

PFAS IN DRINKING WATER AND REUSE: TRANSLATING US EXPERIENCE AND INNOVATIONS FOR AUSTRALIA'S FUTURE

Nathan Boyle ¹

1. Hazen and Sawyer, Los Angeles, California, USA

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ABSTRACT

This paper will give an overview of PFAS projects that have been implemented in the US to treat for PFAS including GAC, IX and RO. Some case studies from California will be included covering capital and life cycle costs, project feasibility studies and bench tests to develop preferred treatment schemes. The paper will briefly cover a summary of emerging efforts in PFAS destruction technologies. The presentation will provide some useful insights into project pathways and treatment solutions for water utilities in Australia who are faced with PFAS detections.

INTRODUCTION

As Australia intensifies its focus on PFAS management in both drinking water and reuse applications, valuable insights can be drawn from direct experiences across the Pacific, where utilities have been navigating PFAS regulatory, technical, and operational challenges for over a decade.

REGULATORY LANDSCAPE

The U.S. EPA finalized national PFAS drinking water standards in April 2024, establishing enforceable maximum contaminant limits (MCLs) and associated monitoring/compliance timelines (monitoring within several years and compliance within five years of promulgation). The rule sets enforceable MCLs for PFOA and PFOS at 4 ppt each and also established requirements for additional PFAS compounds present in a water matrix using a risk based Hazard Index.

California has implemented PFAS notification levels (NLs) and monitoring orders that while not directly an enforceable MCL can trigger a public notification and reporting in the utilities consumer confidence report, ultimately driving utilities to take action either

through ceasing use of the source temporarily or adding treatment.

One challenge that utilities face is accurately sampling PFAS at low detection levels without interference from outside contaminants such as clothing, food and personal care products. Specialized sampling procedures including coverall suits and limits on specific foods and personal care products that can be used by the sampling individual on the day of sampling have been implemented. Even the sampling apparatus itself has in some cases caused challenges with PTFE (Teflon) tape on threads.

Australian utilities should consider the public and political implications that may drive the need for PFAS action before state regulators force compliance with risk based guidance set in the Australian Drinking Water Guidelines or through other avenues.

TREATMENT ALTERNATIVES

The majority of PFAS systems in municipal water are focused on removal rather than destruction approaches. Various destruction technologies that utilize thermal, electrochemical and plasma are and have been trialed at bench and pilot scale, with some showing promise in capabilities and cost effectiveness. It currently appears that it will be some time before destruction technologies are accepted and implemented for full scale treatment systems.

Single pass ion exchange (IX), granular activated carbon (GAC) and nanofiltration (NF) / reverse osmosis (RO) are the primary treatment alternatives considered, each has benefits and drawbacks that are dependant on site specifics, so there is no one size fits all approach. Management of the spent media/resin is a crucial component that designers must consider the end fate of the products installed

to avoid transferring the issue from one location to another.

Single pass IX uses anion exchange media, similar to that used for perchlorate removal and other similar volatile organic compounds (VOCs). One of the main advantages of IX over GAC is the significantly smaller footprint that make it more favourable for well head treatment sites that are space limited. There are other considerations to using IX such as significant head losses increasing energy requirements and often requiring upgraded pumping infrastructure. The IX resin is also not compatible with chlorine residuals which is something that needs to be considered when used in series with other treatment technologies such as iron/manganese greensand.

Single pass GAC uses adsorptive carbon media to remove VOCs and other organic contaminants through physical adsorption. One of the main advantages of GAC is the operational simplicity and relatively low head loss compared to IX, which generally results in lower energy demands and minimal pumping upgrades. However, GAC systems typically require a larger footprint due to longer empty bed contact times, making them less favorable for space-constrained sites. Other considerations include media exhaustion and the need for frequent changeouts or off-site regeneration, as well as the potential for biological growth or fouling if influent water quality is not well controlled. Spent GAC is most often handled through off-site thermal reactivation or disposal as a non-hazardous solid waste, ensuring that any potential leachable contaminants are properly controlled and do not pose environmental or regulatory risks.

In the case of both GAC and IX pressurized vessel systems a 'lead-lag' multi barrier approach is typically implemented which aids in maximizing media and resin usage rates. Some sites have considered a lead vessel of GAC and lag vessel of IX which can provide benefits where multiple PFAS compounds are present in a water source or when other contaminants require treatment with a certain process, such as VOCs.

Other novel media such as Fluorsorb™ have been considered in design development, piloted at sites and show promising results. The general design approach across the industry is to design equipment

with future flexibility in mind to be able to take advantage of future innovations in media.

To determine resin and media performance pilot scale studies can be used. Pilot provide good, scalable information and can be critical for testing other aspects such as backwash rates, forward flushing, leaching impacts or overall system performance. They can also be used to compare media or resin performance but normally take much too long to provide meaningful information to inform design. A rapid small scale column test (RSSCT) is often used to compare media and estimate breakthrough curves. The media is crushed up and the water sample is run through small scale columns. RSSCT can provide useful information in a matter of weeks which is more economical. Engineers need to consider that RSSCT are useful for comparison and ballpark information but are not always directly scalable depending on the water quality matrix being tested. For more accurate results a pilot with actual media will be the preferred method.

Machine learning and using AI to compare isotherm research data from different waters on a water input can also provide useful information on estimated breakthrough life. A number of consulting firms have this capability developed that have been applied on projects. Using machine learning is limited on more emerging compounds but is expected to expand in the future.

Nitrate peaking can occur in GAC systems when previously adsorbed nitrate or nitrogen compounds are released back into the treated water, often during changes in influent water quality or when stronger-adsorbing organic compounds displace weakly held anions. In biologically active GAC beds, nitrification of ammonia can also result in transient nitrate increases, particularly during startup or after operational upsets. In the United States, nitrate peaking is typically managed through careful monitoring during initial operation and media changeout, controlling influent water chemistry, and, where necessary, pairing GAC with downstream treatment such as blending, ion exchange, or operational bypass to ensure compliance with the 10 mg/L nitrate-as-N drinking water standard.

Another design issue encountered with GAC, particularly coal based GAC are leachates. GAC may contain trace amounts of compounds such as arsenic, uranium, aluminium and other naturally occurring metals depending on the carbon type. On

initial startup these items present naturally in the carbon can leach into the water and put the treated water out of compliance. This is currently typically managed with flushing, however the flushing can be up to 100 bed volumes at some sites in Southern California which can be very onerous to waste particularly in large scale installations. This issue can also be managed through pre-rinsing and conditioning of GAC prior to service, controlled disposal of backwash and rinse water to sanitary sewer or approved treatment systems.

PFAS IN REUSE AND MEMBRANE TREATMENT

RO membranes are highly effective at rejecting PFAS, but generates an RO concentrate where the PFAS is transferred to, resulting in a smaller-volume waste stream with significantly elevated PFAS concentrations. RO concentrate is difficult to treat because PFAS are chemically stable, poorly biodegradable, and not easily removed by conventional wastewater treatment processes. RO concentrate has a high potential for scale formation making removal in the concentrate stream difficult. For example GAC on RO concentrate would scale very quickly and would be an operational burden. Other options such as thermal destruction are costly and not widely implemented at municipal facilities.

As a result, the fate and ultimate management of PFAS-laden concentrate must be carefully considered during project planning, with increasing emphasis on source control and evaluation of end-of-life treatment or disposal pathways to avoid creating other problems elsewhere.

SELECT CASE STUDIES

Santa Clarita Valley Water Agency (SCV water)

Santa Clarita is a City located north of Los Angeles and was among the first California agencies to respond aggressively to PFAS detections after the State Water Resources Control Board lowered response levels for PFOA and PFOS in 2019–2020. PFAS impacts led SCV Water to temporarily shut down nearly half of its groundwater wells, which supply a significant portion of the agency's potable demand.

SCV Water implemented one of California's earliest full-scale PFAS treatment programs using single-use PFAS-selective ion exchange (IX)

systems at multiple well sites. Following bench- and pilot-scale testing, IX was selected over GAC due to faster kinetics, improved removal of short-chain PFAS, and a significantly smaller footprint—critical for constrained wellhead sites. Treatment facilities were designed and constructed on an accelerated schedule, returning impacted wells to service while meeting California notification and response levels. SCV Water continues to expand its PFAS treatment across other wells following the development of a system master plan to aid in the roll out and prioritization of projects.

Rubidoux Community Services District

Rubidoux Community Services District detected elevated concentrations of PFOA and PFOS in groundwater wells serving the Jurupa Valley area, triggering regulatory action under California's PFAS response level framework. To maintain potable supply and regulatory compliance, the District moved quickly to design and install a treatment system at its existing site that also contained manganese treatment with a capacity of 28 ML/d.

After evaluating compatibility with existing site infrastructure, Rubidoux selected a wellhead ion exchange system to remove PFAS to below California notification limits. The system was designed to fit within the existing facility footprint and avoid major pumping upgrades, enabling rapid implementation in less than one year from conceptual design to operation, during the pandemic with supply chain issues. The project is a success story highlighting how utilities can deliver projects if a clear plan is laid out to implement the project. This facility required dechlorination following manganese treatment.

Orange County Water District

Orange County Water District manages one of the nation's largest groundwater basins, supplying up to 85% of drinking water for 2.5 million residents. Beginning in 2019, PFAS detections across the basin forced multiple retail water providers to shut down dozens of wells, increasing reliance on imported water. Likely PFAS sources include regional stormwater and wastewater inputs to the Santa Ana River, underscoring the basin-wide and interconnected nature of the problem.

OCWD launched a large-scale, regional PFAS treatment program, funding pilot studies and

full-scale implementation across more than 30 groundwater treatment systems. Pilot testing evaluated GAC, ion exchange, and alternative adsorbents, with IX emerging as a preferred solution for many wells due to performance and operational efficiency. OCWD now partners with retail producers to design, fund, and operate PFAS treatment facilities, supported by significant state and federal funding. This program is widely regarded as one of the most comprehensive PFAS mitigation efforts in the U.S. and serves as a model for basin-scale PFAS management.

Cape Fear, NC

In the Cape Fear River basin, PFAS mitigation for surface water supplies has included the retrofit of existing rapid sand and dual-media filters to granular activated carbon (GAC) as an interim and long-term compliance strategy. The project first considered the feasibility of converting conventional filtration assets to GAC contactors, focusing on hydraulic capacity, available bed depth, and achievable empty bed contact times (EBCT) under existing filter geometries.

Implementation considerations included increased headloss across GAC media, impacts to filter run times, backwash expansion requirements, and the need to modify underdrains and backwash rates to accommodate lower-density carbon. Treatability and operational assessments showed that surface-water-derived natural organic matter (NOM) significantly competes for adsorption capacity, requiring conservative EBCT design and more frequent carbon replacement compared to groundwater applications. These conversions allowed utilities to rapidly deploy PFAS treatment using existing infrastructure while longer-term treatment and source-control strategies were evaluated, but they also highlighted the operational tradeoffs associated with PFAS removal in high TOC river water sources such as the Cape Fear.

Western Municipal Water District

An extended pilot study conducted at Western Municipal Water District evaluated PFAS behavior and treatability in a system strongly influenced by tertiary wastewater effluent and recycled water. The study assessed adsorption-based treatment performance using tertiary effluent representative of

indirect potable reuse and downstream surface water discharge conditions.

Results confirmed that conventional wastewater treatment provides negligible PFAS removal and that elevated dissolved organic carbon, algal byproducts, and temporal variability in effluent quality significantly reduce adsorption capacity and accelerate breakthrough for both granular activated carbon and ion exchange media. The pilot also demonstrated that PFAS removal processes in reuse applications largely redistribute PFAS mass into residual streams or concentrates that are typically returned to the wastewater system, rather than achieving destruction. These findings highlight the importance of evaluating PFAS at the system scale accounting for influent sources, reuse treatment trains, residuals handling, and discharge pathways to avoid downstream consequences.

CONCLUSIONS

Experience from PFAS projects implemented across the United States demonstrates that effective PFAS management is less about identifying a single “best” treatment technology and more about understanding site-specific water quality, infrastructure constraints, regulatory drivers, and long-term residuals management. Granular activated carbon, ion exchange, and membrane processes are all effective at PFAS removal, but each introduces distinct operational, hydraulic, and lifecycle considerations that must be evaluated. U.S. case studies show that rapid deployment is often achieved through adaptation of existing assets such as wellhead treatment systems or conversion of conventional filters.

Most full-scale systems remain focused on PFAS removal rather than destruction, transferring PFAS mass into spent media, residual streams, or membrane concentrates that require careful end-of-life management to avoid unintended downstream impacts. The industry is evaluating destruction technologies and there are a number of startups and established companies that are showing promising results with technologies in this space.

For Australian utilities, the U.S. experience highlights the importance of early feasibility assessments, realistic lifecycle cost evaluations, and system-wide thinking that extends beyond the drinking water plant boundary. PFAS challenges

associated with reuse and wastewater discharges demonstrate that PFAS should be considered holistically rather than at a single treatment site. As PFAS technology and regulations continues to evolve, developing solutions that are flexible and focused on current and future plant operational modes are going to be critical to avoid overbuilding or extremely high costs that leave a burden on the industry and rate payers.

