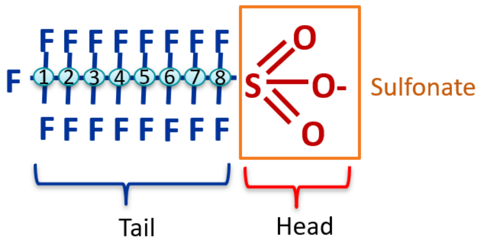
PFAS Cleanup Approaches – GAC vs Anion Exchange Resin

March 2019

Which PFAS Treatment Technologies Are Frequently Chosen to Mitigate PFAS Exposure in Drinking Water?

Unlike organic hydrocarbons, the carbon-fluorine bond (C-F) of per- and polyfluoroalkyl substances (PFAS) is the shortest and strongest bond in chemistry. Some PFAS are stable, persistent, bioaccumulative, and not biodegradable. These properties result in their high occurrence in the environment. PFAS cannot be completely removed or destroyed by many conventional treatment technologies. Their hydrophobic C-F "tail" and hydrophilic "head" make technologies such as granular activated carbon (GAC) and anion exchange resin (AIX) effective for PFAS removal. Membrane technologies have also been effectively used to treat PFAS in drinking water. These PFAS separation technologies do not convert precursors into more toxic subgroup of PFAS (i.e., perfluoroalkyl acids, PFAA) like some other chemical or biological processes, but they generate spent media or rejected concentrates requiring further waste management.



Granular Activated Carbon is the most common treatment method and its application for PFOA and PFOS removal has been practiced for more than 15 years. With sufficient GAC capacity and adsorption rates, an acceptable operating time between carbon changeouts can be achieved. One of the major advantages of GAC is practitioners' familiarity of spent GAC management, as spent activated carbon is either thermally destroyed or reactivated. Backwashing is limited to washing the fines off the GAC during the first GAC fill and at every re-fill event.

A potential disadvantage of GAC is its lower removal effectiveness for shorter carbon chain PFAS. The fate of regulations for short-chain PFAS is uncertain, therefore, bench-scale testing for both long-chain and short-chain PFAS is valuable for the long-term reliability of a GAC treatment process. Another disadvantage is that the performance of GAC treatment of PFAS can be reduced due to competitive adsorption with other compounds.

Anion Exchange involves the use of synthetic resins to remove negatively charged contaminant ions through the exchange sites of the resin beads. Factors that influence AIX performance include influent contaminant concentration, treatment design (e.g., flow rate, resin bead size and material), and competing ion concentrations, such as sulfate, nitrate, and bicarbonate. Although used less extensively than GAC, AIX has been effective at removing long-chain PFAS. The research shows increased potential for short-chain PFAS removal (removal of PFBA is still not promising), and bench-scale testing is recommended to confirm performance on a given water source. AIX also faces the same disadvantage of competitive adsorption with other anionic compounds. AIX typically requires a resin regeneration step and corresponding management of brine waste, but in PFAS application, single-use selective resins have been widely used.

Membrane technologies, specifically reverse osmosis (RO) and nanofiltration (NF) have been studied for PFAS removal application. Low pressure RO (LPRO) has demonstrated significant removal of all the PFAS, including the short-chain compounds. Despite LPRO's effectiveness, it is typically the costliest method for removal, due to high capital cost and energy demand. Data on NF performance are more limited, but positive bench-scale test results have been reported for removal of PFAS with a range of molecular weights. Importantly, both LPRO and NF generate a waste stream containing high concentrations of reject contaminants, and the management and treatment of the waste stream must be addressed in design and managed for the life of the installed system. Also, LPRO and NF are susceptible to fouling, thus an anti-scaling chemical and/or a pre-treatment step may be required to reduce fouling.

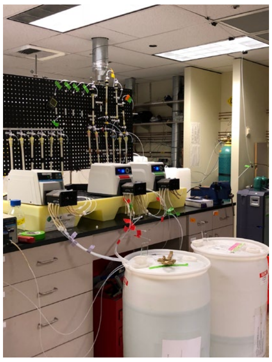
For all three technologies, bench-scale and/or pilot-scale testing is critical to confirm the viability of the solution for the site-specific water matrix, as well as for developing system design and cost performance parameters. Bench- and pilot-scale testing will be aid in identifying the most effective treatment approach and will yield insight into estimated breakthrough and anticipated changeout frequency. The importance of the testing cannot be overstated as the information gained from the bench-scale testing can be directly related to long-term operating cost savings.

Selecting GAC vs AIX

Table below provides technical facts about selecting between GAC and AIX for PFAS treatment.

GAC	AIX
~10 minute EBCT	**~3 minute EBCT**
Larger & taller infrastructure footprint	Smaller & shorter infrastructure footprint
Typical bed life: 50-120,000 bed volumes	Typical bed life: 250-300,000 bed volumes (last longer)
GAC media unit cost is lower	AIX media unit cost is higher
Less effective for short chain PFAS	Effective for a wider range of PFAS
Well established technology	Not as extensively practiced as GAC
Initial backwash is required	Backwash recommended with some resins
Spent GAC is reactivated	Spent AIX is incinerated
Remove other organic pollutants	Remove other anionic compounds
Little to no corrosion control impact	Likely impact on chloride-to-sulfate ratio for corrosion control
Coconut shell based and coal based GAC can both effective	Not all AIX products achieve effective PFAS removal

Note: Pretreatment may be needed for both technologies to increase media life span



Conducting a bench-scale test when screening different pre-treatment and treatment options is advisable. Pilot scale study should be conducted to confirm full-scale design parameters.

CDM Smith's Bellevue laboratory has extensive PFAS treatability testing experience. It recently completed a bench scale column test to evaluate PFAS removal from groundwater. This column study compared the PFAS treatment effectiveness between GAC vs AIX (Figure 1). The study confirmed that in this water, AIX is more effective than GAC in removing short chain PFAS. Poor PFAS removal was observed when AIX not designed for PFAS removal was used (Figure 2).

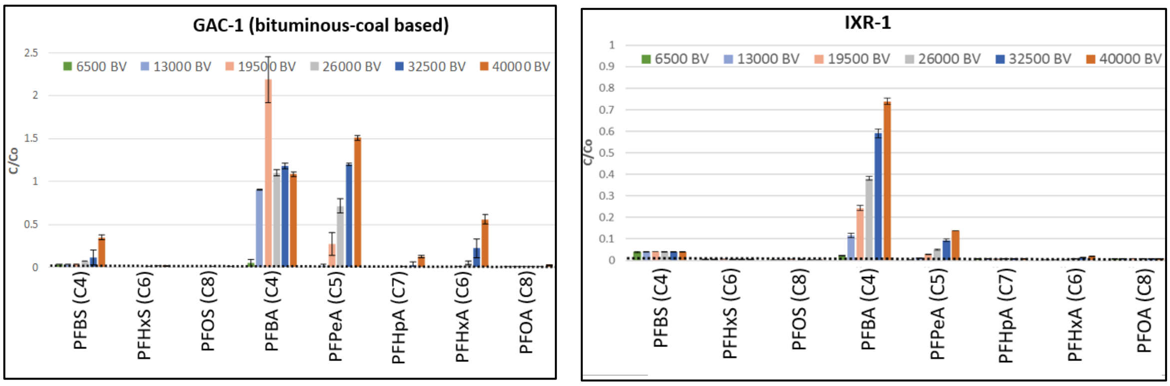


Figure 1. Bench-scale column study comparing GAC (GAC-1) and AIX (IXR-1) treatment performance using PFAS impacted groundwater.

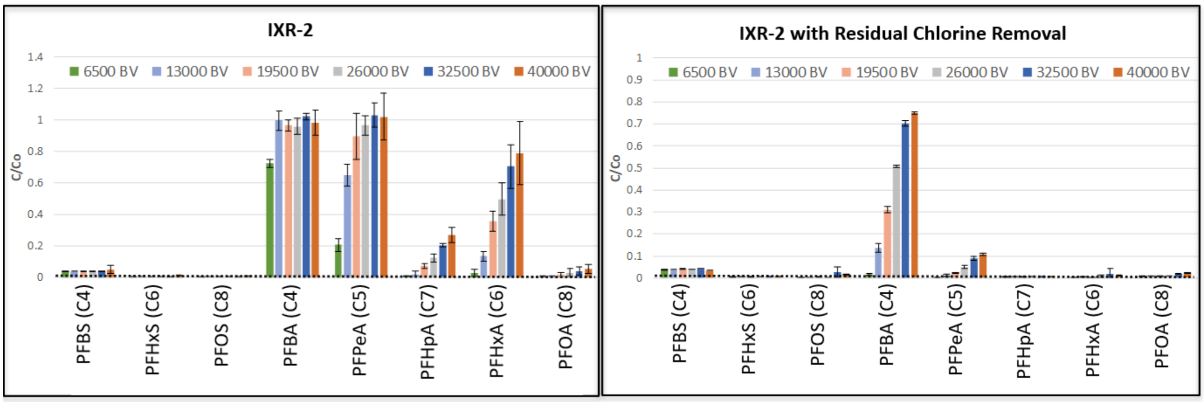


Figure 2. Poor PFAS removal when non-PFAS specific AIX (IXR-2) was used. IXR-2 performance improved when residual chlorine in the AIX influent was removed.

Additional Considerations for PFAS Treatment

Many factors need to be considered when selecting PFAS treatment technologies:

- Sense of scale is important. Treatment goals for PFAS are in low parts per trillion (ppt), and therefore, it is important to consider competitive co-contaminants that can be orders of magnitude higher in concentrations, such as organic compounds, and reduce PFAS treatment effectiveness.
- Inorganic parameters commonly found in groundwater, such as iron and manganese, can hinder pressure vessel performance.
- Many existing infrastructure factors, such as chemical usage, hydraulics, and electrical capacity, can play a significant role in selection of the ideal PFAS treatment technology at an existing facility.
- Residual handing and discharge options at an existing facility or on a greenfield site can be an important consideration. State and local waste management requirements and disposal permits must be investigated.
- Whether it is installation of a new system or upgrading an existing system for PFAS removal, operation of other treatment processes should be evaluated individually and in combination to verify if those processes would reduce PFAS removal effectiveness.
- Performance of different commercial products.

Life Cycle Cost Estimation Considerations

Both the capital cost and operating cost can play an important factor evaluating the three treatment technologies, as they can vary significantly. Each technology requires unique considerations for the items that make up the most significant proportions of life cycle costs, such as equipment cost, pumping requirements, and chemical needs. On capital costs, although the AIX resin is more expensive than GAC, because it requires a smaller footprint, the capital costs can be comparable depending on site-specific design parameters.

AIX systems have higher capacities to remove PFAS, which may lead to less frequent changeouts than GAC and lower operating costs. However, source water testing is critical for estimating operating costs as they vary significantly depending on the number of bed volumes until breakthrough and the associated changeout frequency. A much higher number of bed volumes need to be treated by AIX to be cost-competitive with GAC.

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