

# QUALITY DETOXIFIES.



## Efficient PFAS Removal with Selective **Lewatit®** Ion Exchange Resins

Product Information and Operational Guidelines

**X** Lewatit®

QUALITY **WORKS.**

**LANXESS**  
Energizing Chemistry

# LET OUR COMPETENCE AND EXPERIENCE ASSIST YOU

## LANXESS – your global partner for success

We are a leading specialty chemicals company based in Cologne, Germany, well-established on the global market. Our primary expertise lies in producing, developing, and marketing chemical intermediates, additives, specialty chemicals, and plastics.

We manage our operating business through four segments: Advanced Intermediates, Specialty Additives, Consumer Protection, and Engineering Materials. The business units within these segments work with a broad range of applications and markets. As a specialist and efficient partner, we offer solutions for all kinds of challenges faced by our customers. We focus on our customers' requirements in order to drive progress and reliably provide innovative product, material and service solutions. Our manufacturing, administration, and logistics processes are designed for efficiency and performance.

The Liquid Purification Technologies (LPT) business unit offers a broad range of technologies and solutions for the treatment of water and other liquid media. It is one of the leading manufacturers of ion exchange resins with production sites in Germany and India. Its excellent technical know-how and extensive customer service, based on many decades of experience, are highly acknowledged. In addition, LPT also offers a range of **Bayoxide®** iron oxide adsorbers for various water treatment applications.

Additionally, our unique calculation and design software **LewaPlus®** enables the planning of ion exchange, reverse osmosis, and ultrafiltration systems, and combinations thereof under various system configurations, including process configurations only available with **Lewatit®** product technology.

## Lewatit® – our valued brand

For more than 80 years our **Lewatit®** ion exchange resins and adsorbers have been employed in numerous industries to purify, treat, and remediate water and other liquid media. Important areas of application include:

- Chemical and petrochemical
- Food and beverages
- Household
- Mining and metallurgy
- Municipal water treatment
- Paper and pulp
- Pharma and biotech
- Power generation
- Semiconductor and photovoltaic

In the treatment of drinking water and wastewater, ion exchange resins benefit from their unique ability to selectively bind ions. Thus, special grades of **Lewatit®** can be used to remove harmful constituents such as iron or manganese from drinking water, as well as traces of pollutants such as arsenic and lead. Even groundwater can be treated efficiently in this way, in which detrimental constituents such as chromate, nitrate, per- and polyfluoroalkyl substances (PFAS), surfactants, and perchlorate are bound to ion exchangers.

We offer a strong portfolio of **Lewatit®** ion exchange resins for the removal of pollutants and harmful substances from drinking water and wastewater. In this brochure our PFAS selective ion exchange resins **Lewatit® TP 108 DW** and **Lewatit® MP 62 WS** are presented and compared with different PFAS treatment technologies.

# PRODUCT INFORMATION

Lewatit® TP 108 DW is a gel-type polystyrene-based strong base anion exchange resin with a heterodisperse particle size distribution. In comparison with conventional strong base anion exchange resins, its modified functional group facilitates a very selective uptake of per- and polyfluoro-alkyl substances (PFAS) from industrial and potable water with a high background of chloride and sulphate. Thus Lewatit® TP 108 DW is particularly applicable for the

removal of short- and long-chain PFAS to very low levels, including perfluorooctanoic acid (PFOA), perfluorooctane-sulfonic acid (PFOS), perfluorononanoic acid (PFNA), perfluoroheptanoic acid (PFHpA), perfluorohexanoic acid (PFHxA), perfluorohexanesulfonic acid (PFHxS), perfluorobutanesulfonic acid (PFBS) and perfluorobutanoic acid (PFBA).

## Comparison among different PFAS removal methods

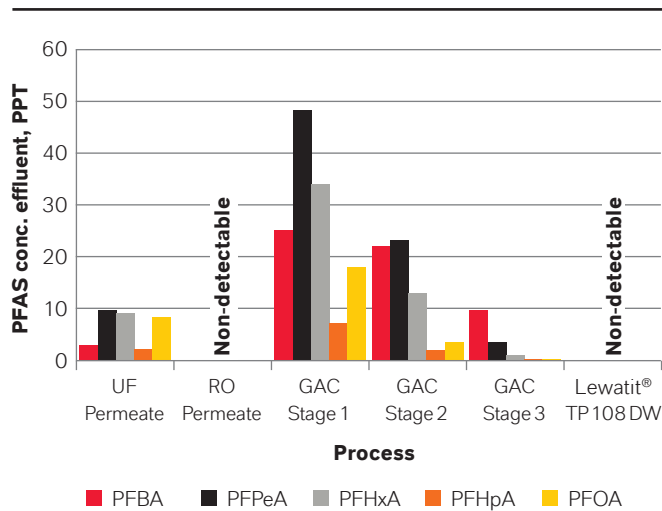
The following table lists the comparison among three popular treatment methods (IER, RO, and GAC).

Items for comparison	Ion exchange resin (IER)	Reverse osmosis (RO)	Granulated activated carbon (GAC)
Selectivity to PFAS	High	Low	Low
Loading capacity	High	N/A	Low
Operating cost	Low	High	Low
Efficacy on short-chain PFAS	High	High	Low
Absorption kinetics	High	N/A	Low
Empty bed contact time (EBCT), min	1–3	N/A	10–30
Media cost	High	High	Low
Compatible with strong oxidizers	Less compatible	Less compatible	Compatible
Footprint	Small	Small	Large
Regeneration	High selective gel resins: not recommended for regeneration	Results in large waste stream	Can be reactivated at high temperature
Destruction of PFAS	Primarily by incineration. New technologies under development to treat regenerants from Lewatit® MP 62 WS	Difficult to treat the large RO reject waste stream	Incineration or reactivation

GAC is a widely used method for removing organic contaminants (e.g. PFAS). It is a proven technology and works in special conditions (e.g. high oxidizer, high TDS), but has major drawbacks including low selectivity, low loading capacity, and slower absorption kinetics. RO can be used to treat PFAS water, but the reject is not concentrated enough to destroy PFAS economically. Therefore another PFAS concentration step and final treatment is required. It has a

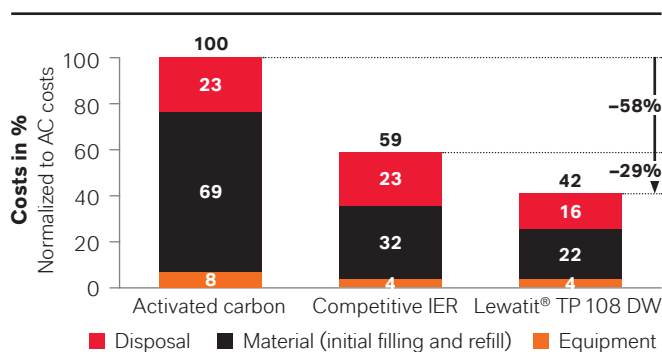
major disadvantage of resulting in a large volume of concentrated PFAS waste stream to be further treated. In terms of the PFAS removal efficiency, both IER and RO provide much better performance than GAC and UF, as shown by the following data (Figure 1). Based on overall consideration, IER is a better choice for treating PFAS than the other two alternative methods.

## Comparison of PFAS concentrations among treatment processes after 90 days operation



**Figure 1:** Comparison of the PFAS removal efficiency showing the PFAS effluent concentrations among IER, RO, UF, and GAC

The excellent performance of PFAS selective ion exchange resin **Lewatit® TP 108 DW** leads to a substantial benefit when it comes to a cost comparison of different PFAS treatment technologies. Due to the lower selectivity towards PFAS, GAC breaks through about five times earlier than **Lewatit®** ion exchange resins. As a result, customers need to replace the **Lewatit®** ion exchange resin less frequently and achieve savings in investment costs. The much shorter EBCT of IER enables a smaller footprint while treating a larger volume of waste stream. A cost calculation for a plant with five years' operation to remove PFHpA (Figure 2), indicates **Lewatit® TP 108 DW** costs 58% less than GAC, and 29% less than a competitive resin.



**Figure 2:** Cost calculation using Lewatit® TP 108 DW, a competitor ion exchange resin (IER), and activated carbon

## Key chemical and physical properties

Parameters	Lewatit® TP 108 DW	Lewatit® MP 62 WS
Delivery form	Cl-	Free base
Functional group	Quaternary ammonium	Tertiary amine
Appearance	White, opaque	Beige, opaque
Uniformity coefficient	<1.7	<1.7
Effective size	0.46–0.61 mm	0.5–0.6 mm
Fines (<0.315 mm)	<1%	> 90 vol%, 0.4–1.25 mm
Total capacity (in delivery form)	min. 0.7 eq./liter	min. 1.7 eq./liter
Bulk density	655.5–724.5 g/liter	589–651 g/liter
Water retention (in delivery form)	33–43 wt.%	50–55 wt.%
Stability pH range	0–14	0–14
Stability temperature range	1–80°C	1–130°C
Storage temperature range	–20–40°C	–20–40°C

## Filter arrangement

Depending on the influent PFAS concentration, **Lewatit® TP 108 DW** can be used in a lead-lag configuration, used after GAC to remove the PFAS, as a polisher resin after a GAC and another resin pretreatment step to remove the bulk load of PFAS. The three arrangements are schematically listed below.

When the influent concentration of PFAS is low-medium levels (ppt to low ppb) and natural organic matter (NOM) is low, two **Lewatit® TP 108 DW** filters can be arranged in a lead-lag configuration (Figure 3a). The primary lead filter acts as the working filter removing the larger portion of PFAS, and the lag filter brings additional operating assurance for meeting the discharge compliance. The primary filter can be over-run. After exhaustion, the lag polisher will be switched as the primary lead, and the primary filter will become the lag polisher after being taken out of service and exchanged with new resins. This configuration allows full resin utilization.

If the influent water contains excessive NOM or chlorine, GAC can be placed in front of **Lewatit® TP 108 DW** to capture these species before it fouls and damages **Lewatit® TP 108 DW** (Figure 3b).

If the influent water contains excessive NOM, chlorine, and PFAS (ppb and ppm levels), GAC can be placed upfront, followed by the regenerable macroporous ion exchange resin **Lewatit® MP 62 WS**, then the selective **Lewatit® TP 108 DW** (Figure 3c). This will ensure long operational resin life and low PFAS in effluent discharge.

## Design and operational guidelines

### Feed water analysis is crucial

A detailed feed water analysis with concentration and type of each PFAS as well as other water constituents such as total suspended solid (TSS), anions (sulfate, nitrate, perchlorate), and NOM is required. It will provide valuable information on predicting resin's operating capacity and establishing the right operational parameters.

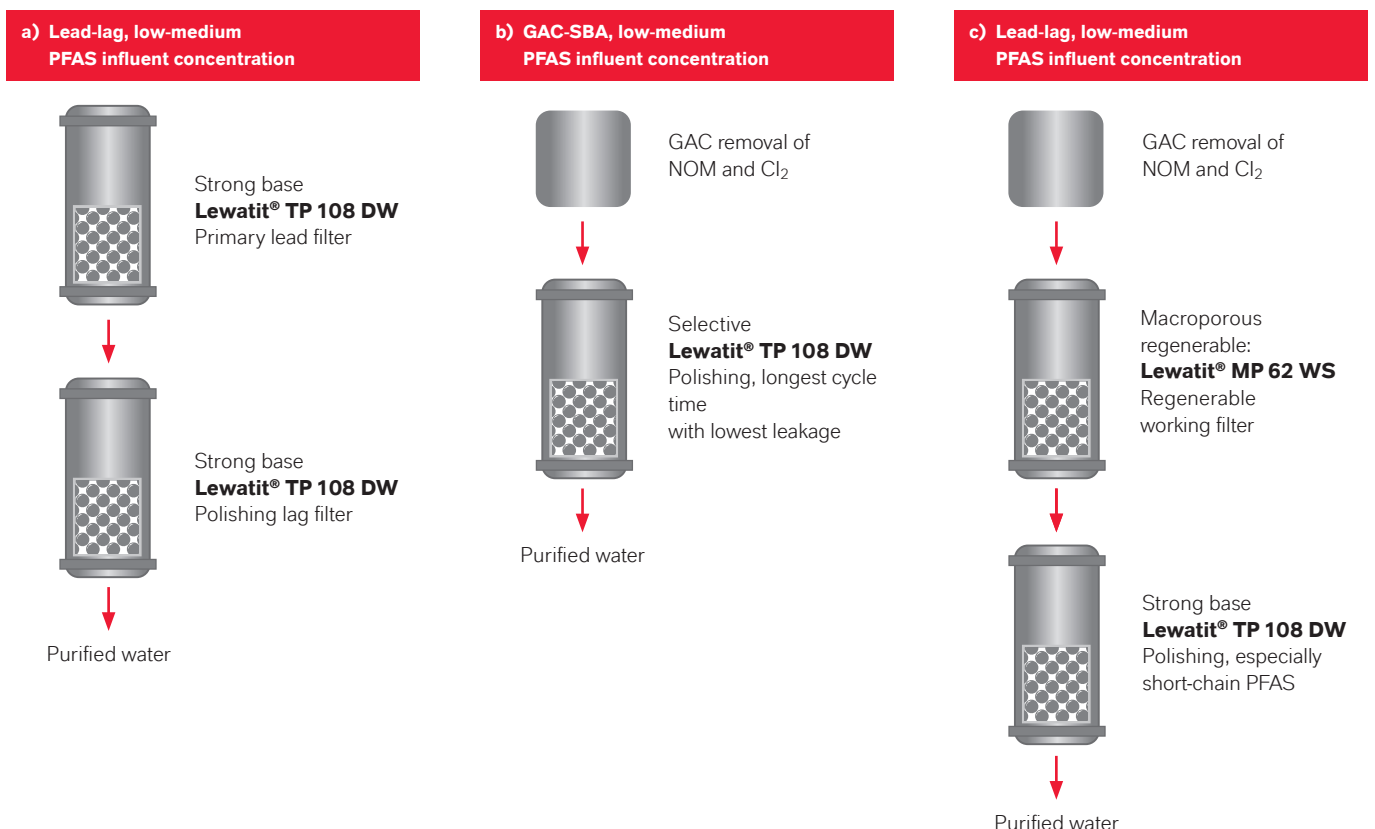


Figure 3: Three typical filter arrangements for Lewatit® TP 108 DW

### Effective pre-treatment to protect the resins (solids, scaling and fouling)

Ion exchange resins act as a mechanical filter in which solid particles can get caught in the void space of the beads. High TSS in feed water will increase differential pressure, and can cause filter blockage, channeling, and bead breakage.

Prefiltration with 5 micron bag or cartridge filters to reduce TSS to <1 ppm is strongly recommended. The required threshold TSS value depends on the expected throughput and cycle time. A typical filter (e.g. ion exchange filter) has a solids removal capacity of 0.8 kg/m<sup>3</sup>. A throughput of 1,000 BV would require 0.8 ppm TSS, and 100,000 BV would require 0.008 ppm TSS.

### Bed depth

We recommend a minimal bed depth of 2.6 feet (0.8 m) to ensure a homogenous flow of the water through the resin bed.

### Ideal specific flow rate at 20 BV/h

20 BV/h is an ideal flow rate that ensures most compact resin bed design with maximum PFAS removal efficiency at low leakage and high operating capacity. It corresponds to 3 min EBCT.

### Backwash

Backwash for **Lewatit® TP 108 DW** is not recommended, because this resin is used once through and it would destroy the polishing zone. However, a backwash is normally needed at start-up to homogenize the resin bed or it is included in the regeneration cycle of **Lewatit® MP 62 WS**.

Backwash is most efficient at a bed expansion of 70–80%. **Lewatit® TP 108 DW** has a bed expansion of 15% per m/h. A bed expansion of 80% would therefore require a linear flow rate of 5.3 m/h (2.16 gpm/square feet). At 1 m (3.28 feet) bed depth, this corresponds to 5.3 BV/h. As a reminder, a 5 micron bag or cartridge filter is recommended to pretreat the TSS to prevent large increase of pressure drop during operation, so that a backwash during operation is not needed.

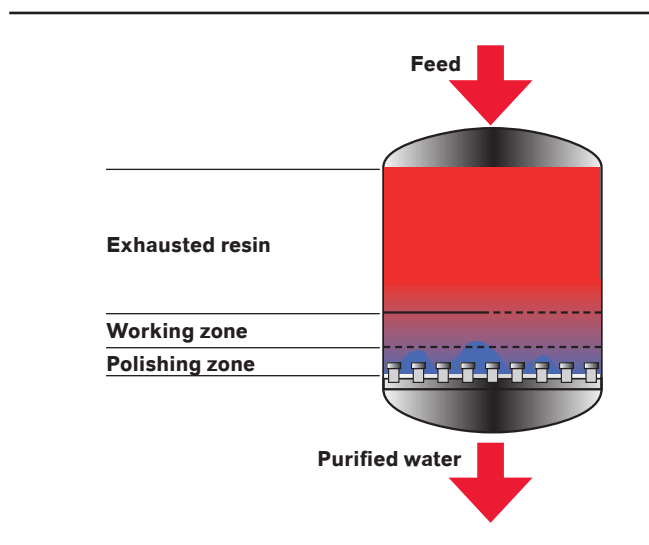


Figure 4: Schematic representation of the polishing zone

### pH control

For drinking water applications pH is usually in the neutral range. For other applications, we recommend a pH range of 3–10. If pH is too low, the carboxylate groups of PFAS may be protonated. For acidic waters with pH <3, we recommend the weak base anion product **Lewatit® MP 62 WS**.

### Differential pressure < 21.75 psi (150 kPa) to prevent mechanical stress on resin bed

We recommend a maximum pressure drop of 36.25 psi (250 kPa) to prevent mechanical stress and damage on the resin beds. Since pressure drop keeps increasing due to solids buildup, we recommend starting a cycle with fresh resin at a pressure drop <11.6 psi (80 kPa) especially for long cycles (>100,000 BV). Again, a 5 micron filter is strongly recommended prior to the resin bed to prevent a premature large pressure drop.

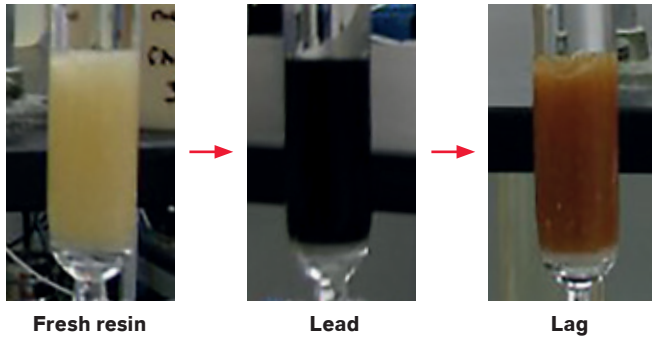
### Free chlorine < 0.05 ppm

Presence of a significant amount of chlorine (>0.05 ppm) for a prolonged contact time will cause irreversible chemical damage to resins. The major mechanism is de-crosslinking of the resin structure. Other oxidants (e.g. ozone, permanganate and hydrogen peroxide) will have a similar negative effect.

### Limit organic contamination

Dissolved organic concentration is preferably kept (DOC) <1 ppm. Oil and grease are not tolerable. Otherwise, effective pre-treatment is required to prevent resin fouling.

An example of resin fouling is shown in the picture below:



**Figure 5:** Ion exchange resin color change after PFAS removal indicating the resin fouling. The resin color changed from light yellow (fresh resin) to dark brown (lead column) and brown (lag column), which was caused by excessive NOM in feed water.

### Heavy metals (iron, manganese, etc.) < 0.05 ppm

Heavy metals can catalyze oxidative degradation of ion exchange resins, leading to the loss of exchange sites and decrosslinking of the resin. As a result operating capacities are decreased and resin breakage can be observed. Therefore we recommend removing those heavy metals before reaching the resins.

### Keep operating temperature <176°F (80°C)

SBA resins are generally quite stable, but high temperature (>176°F or 80°C) may lead to irreversible damage of resin adsorption capabilities and can lead to poor performance. Resin will have stable operation when the temperature is less than 176°F or 80°C).

### Startup procedure

Ideally, **Lewatit® TP 108 DW** is recommended for single-bed ion exchange application for potable water. A single-bed ion exchange application is one that uses only one resin type and is not subjected to insituregeneration after exhaustion. In addition, these instructions are for resin used on potable applications including those with a designated NSF 61 certification for the intended application. Specific information regarding a **Lewatit® NSF 61** certified resin may be found on the WQA Gold Seal “Find Products” database located at <https://www.wqa.org/find-products#/>

### Instructions prior to resin loading:

- For new construction, inspect the vessel to be loaded as well as all influent and effluent piping, headers, and

outlet strainers to ensure they were properly installed and that there are no damaged or plugged strainers. Insure all construction debris has been removed from the vessel and piping.

- For existing installation and re-beds, check vessel interior and lining, headers and underdrains, as well as manway gaskets. Replace and/or repair as needed.
- In potable applications for new construction or installations that have been out of service for an extended period follow all American Water Works Association (AWWA) procedures for the proper disinfection of all pipelines and vessels.

### Loading resins into the vessel:

- For a potable water application, make sure potable water is available or use untreated raw water with discharge of any water prior to treatment by the resins to discharge points outside the potable system.
- Fill the vessel with water to one-quarter to one-third of the final resin bed height.
- Load the ion exchange resin by emptying the shipping or intermediate container so the resin falls into the water. All safety practices should be followed to avoid injury of personnel.
- Alternatively, ion exchange resin may be loaded using a water educator system; in this case load the vessel with water only to the height of the underdrain and watch the water volume while loading. Stop the loading process and drain down to the bed top as needed.
- After the specified volume of resin has been loaded close the vessel and drain the resin bed to waste.
- If the vessel is equipped with backwash capabilities slowly introduce backwash water and backwash to approximately 50% expansion for 10 minutes to classify the bed. A proper resin trap should be used to avoid resin loss.
- Begin forward flow.
- Place in service per the design OEM manual monitoring for performance and exhaustion.

### Conditions for using once-through resin

- Low PFAS influent (<1,000 ppt total PFAS)
- Low TDS, low anions, low DOC
- Minimum bacterial contamination/growth opportunities
- Practical conditions allows easy handling of solid PFAS wastes

# TROUBLE-SHOOTING OF OPERATING PROBLEMS

## Continuous high leakage of the resin bed

It can be caused by uneven flow through the ion exchange resin bed. If part of the water stream is not in contact with the ion exchange resin beads, PFAS removal cannot take place.

### Causes for the uneven flow:

- Partial nozzle plate plugging: replace plugged nozzles
- Uneven head distributor: readjust head distributor
- Uneven resin distribution: backwash
- Infiltrated particles leading to disturbance in the filter: improve prefiltration to avoid particle infiltration

## Early breakthrough with reduced cycle time

### Causes for early breakthrough:

- Physical loss of the resin. If the amount of resin is decreasing over the cycle, the cycle time will also decrease. Check resin level and replace broken nozzles
- Oxidation of functional groups and resin matrix: reduce the amount of strong oxidants, e.g. free chlorine
- Fouling of the resin: reduce organics, e.g. NOM, oils, and grease

## Increased pressure drop

### Causes of high pressure drop:

- Broken resin beads plug the voids: avoid bead breaking by controlling the differential pressure of bed
- Suspended particles plug filter bed: improve prefiltration
- Strainers plugged: apply air scour, renew strainers

## Resin fouling by NOM or biofilm

Resin fouling by organic matters and biofilms cause blockage of the ion exchange sites. As a result a reduced water quality with leakage of PFAS and bacteria growth are observed. Additionally the operating capacity of the resin is suffered, because PFAS can access the exchange sites only partially.

**Resin cleaning:** The best solution is prevention. Remove organic matter and bacteria before they reach the resin. This will involve using pre-filters and activated carbon bed before the ion exchange resin vessel. If the incoming organic matter still get through and eventually fouls the resin, following the following cleaning procedures:

### Regeneration of Lewatit® MP 62 WS:

- Backwash with procedure mentioned above in 2.
- Regenerate the resin with 4% NaOH, 3–4 BV, 4 BV/h
- Wash with 5 BV demineralized water

### Special cleaning of Lewatit® MP 62 WS with alkaline brine

If **Lewatit® MP 62 WS** is fouled with organics and the capacity within the operational cycle has significantly dropped, the following cleaning procedure can be applied:

- Prepare 10% NaCl solution (approx. 100 g/l NaCl) + 2% NaOH (approx. 20 g/l NaOH)
- Heat up to 104°F (45°C), if necessary
- Injection of approx. 2 BV of cleaning solution, air scour if necessary
- Let it soak for at least 3 hours, then drain the resin bed
- Rinse with demineralized water until p-alkalinity is less than 1 meq/l.

### For severe bacterial contamination, resins can be treated with sodium hypochlorite

The sodium hypochlorite can be used for the resin. Its action is very effective but has to be applied with care as it can be detrimental to the performance of the resin (crosslinking damage and functional groups destruction). The following procedure can be used:

- Thorough air scour and backwash the resin.
- In case of iron or other metal contamination, the resin should be pre-treated with approximately two bed volumes of 10% HCl solution.
- Before applying the sodium hypochlorite, the resin must be in a fully exhausted form by treating it with a 2–5% solution of sodium chloride.
- The sodium hypochlorite solution must be at a concentration of 0.10% (1,000 ppm).
- Apply 5 g free  $\text{Cl}_2$  per liter resin by passing five bed volumes of the NaOCl solution at ambient temperature down through the resin bed with a 30–45 minute contact time. Allow the resin to soak in the solution for 1–2 hours.
- Rinse out with 1–2 bed volumes demineralized water.
- The  $\text{Cl}_2$  concentration at the outlet of the filter must be at least 1 ppm. If this is not the case, repeat the treatment.
- Finally, rinse with 3–4 bed volumes demineralized water (until no  $\text{Cl}_2$  is detectable in the effluent).

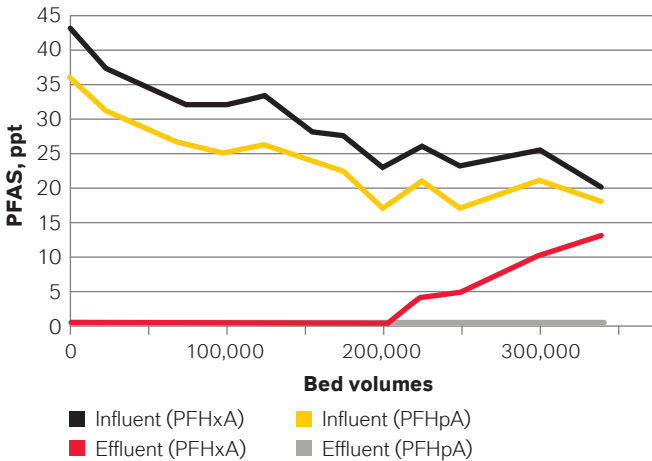


# FIELD TRIALS

## Field trial 1

Lewatit® TP 108 DW was tested for removing PFHxA and PFHpA from a water source containing about 20–40 ppt PFAS species. As shown in Figure 6, Lewatit® TP 108 DW demonstrated exceptional performance with 200,000 bed volumes for PFHxA, and breakthrough has not been reached even at 340,000 bed volumes for PFHpA. The long cycle time is critical for a single-use PFAS removal resin, whether used as the primary removal technology or as a polishing resin. In this trial it was expected that PFHxA reached a breakthrough earlier than PFHpA due to its shorter chain length.

a) PFHxA and PFHpA removal by Lewatit® TP 108 DW



b) Comparison between Lewatit® TP 108 DW with a conventional tributyl resin in removing PFHxA

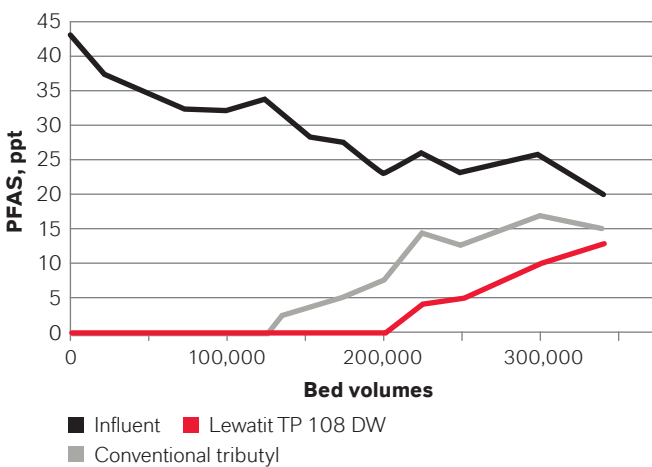


Figure 6: (a). PFHxA and PFHpA breakthrough curves by Lewatit® TP 108 DW. (b). Comparison between Lewatit® TP 108 DW and a conventional tributylamine SBA resin in PFHxA removal

## Field trial 2

In field trial 2, Lewatit® TP 108 DW demonstrated a better performance compared to a conventional tributyl resin at the same operational conditions. It is remarkable that PFOA still did not break through for Lewatit® TP 108 DW while the conventional resin already showed high PFOA leakage at only 80,000 bed volumes.

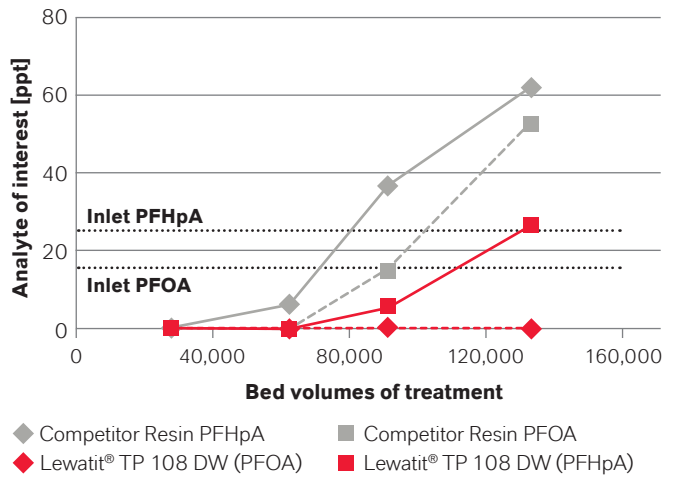


Figure 7: PFHpA (solid line) and PFOA (dashed line) breakthrough curves of a modified highly selective PFAS resin (red) and conventional competitor (gray) resin in field trial 2

# CASE STUDY

## Efficient PFAS removal at fire department training grounds at Australian airports

High concentration of PFAS (up to 200 ppb) were detected in impounded waste water in a fire and emergency services training facility in regional Victoria, Australia. For many years, training was conducted at this particular site using aqueous fire-fighting foam (AFFF) containing PFAS, and these persistent chemicals eventually severely impacted groundwater.

The initial design criteria for the PFAS water treatment plant was to meet the following Australian Drinking Water Guidelines specification/limits:

- PFOS and PFHxS combined total less than 0.07 ppb
- PFOA less than 0.56 ppb

However, during the project, the short-chain PFCs were also a part specification for the treated water with effluent criteria being the lowest possible limit of detection. The key design and operating parameters are:

- Polyamide resin columns with the newly developed resin were operated in a lead-lag-polisher configuration. Average feed flow rate was 20 m<sup>3</sup>/h
- Operating specific flow rate was 10–20 BV/h
- Feed pH was maintained between 5.0 and 7.0

Figure 8 shows the flow diagram for the PFAS treatment. The waste stream was treated by GAC for NOM, then went through a primary treatment by ion exchange resin **Lewatit® MP 62 WS** (a macroporous weak base anion), and a polishing treatment by **Lewatit® TP 108 DW** resin before being discharged or reused.

Figure 9 illustrates the effluent concentrations of some common PFAS compounds (PFBA, PFHxA, PFHpA, PFOA, PFHxS, and PFOS) after different treatment stages.

The data in Figure 9 demonstrates that GAC only had limited PFAS removal, while the macroporous resin **Lewatit® MP 62 WS** was able to reduce PFHpA, PFOA, PFHxS, and PFOS from ppb levels to ppt levels. **Lewatit® MP 62 WS** could also remove the shorter-chain compounds PFBA and PFHxA, but the breakthrough occurred early. It should be noted that the **Lewatit® MP 62 WS** was not operated under ideal conditions, otherwise it would work even better. **Lewatit® TP 108 DW**, however, removed all PFAS compounds from ppb levels down to non-detectable level. The data also shows that the selective **Lewatit® TP 108 DW** resin produced a stable effluent despite significant PFAS fluctuations in the feed.

This case study exhibits the effective removal of high levels of PFAS by a combination of different treatments. It clearly exemplifies the effectiveness of **Lewatit® TP 108 DW** in treating different types of PFAS with shorter chains or long chains, even at ppb levels of incoming concentration. After running continuously for 12 months and treating nearly 14 million gallons of water, this project site was decommissioned. It is deemed one of the most successful PFAS water treatment plants in Australia.

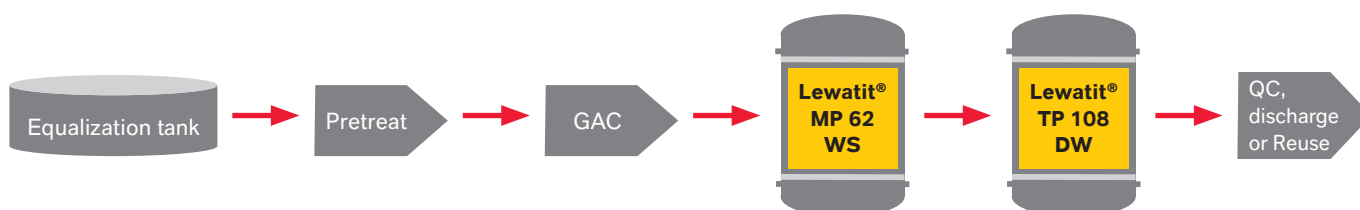
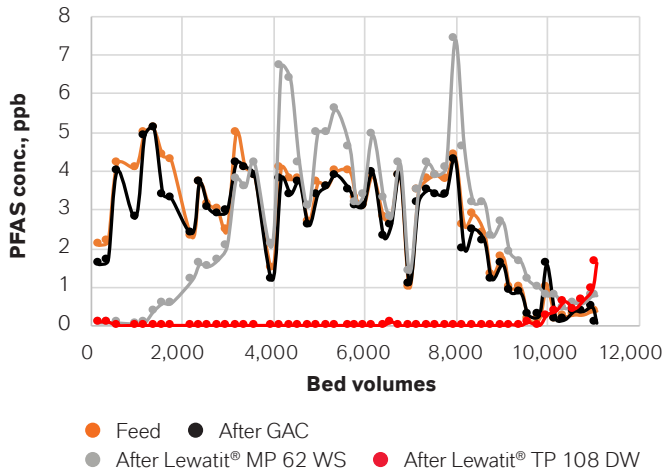
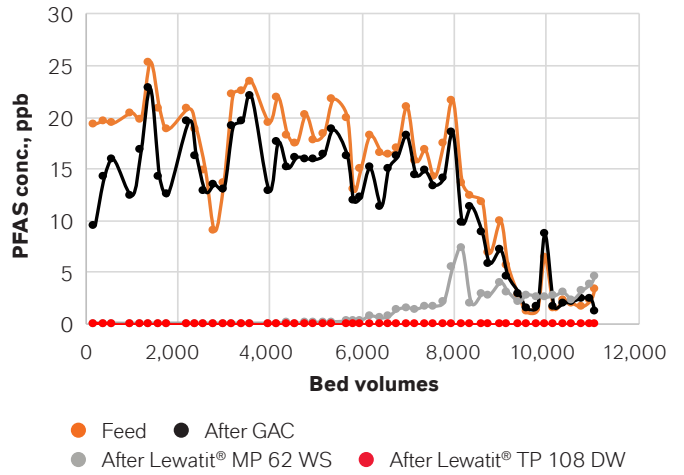


Figure 8: Flow diagram for PFAS treatment at an Australian fire/emergency services training facility

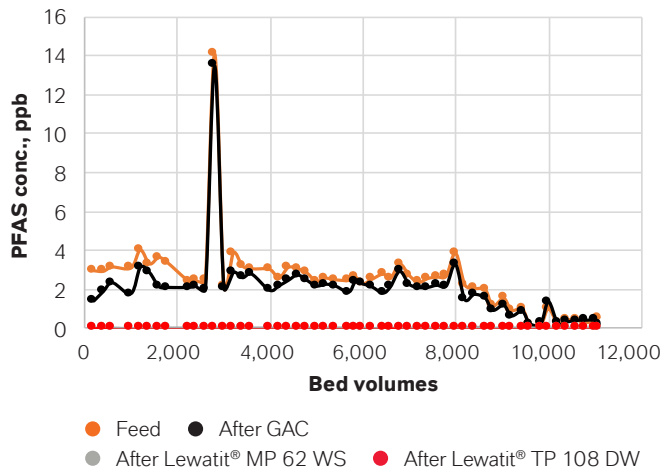
**a) PFBA removal**



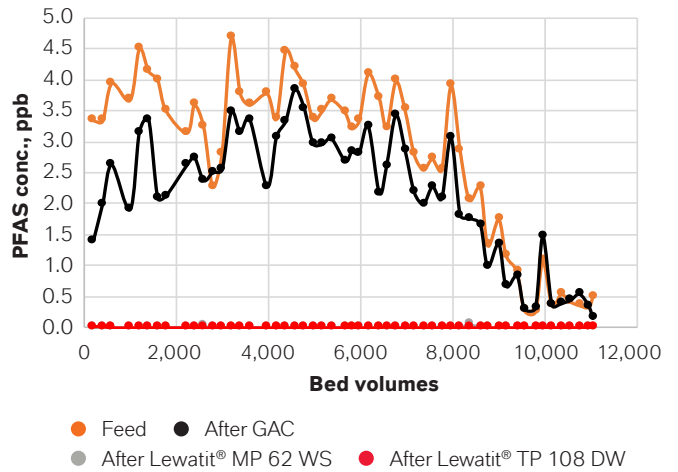
**b) PFHxA removal**



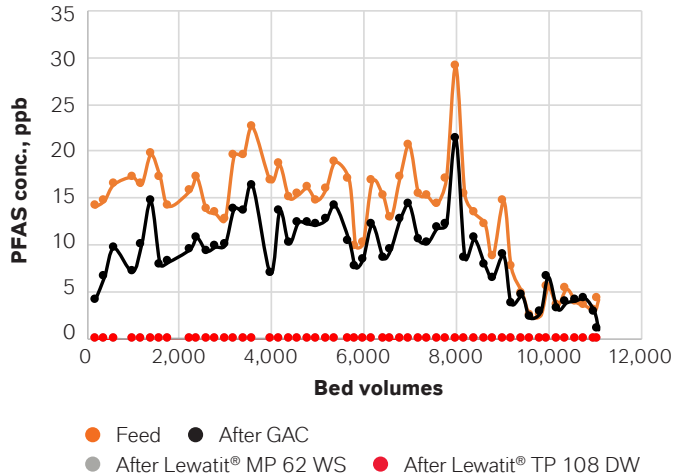
**c) PFHpA removal**



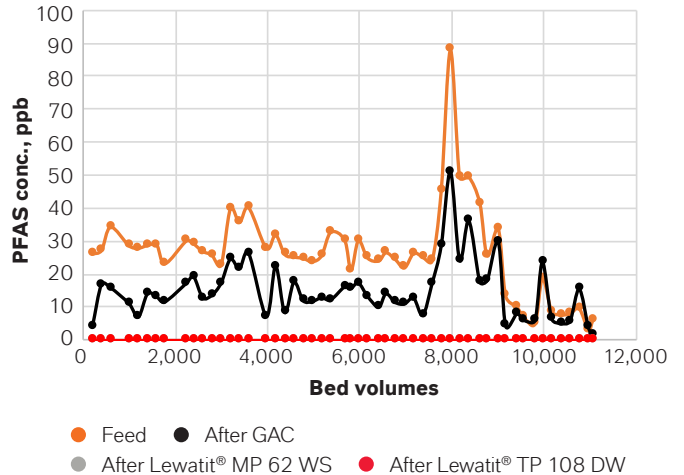
**d) PFOA removal**



**e) PFHxS removal**



**f) PFOS removal**



**Figure 9:** PFAS removal at different treatment stages at an Australian AFFF remediation facility.  
a) PFBA · b) PFHxA · c) PFHpA · d) PFOA · e) PFHxS · f) PFOS concentrations in the effluent.



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