

The Cost to Remove PFAS: A Review of US Water Treatment Plants

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Key Takeways

For US water utilities, having treatment systems for removing per- and polyfluoroalkyl substances (PFAS) is a given, although determining the best approach is not as clear.

Several US groundwater PFAS treatment systems were studied to form an overview of capital and operational costs, showing the influence of plant capacity, location, and specific project requirements.

Among other findings were the importance of considering background water chemistry and emerging PFAS compounds, communicating often and honestly with all stakeholders, and collaborating on treatment projects.

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With the introduction in the United States of new maximum contaminant levels for per- and polyfluoroalkyl substances (PFAS), water treatment plants are pressured to comply with the updated regulations. Utilities must navigate significant challenges in determining the most effective and cost-efficient methods for PFAS removal, whether by upgrading existing infrastructure or constructing new facilities. As PFAS treatment systems are relatively recent developments, guidance is limited on the nuances of building and operating them. This article reviews several PFAS treatment projects in the United States, focusing on their capital and operational costs, lessons learned, pilot-testing considerations, and collaborative approaches.

Groundwater PFAS Treatment Systems

The groundwater PFAS treatment systems included in this review are described in the following sections.

N Wells Treatment Facility

Located in Santa Clarita, Calif., the N Wells Treatment Facility (Photo 1) is owned by the Santa Clarita Valley Water Agency and started operation in December 2020. The facility includes six ion exchange (IX) vessels, pumping facilities, and other ancillary equipment. The IX

system uses a mixture of Evoqua Purolite PSR2+ and PFA694E resins to remove PFAS and provide 9 mgd of treated water. The spent media is incinerated.

Perfluorooctanoic acid (PFOA) is the primary substance driving replacement of IX resin, which in the raw water from these wells ranges from 15 to 20 ng/L. However, all finished water from the facility tests as non-detect for all PFAS analyzed.

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The facility uses three treatment trains (A, B, and C) in lead-lag configuration and has experienced varying media lifespans:

- Train A: First round lasted two years and two months; ongoing in the second round.
- Train B: First round lasted one year; second round lasted one year; third round lasted one year and three months.
- Train C: First round lasted one year and five months; second round lasted one year; third round lasted one year.

Valley Center Well Water Treatment Facility

The Valley Center Well Water Treatment Facility, located in Santa Clarita, Calif., and owned by the Santa Clarita Valley Water Agency, started operation in October 2022. The facility includes an IX system (PSR2+ resin), pumping facilities, a disinfection system, and other ancillary equipment. The facility produces 1.7 mgd after PFAS is removed from the groundwater. The spent media is incinerated.

The primary PFAS driving resin replacement was PFOA, which appears at concentrations around 25 ng/L in the raw water from these wells. However, finished water from



Santa Clarita Water N Wells Treatment Facility (ion exchange vessels). Photo credit: Santa Clarita Valley Water Agency

Photo 1

the treatment facility tests as non-detect for all analyzed PFAS chemicals. The resin lifespan was one year and five months, so to improve performance, a 12-month pilot test exploring five different media was conducted at the facility.

J. Wayne Miller, PhD Water Treatment Plant

The J. Wayne Miller, PhD Water Treatment Plant (Photo 2; formerly the Yorba Linda PFAS Water Treatment Plant [WTP]) is operated by the Orange County and Yorba Linda Water Districts. The facility is located in Placentia, Calif., and began operations in December 2021. It is designed to produce up to 19 mgd, with a 25-mgd booster pumping station.

The plant uses IX for PFAS removal, where treatment consists of six 5- μ g cartridge filters, 22 IX vessels (11 pairs of lead-lag configuration), and a 1,000-kW natural gas backup generator to ensure continuous operation in case of power outages.

Stratmoor Hills Central WTP

The Stratmoor Hills Central WTP (Photo 3) in Colorado Springs, Colo., was developed in May 2022 in collaboration with the US Air Force and the Colorado Water Resources & Power Development Authority. It can produce 1 mgd of treated water and uses a combination of cartridge filtration, ultraviolet treatment, and IX (PSR2+ resin) to remove PFAS from the water supply. The spent media is incinerated, though changes in regulations may affect this disposal method in the future. The PFAS levels in the groundwater range between 34 and 68 ng/L for perfluorooctanesulfonic acid (PFOS) and between 11 and 20 ng/L for PFOA, but finished water from the WTP tests as nondetect for all analyzed PFAS chemicals.



J. Wayne Miller, PhD Water Treatment Plant (ion exchange). *Photo credit: Yorba Linda Water District*

Photo 2



Stratmoor Hills Central Water Treatment Plant (ion exchange). *Photo credit: Stratmoor Hills Water and Sanitation Districts*

Photo 3

Aga Park IX Treatment Facility

Located in Fountain, Colo., the Aga Park IX treatment facility (Photo 4) commenced operation in October 2022 and treats groundwater to produce 1,500 gpm (2.16 mgd) product water. For this project, the city



Aga Park ion exchange treatment facility. Photo credit: City of Fountain, Colo.

Photo 4



City of Stuart Water Treatment Plant (ion exchange). Photo credit: City of Stuart

Photo 5

collaborated with the US Army Corps of Engineers, which managed the design and construction of the plant on behalf of the US Air Force. The average PFOS level in the influent water was noted to be 33.1 ng/L, and the average PFOA level was 20.1 ng/L. A seven-month pilot

study of IX and granular activated carbon (GAC) technologies was used to select the optimal treatment method.

The plant process consists of blending from well water sources, 10- μ m pre-filtration, PFAS treatment through IX pressure vessels (PSR2+), post-chlorination, and discharge into the distribution system.

City of Stuart IX WTP

The IX WTP (Photo 5) in Stuart, Fla., started operation in July 2019 and draws raw groundwater from 24 shallow wells to produce 4 mgd of treated water. Initially, the facility used Calgon Carbon's CalRes 2304 IX resin but is looking to switch to Amberlite resin. The influent-water PFOS levels range from 46 to 2,100 ng/L, and PFOA ranges from 4.8 to 52 ng/L.

The water treatment system includes softening units and filtration through six single-media gravity filters. Spent media is incinerated, whereas media replacement is required about twice a year. A pilot study was conducted before the plant's construction, testing both GAC and IX technologies.

Whitcomb Avenue Treatment Plant

The Whitcomb Avenue Treatment Plant (Photo 6) in Littleton, Mass., which can produce 1.8 mgd of treated water, began operations in December 2023. The influent groundwater has high levels of iron and man-

ganese, which can clog PFAS filters. To manage this, the plant uses biological filtration to remove iron and manganese first, followed by GAC (Calgon Carbon Filtrasorb 400) to remove PFAS. The GAC media is replaced annually.

Bemidji WTP (Phases 1 and 2)

The Bemidji WTP in Bemidji, Minn. (Photo 7), which can produce 3.6 mgd of treated water, uses greensand filtration for iron and manganese removal, followed by GAC (Calgon Carbon Filtrasorb 400) to remove PFAS. The facility was built in two phases: phase 1 began operation in March 2021, while phase 2 began in August 2024. Phase 2 expanded the plant's capacity from 1,500 gpm (2.16 mgd) to 2,500 gpm (3.6 mgd) by adding four greensand filters and two additional GAC trains.

The spent carbon media is sent to an approved landfill, and two carbon change-outs have been completed so far on the phase 1 GAC trains. The first GAC media change-out occurred about two years after phase 1 startup in spring 2023, and the second change-out took place one year later in spring 2024.

Well 5A WTP PFOS Treatment System Upgrade

The PFOS treatment system for the Well 5A WTP (Photo 8) is owned by the Willingboro Municipal Utilities Authority in Willingboro, N.J. It can produce 2.0 mgd of treated water and was added to an existing radium treatment system. Raw water samples from 2020 to 2023 showed PFOS levels ranged from 1.3 ng/L to 110 ng/L, with multiple results below the detection limit. Similarly, the PFOA levels in the raw water ranged from 0.5 ng/L to 24 ng/L, with multiple results below the detection limit.

The PFOS treatment system uses GAC treatment with Calgon Carbon Filtrasorb 400 AR (acid rinsed) to remove PFOS and other PFAS contaminants. The project was completed in March 2024 and included four 12-foot GAC vessels, a new building with a heating/ventilation/air conditioning system, and a generator. Additionally, a 50- μ g self-cleaning filter was installed

upstream of the radium removal system to eliminate iron and suspended solids, and upgrades included redevelopment of the well and increasing the size of the well pump to overcome additional pressure losses in the new GAC vessels and process piping.



Photo 6

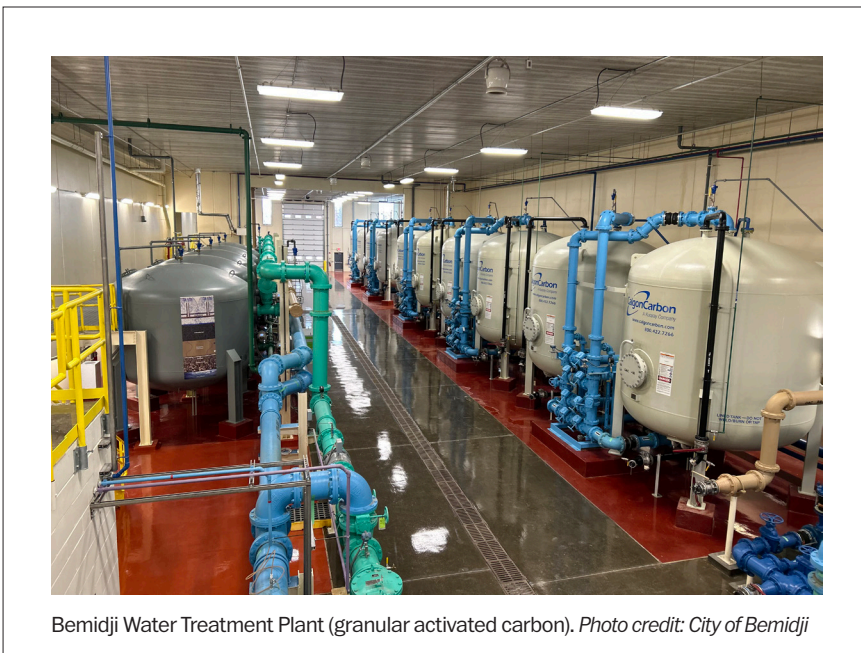


Photo 7



Willingboro Well 5A Water Treatment Plant (granular activated carbon). Photo courtesy of Willingboro Municipal Utilities Authority

Photo 8

Aga Park Wells 2 and 3 GAC Pods

Fountain’s Aga Park facilities for wells 2 and 3 use GAC systems to remove PFAS. The pilot for this facility lasted seven months and evaluated four types of GAC media, with Calgon Carbon Filtrasorb 400 ultimately selected.

The facilities were developed through collaboration with the US Air Force and commenced operation in 2018 to produce 1.44 mgd of treated water (0.72 mgd from each well). The well water enters directly into the GAC pressure vessels and is followed by chlorination before the water enters the distribution system. Vessels were operated in lead-lag configuration, and lead-vessel media change-outs were needed every six to eight months. The spent media was incinerated by Calgon Carbon. The facilities were decommissioned in 2021, as discussed subsequently.

Treatment Cost Analysis

Table 1 presents data on the PFAS projects as described, with capacities ranging from 1 to 19 mgd and with GAC and IX treatment included. The average capital costs of the infrastructure to treat drinking water for PFAS ranges from

\$0.75 to \$6.02/gallon for IX plants and from \$2.99 to \$8.89/gallon for GAC plants. Note that many of these treatment systems include project-specific considerations in their overall cost, such as additional chemical systems, permitting, new building requirements, and other essential items.

For IX PFAS treatment, the normalized capital cost (dollars per gallon) generally decreases as the plant capacity increases. Considering the location of the plants studied, those in Colorado had higher normalized capital costs, followed by California, with the lowest costs in Florida. Plants built from 2019 to 2021 had lower costs, and after-period costs increased significantly in 2022, likely as a result of inflation and other external drivers.

For the normalized capital cost (dollars per gallon) for GAC treatment, the plants from Massachusetts, Minnesota, New Jersey, and Colorado were of similar capacity. The treatment plants in Massachusetts and Minnesota were higher because they included systems for iron and manganese removal. According to this limited data set, the normalized GAC capital costs (dollars per gallon) were more than those for IX treatment for PFAS.

Table 2 provides the operations and maintenance (O&M) costs for most of the plants in Table 1. The average O&M cost to remove PFAS from drinking water ranges from \$0.09 to \$0.25/gallon for IX plants and \$0.06 to \$0.28/gallon for GAC plants.

The normalized O&M costs (dollars per gallon) for these IX plants was higher on the west and east coasts (California and Florida) compared with the plants in the central-western United States (Colorado). In the case of O&M costs, higher capacity didn’t lower the cost as O&M was proportional to the plant’s maximum capacity.

The normalized O&M costs (dollars per gallon) for the GAC plants were similar to those for IX. Although the Massachusetts and Minnesota plants included manganese and iron removal, along with GAC, the O&M cost for the plant in Massachusetts was significantly higher, indicating higher power, chemical and/or media replacement costs.

In summary, the costs for PFAS treatment varied significantly in both capital and O&M costs, highlighting how plant capacity, location, and specific project requirements affect the overall cost of PFAS treatment.

Lessons Learned

Additional lessons were learned through the design, operation, and pilot-testing considerations of the PFAS treatment plants in this review.

Water Quality Considerations and Media Selection

Before media selection, it is critical to account for the background water chemistry, including high total dissolved solids, iron, or manganese, which can reduce the

Summary of Capital Costs for PFAS Treatment for Drinking Water

Plant	State	Start Date	Capacity <i>mgd</i>	PFAS Treatment System	Capital Cost \$, <i>millions</i>	Capital Cost \$/ <i>gal</i>
Stratmoor Hills Central WTP	CO	May 2022	1	IX	3.8	3.80
Valley Center Well Water Treatment Facility	CA	Oct. 2022	1.7	IX	5.9	3.47
Aga Park IX Treatment Plant	CO	Oct. 2022	2.16	IX	13.0	6.02
City of Stuart IX WTP	FL	July 2019	4	IX	3.0	0.75
N Wells Treatment Facility	CA	Dec. 2020	9	IX	9.6	1.07
J. Wayne Miller, PhD WTP/ Yorba Linda PFAS WTP	CA	Dec. 2021	19	IX	27.0	1.42
Aga Park Wells 2 and 3 GAC Pods	CO	June 2018	1.44	GAC	4.3	2.99
Whitcomb Avenue Treatment Plant	MA	Dec. 2023	1.8	GAC	16.0	8.89
Well 5A WTP PFOS treatment system upgrade	NJ	March 2024	2	GAC	5.267	2.63
Bemidji WTP (phases 1 and 2)	MN	Phase 1: March 2021 Phase 2: Aug. 2024	3.6	GAC	24.9	6.92

GAC—granular activated carbon, IX—ion exchange, PFAS—per- and polyfluoroalkyl substances, PFOS—perfluorooctanesulfonic acid, WTP—water treatment plant

Table 1

Summary of Annual O&M Costs for PFAS Treatment for Drinking Water Treatment

Plant	State	Start Date	Capacity <i>mgd</i>	PFAS Treatment System	Current Annual O&M Cost \$, <i>millions</i>	O&M Cost \$/ <i>gal</i>
Stratmoor Hills Central WTP	CO	May 2022	1	IX	0.09	0.09
Valley Center Well Water Treatment Facility	CA	Oct. 2022	1.7	IX	0.40	0.24
Aga Park IX Treatment Plant	CO	Oct. 2022	2.16	IX	0.35	0.16
City of Stuart IX WTP	FL	July 2019	4	IX	1.00	0.25
N Wells Treatment Facility	CA	Dec. 2020	9	IX	1.70	0.19
J. Wayne Miller, PhD WTP/ Yorba Linda PFAS WTP	CA	Dec. 2021	19	IX	3.71	0.20
Aga Park Wells 2 and 3 GAC Pods	CO	June 2018	1.44	GAC	0.26	0.18
Whitcomb Avenue Treatment Plant	MA	Dec. 2023	1.8	GAC	0.50	0.28
Well 5A WTP PFOS treatment system upgrade	NJ	March 2024	2	GAC	Recent 2024 installation; O&M costs not available	Recent 2024 installation; O&M costs not available
Bemidji WTP (phases 1 and 2)	MN	Phase 1: March 2021 Phase 2: Aug. 2024	3.6	GAC	0.30	0.08

GAC—granular activated carbon, IX—ion exchange, O&M—operations and maintenance, PFAS—per- and polyfluoroalkyl substances, PFOS—perfluorooctanesulfonic acid, WTP—water treatment plant

Table 2

Taking early action and proactive measures to pilot-test, design, and install PFAS treatment facilities can significantly reduce costs in the long run.

lifespan of media like GAC. For the City of Fountain, while GAC proved effective during pilot testing, it exhibited a much shorter lifespan at full scale due to interference from other constituents, necessitating frequent and costly media change-outs that led to decommissioning the plant.

GAC acts as a broad-spectrum filter, removing many contaminants in addition to PFAS. However, this can be a drawback in PFAS-specific treatment if the GAC media becomes saturated with competing compounds, which reduces its life expectancy and effectiveness for PFAS.

System Design and Backwash Constraints

System design must account for operational constraints such as avoiding exposure of certain IX resins to chlorine. For the City of Fountain, the facility wasn't plumbed to allow backwashing with raw water, and the backwash water was chlorinated (occurring immediately post-IX filtration). Retrofitting was required, which was both complex and costly. Proper attention during initial system layout may avoid expensive modifications later.

Continuous Operation to Avoid Media Fouling

For GAC systems, regular cycling is crucial to preventing bacteriological growth. Even outages as short as a week can foul the media, requiring costly media replacement and vessel cleaning. This highlights the need for constant operational oversight and caution for any system downtime.

Post-Media Filtration

The City of Fountain's experience with GAC media escaping into the distribution system due to system failure highlights the importance of incorporating a post-GAC filter or another physical barrier in the process to avoid such a scenario. While this wouldn't necessarily save the media, it could prevent costly customer and regulatory issues that can arise from contaminated distribution systems.

Communication and Transparency

Santa Clarita's experience with the N Wells and Valley Center Well WTPs emphasizes the importance of frequent communication between engineering, operations, finance, communications, and regulatory

bodies. In addition, smooth operations and trust can be reinforced by sampling all sources—not just those mandated by regulators—and maintaining transparency with governing bodies and the public.

Media Selection for Emerging PFAS Compounds

Media selection should consider short-chain PFAS compounds that are not yet regulated in the United States but that may appear in the fifth Unregulated Contaminant Monitoring Rule. While IX resins can effectively treat certain regulated PFAS, some short-chain variants break through quickly. During media selection, planning ahead to account for potential regulations for short-chain PFAS can help utilities better prepare.

Collaboration for Efficient Project Selection and Execution

Collaborations from this review include the City of Fountain and the US Air Force for the Aga Park IX treatment facility and Aga Park GAC WTP; Stratmoor Hills WTP in collaboration with the US Air Force and the Colorado Water Resources & Power Development Authority; and Orange County Water District's partnership with Yorba Linda Water District (for the J. Wayne Miller, PhD WTP). When possible, utilities should consider collaborations for PFAS treatment projects.

Acid Rinse

Before GAC media is used, an acid rinse can remove impurities in the raw carbon, such as residual ash, metals, or minerals. Acid rinsing also conditions the surface of the carbon, improving PFAS removal efficiency (as cleaned media has more efficient adsorption), reducing operational issues like leaching contaminants from the GAC media, reducing maintenance costs, and prolonging media life.

Plan Ahead for PFAS Treatment Challenges

With the US Environmental Protection Agency mandating implementation of PFAS treatment systems in the United States by spring 2029, future capital costs are likely to increase significantly. These costs will be driven by factors such as general price escalation and demand as well as the limited availability of contractors and consultants. The growing demand for PFAS treatment systems, coupled with potential supply constraints, is likely to push costs higher as the deadline approaches.

Taking early action and proactive measures to pilot-test, design, and install PFAS treatment facilities can significantly reduce costs in the long run. Advance planning and implementation not only spreads costs over time but also allows for more efficient project execution and resource allocation.

The lessons from this review underscore the importance of comprehensive planning, operational flexibility, and cross-disciplinary collaboration when designing and operating PFAS treatment plants. Insights in this article can support utilities aiming to build their own PFAS treatment systems. 💧

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AWWA Resources

- Removal of PFAS From Groundwater Using Weak-Base Anion Exchange Resins. Kassir C, Boyer TH. 2023. *AWWA Water Science*. 5:1:e1325. <https://doi.org/10.1002/aws2.1325>
- Water Systems Could Face Costly PFAS Waste Rules. Moody C, Murray C. 2023. *Journal AWWA*. 115:9:6. <https://doi.org/10.1002/awwa.2174>
- Exploring Treatment Options for PFAS Removal in Brunswick County, North Carolina. Dowbiggin B, Treadway J, Nichols J, et al. 2021. *Journal AWWA*. 113:4:10. <https://doi.org/10.1002/awwa.1705>

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