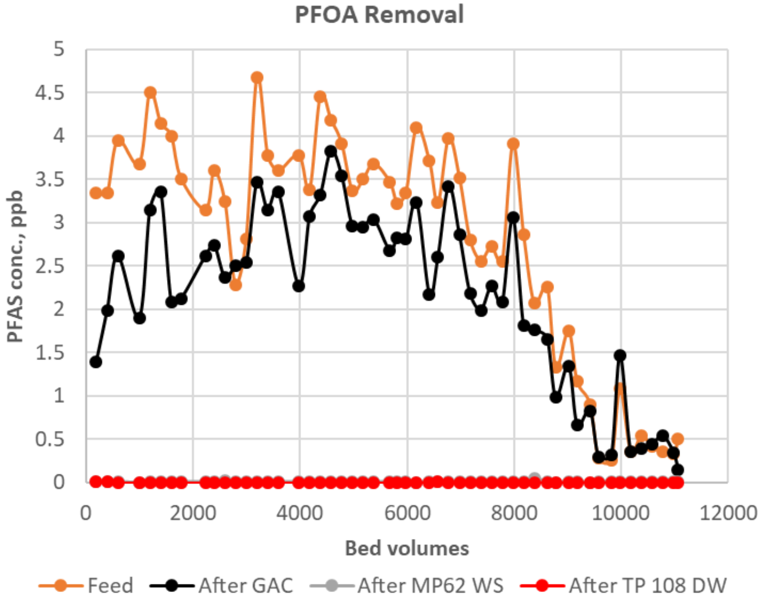
Characteristics

- Training using aqueous fire-fighting foam (AFFF) containing per- and poly-fluoroalkyl substances (PFAS)
- PFAS leached into groundwater
- Discharge criteria for **long and short-chain PFAS** to comply with
- Processes: oxidation, pH adjustment, flocculation, solids separation, media filtration, ion exchange and adsorption

PFAS treatment in a fire-fighting facility

Effient short chain PFAS removal only with Lewatit® TP 108 DW!





Lewatit® TP 108 DW reduced most PFAS compounds to non-detect!

PFAS treatment summary

- Influent: total PFAS up to 200 ppb
- **Effluent targets**
  - PFOS and PFHxS combined total less than 0.07 ppb
  - PFOA less than 0.56 ppb
  - PFBA to non-detect level up to 10,000BVs
- 20 m^3/hour flow rate
- In operation for 12 months and treating nearly 14 million gallons of water
- Deemed one of the most successful PFAS water treatment plants in Australia

LANXESS has the right products and technical expertise for every application

PFAS can be found in a wide range of concentrations and therefore, efficient purification solutions are required

Lewatit® offers unique resins for unsurpassed performance in even the most challenging scenarios

Lewatit® ion exchange resins have proven reliability on commercial scale

Longer run length between resin exchange results in a significant reduction in operating cost

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