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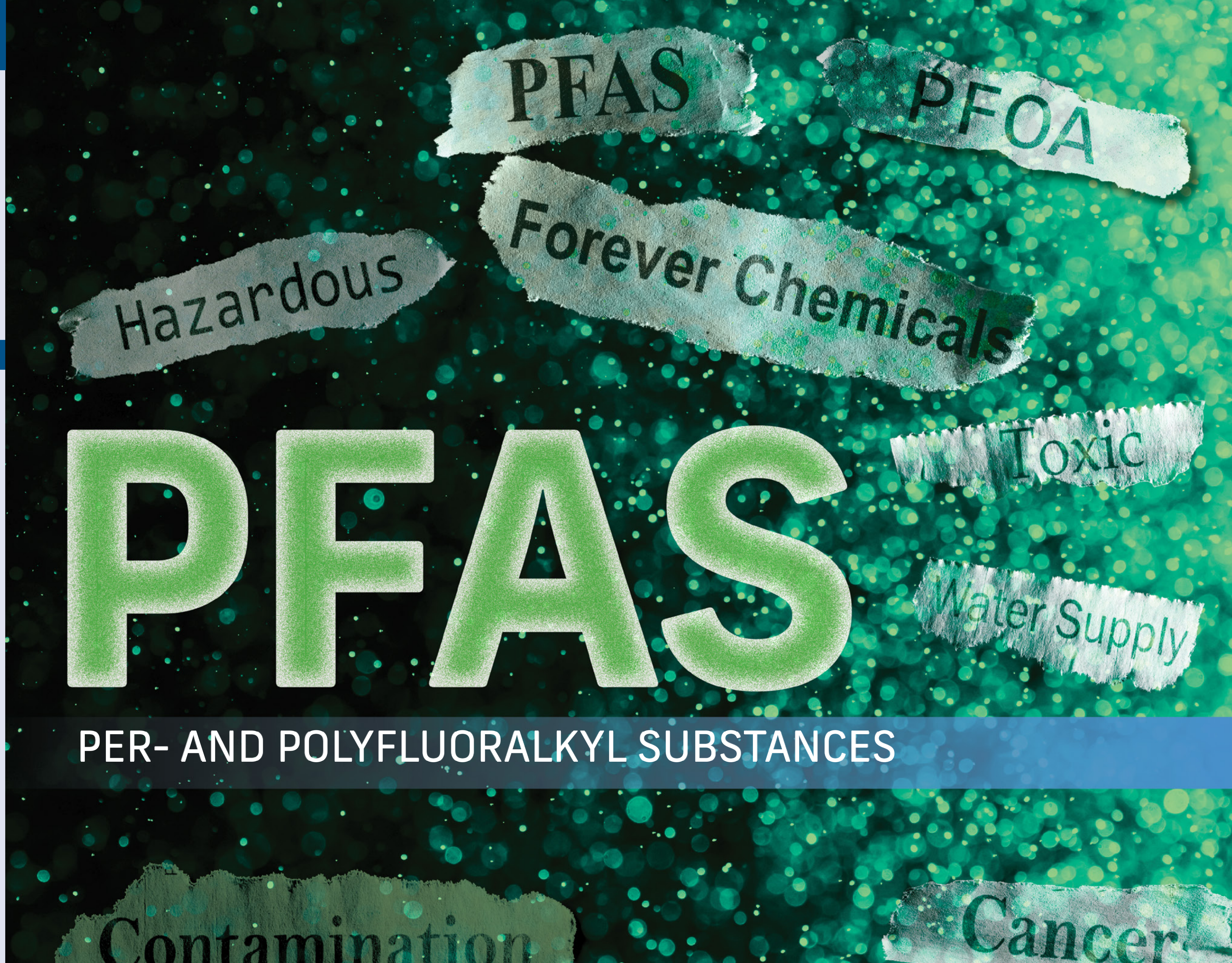

PER- AND POLYFLUORALKYL SUBSTANCES

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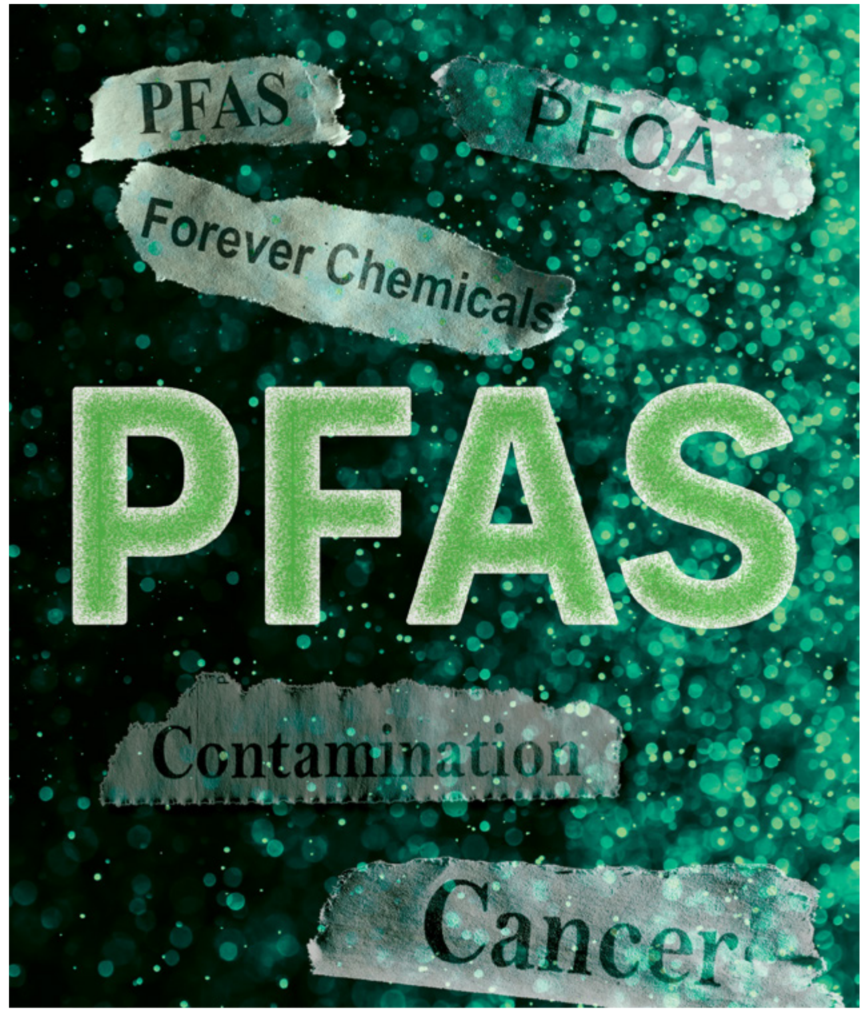

Contents

Not So Forever Chemicals

For years, mass media has used the term forever chemicals when talking about per- and polyfluoroalkyl substances, but the more I have talked with utilities directly involved with PFAS issues the more I have come to realize the forever chemical term creates a sense of complacency.

This issue is complex and requires sophisticated solutions along with a ton of money. It is not something that will change overnight. It is not a problem that we can solve in the next 12 months. It is a problem we have been living with for decades and are just now beginning the process to institute sustainable long-term solutions.

The complexity here is multifaceted. It stretches across business markets. Due to the nature of water alone, everything is attached to the issue of PFAS.

In this eHandbook we aimed to explore how the market verticals in the water sector are attacking this problem head on. We sought to present the nuanced approaches, the deep and thoughtful considerations, and the complex web of emotions and science underpinning perhaps the most enormous contaminant removal movement of our lifetimes.

Now with all of that said, I can understand the burden that you likely feel. I can sense that tightness of stress building in the center of your chest as I feel it in mine. This is enormous work, and it is daunting.

But we are here with you and so are all of your peers. We do not have to solve this problem in a vacuum. We have incredibly intelligent minds in this industry ready to take this thing and run with it. The technology exists to deal with these chemicals. Some of them are very novel and may give you pause. Others are trusted and have existed for a long time but require additional training.

The pieces of the puzzle are on the table. It is just a matter of fitting them all together and getting the buy-in from our legislators to fund our sectors and protect public health for the long haul. Because even if we cannot end forever chemicals, we damn well have the agency to lessen their impact.

Bob Crossen, is the editorial director for the Endeavor Business Media Water Group, which publishes *WaterWorld*, *Wastewater Digest* and *Stormwater Solutions*. Crossen graduated from Illinois State University in Dec. 2011 with a Bachelor of Arts in German and a Bachelor of Arts in Journalism. He worked for Campbell Publications, a weekly newspaper company in rural Illinois outside St. Louis for four years as a reporter and regional editor.

ADVANCE TO TOPICS

Can You Handle PFAS in Time?

What utility managers need to know about PFAS remediation, and considerations to make their strategies successful.

By Mandy Crispin

Crisis management is not something water utilities deal with every day. In fact, unplanned maintenance or a water main break is generally as bad as it gets. However, Jeaniece Slater, the general manager of West Morgan East Lawrence Water and Sewer Authority (WMEL), and Kenneth Waldroup, the executive director of Cape Fear Public Utility Authority (CFPUA) have faced down PFAS.

Mike McGill, president of WaterPIO characterizes Slater as “someone who might have the most tangled path to the construction of an RO plant targeting PFAS in history,” and CFPUA “was ground zero for the GenX mess back in 2017 that has been addressed through the construction of ~$50 million in GAC.”

McGill lauds both as the best leaders there are in PFAS remediation, noting that their paths to safe water can save other utilities from experiencing a crisis when addressing per-and polyfluoroalkyl substances (PFAS) before the EPA deadline.

FIRST THINGS FIRST

McGill, Slater, and Waldroup all said the same thing: pilot studies are vital.

“Unfortunately, due to the accelerated timeframes utilities will find themselves under, they could be skipped,” McGill said.

Calm waters along the boardwalk along Cape Fear River.

Just how important they are can be contextualized best by understanding which technologies have the most research backed efficacy and how drastically different conditions can affect making the correct decision.

There are many methods to consider, explained Kyle Thompson, national PFAS lead at Carollo.

"Granular activated carbon, ion exchange, and reverse osmosis are often cited as the effective full-scale technologies for PFAS removal from drinking water," he said. "Powdered activated carbon is also an option, particularly for large surface water treatment facilities that only slightly exceed the limits. Certain nanofiltration membranes also effectively remove PFAS and could be the best option in some cases, for example in water with high total organic carbon or if hardness removal is also a goal."

That said, the top three remain granular activated carbon (GAC), ion exchange (IX), and reverse osmosis (RO). Slater said the differences in source water mean treatment will require specific solutions — not one-size-fits-all solutions. Knowing where to start is the first major hurdle.

Both WMEL and CFPUA tested different methods during their pilots, and both ended up choosing GAC. While long-chain PFAS were effectively treated with GAC, WMEL changed to RO after GAC could not accommodate filtering short-chain PFAS in its situation.

"This shift underscores the importance of adaptive management in water treatment facilities, where initial decisions must be open to change in response to new findings and environmental conditions," Slater said.

It also depends on where the utility is located. Waldroup said that during CFPUA's year-long study, it had to consider specific factors. He listed the usual considerations as, "removal rates, environmental impacts, cost, customer (rate) impacts, operational strategies, flexibility, and distribution water chemistry (compatibility for corrosion control)," but noted his system's source water is unusual.

"We are downstream of a PFAS manufacturer and thus have a wide range of PFAS types and concentrations to contend with daily," he said.

Ultimately, the overall decisions on the parts of these utilities were and are nuanced.

"Flexibility (we can use several types of GAC/novel sorbent and, with slight modification, IX), environmental impact (we can recycle/regenerate GAC ensuring the waste PFAS is destroyed in a thermal oxidation process), and cost (the up-front costs were lower than RO and the operational costs were lower than RO & IX)," Waldroup said via email in communicating core considerations for technology selection.

Slater pointed to collaboration as a vital factor.

"The involvement of community activists, regulators, and a forward-thinking board of directors underscores the collective effort and dedication to making decisions that, while financially challenging, prioritize the well-being of the community and its future generations," Slater said.

A view of Wilmington North Carolina from across the Cape Fear River.

BUDGET STRATEGIES

There are several avenues available to help pay for the process. Government funding by way of the Bipartisan Infrastructure Law (BIL) through clean water and drinking water state revolving funds, and the Emerging Contaminants — Small and Disadvantaged Communities (EC-SDC) fund.

"EPA programs provide BIL funds annually to each state's and territory's revolving loan programs.," said Michael Van Antwerp, strategic funding lead at Carollo, via email. "The BIL has provided $5 billion to the EC-SDC to be allocated across the 5-year period (FY22-FY26). The FY24 annual allotment for this program was recently announced by the EPA (Emerging Contaminants (EC) in Small or Disadvantaged Communities Grant (SDC) | US EPA). Each state will manage these funds through its revolving loan program, ensuring alignment with the state's specific priorities and the EPA program."

In addition, settlements from lawsuits where contamination can be proven have been successful sources of funding, while other options include public/private partnerships (P3s) and risk sharing between these parties.

There are also rate payers. While not ideal — water systems had no part in creating or perpetuating the PFAS problem — CFPUA had no choice but to increase rates to pay for treatment. McGill said that based on experience, "utilities that communicated throughout their efforts greatly reduced the shock value involved when it came to the costs involved, and those costs are — with rare exceptions — being paid by the customers, not the polluters."

Slater expended on this comment from McGill, noting that planning is crucial.

"A comprehensive budgeting plan should include cost estimation based on historical data and consultation with experts to anticipate future expenses," she said.

In short: be clear early, have a plan, and communicate.

Then there are these words of caution that are essential when it comes to costs: beware the X factor.

McGill stated that one utility, because of political pressures, chose an expensive technology that was only based on a single round of pilot data. The utility "is looking at a 25+% rate increase."

"The less the decisions are made by water/wastewater professionals, the more sideways the process becomes," he said.

While CFPUA had to increase rates, "the construction and operational costs equate to approximately $5.88/month or $70.56/year on the average water bill" for their implementation, Waldroup said.

CFPUA is pursuing litigation against the polluter, Chemours/DuPont, and is seeking full restitution. In the case of WMEL, litigation was successful, and it did not have to pass the cost to its community.

EDUCATION, TRAINING AND LICENSING FOR ADVANCED TREATMENT SYSTEMS

Workforce training and licensing is important not only to properly operate these advanced treatment systems but also because it is beneficial to have someone on staff to interpret and lead the project from within the utility.

Thompson suggested starting with something less obvious. One such example are Texas AWWA courses for advanced treatment and granular activated carbon and ion exchange that are driven by the growing potable reuse trend in the state. These courses are accepted by the Texas Commission on Environmental Quality for Operator Training Credits, and position water professionals to operate the same systems that are needed for PFAS treatment.

WMEL gets training from experts who visit the plant and educate the staff, which is included in the purchase of the technology. This can be worked into any contracts and licensures when the purchase is made.

"Such programs should be included in the procurement contract and detail the scope of training, guidance on routine maintenance, and procedures for handling replacement parts," Slater said. "Warranties and service agreements play a critical role in safeguarding the interests of the water

A view of Wilmington North Carolina from across the Cape Fear River

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provider, guaranteeing technical support, and ensuring the reliability of the water supply to customers."

For CFPUA, Waldroup noted that creating Standard Operating Procedures (SOP) and Work Process Instructions (WPI) based on the utility's needs makes a difference.

"A certain amount of startup activity allows operators to operationalize the SOPs and WPI, modifying them where necessary during a one-year optimization period," Waldroup explained.

Even once pilot testing, technology choice, budget, and implementation is worked through, there is still another year of fine-tuning system operations and refining operator training.

Although the timeframe for compliance with the relatively new EPA PFAS Maximum Contaminant Levels may seem short, there have been pioneers to take examples from. Expediency and evaluation along with resourcefulness and preparedness will ensure successful remediation and compliance. Slater, Waldroup and McGill all agreed it will take years to complete, but it is doable.

And when it comes to communications, Slater provided one final poignant thought.

"It's a profound truth that the families of those who manage public utilities also rely on the same water supply, underscoring the sincerity and dedication of the professionals involved. Their commitment to public health is unwavering," Slater said. ●

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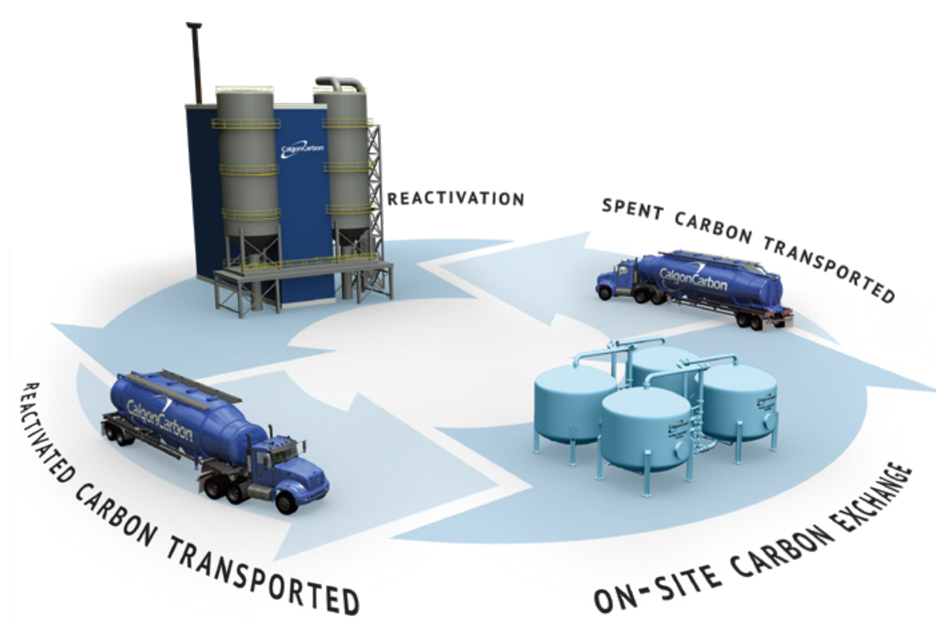
FILTRASORB® Granular Activated Carbon (GAC)

Calgon Carbon is the largest manufacturer of GAC in the US. Additionally, Calgon Carbon holds a distinct advantage by producing a wide range of products, coupled with comprehensive expertise in GAC applications. Calgon Carbon's FILTRASORB® products are designed for the removal of organic compounds (such as PFAS, DBPs, TOC, and others) from water and wastewater. All FILTRASORB products are NSF 61 certified and AWWA B604 approved for drinking water treatment.

AquaKnight™ Water Treatment Equipment

Calgon Carbon offers the most extensive range of equipment solutions with over 35 years of experience in equipment fabrication and installation. AquaKnight™ adsorption systems are available in two distinct offerings, AquaKnight Gold Certified (GC) and AquaKnight Custom Certified (CC). The AquaKnight GC series is the gold standard of adsorption systems. They are designed with the highest level of drinking water purification and safety in mind. Each system is certified to meet NSF 61 drinking water standards.



Custom Municipal Reactivation (CMR)

CMR allows municipalities to recycle and reuse their own carbon. A quality custom reactivated product starts with a quality virgin GAC product. GAC from bituminous coal manufactured via a reagglomeration process, like Calgon Carbon's FILTRASORB®, provides the best starting material for a reliable CMR product. The reactivation process effectively removes the adsorbed chemical constituents from the spent GAC. Calgon Carbon is uniquely positioned to offer turnkey reactivation services for GAC reuse.

How Does PFAS Impact Stormwater?

PFAS is broadly talked about when it comes to drinking water, but stormwater professionals are preparing to tackle it in their sector.

By Katie Johns

Traffic in torrential rain.

When it comes to PFAS, much of the talk surrounds drinking water. In April 2024, the U.S. Environmental Protection Agency (EPA), announced the final National Primary Drinking Water Regulation (NPDWR) for six PFAS contaminants.

But, PFAS, short for per- and polyfluoroalkyl substances, are also in wastewater and stormwater. Most stormwater-related PFAS regulations will come via NPDES permitting through the Clean Water Act.

In fact, in April 2023, the EPA ordered the Chemours Company to take corrective measures to address pollution from PFAS in stormwater and effluent discharges from the Washington Works facility near Parkersburg, West Virginia. According to an EPA press release at the time, that was the first EPA Clean Water Act enforcement action ever taken to hold polluters accountable for discharging PFAS into the environment.

"PFAS is in stormwater everywhere because it's in rainwater," said Brandon Steets, senior principal at Geosyntec Consultants.

Michael Trapp, Water Resources market leader for AtkinsRéalis, said it is important to talk about the chemistry of PFAS when discussing how to treat it. Because PFAS is soluble, it moves quickly through the environment.

"They're not an individual chemical sitting in by themselves having an effect, but they act in concert with the soup that's in stormwater," Trapp said.

DIFFERENT TYPES OF PFAS SITES

Steets said it is important to establish what kind of sites are being discussed when it comes to PFAS in stormwater. For example, there are concentrations in stormwater from wildland areas that are undeveloped as well as urban areas, and Steets said the concentrations usually go up in rainwater concentrations in urban areas. Steets said if he had to guess that would be because of exposure to PFAS-containing consumer products like plastics and pesticides.

Steets said in those areas, there are typically 10 to 50 nanograms of perfluorooctane sulfonic acid PFOS present. PFOS is one of the PFAS chemicals under the most scrutiny alongside perfluorooctanoic acid (PFOA).

Then there are industrial sites, including smaller sites that have secondary use of PFAS-containing materials, which might have a little bit higher levels than the urban sites. Steets said even then, the concentrations are "not terribly high."

And finally, there are acutely contaminated PFAS sites, and those sites typically have air emissions of PFAS or have used aqueous film-forming foam (AFFF). AFFF was commonly used in firefighting for training purposes or for putting out fires. It also can be found in areas where AFFF was stored or where there were spills, such as fuel terminals, refineries or airports.

HOW CAN PFAS IN STORMWATER BE TREATED?

There is a lot of discourse on how to treat PFAS. It could come down to the location and type of site.

Sites can either use active or passive treatment. When it comes to active treatment, those systems typically rely on media transfer such as a media filter like granular activated carbon (GAC) and/or ion exchange and rarely, reserve osmosis. Steets said with these, it is possible to get below 10 nanogram per liter range.

"If you have an acutely contaminated site, generally you need active treatment because you're generally going to need more than one log removal," he said.

A Pipe drains toxic wastewater into a river, causing environmental pollution and ecological damage.

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Passive treatment systems are another option, though they are less able to remove PFAS, putting treatment at about 1 log removal.

Steets said there is a lot of emphasis by regulators on characterizing groundwater as contaminated media and migration pathways. But stormwater is also an important pathway to look at.

"Stormwater is not only significant magnitude of offsite migration, but it is also a much faster speed of offsite migration," he said.

And still there is talk of whether source control is effective with PFAS. Steets said source control in this case is very difficult and, in many cases, unproven, as it is in an experimental stage.

"Its performance is uncertain, and the type of source control will vary on the type of surficial media that is impacted," he said.

For example, when it comes to asphalt, it is less porous, so one may need to investigate asphalt resurfacing. If, rather than asphalt, the media is surface soils, source control might require replacing those soils or repaving that area. Then there is concrete and metal, including stormwater conveyance and catch basins. With these media types, it is important to note that PFAS is a sticky substance. Along the migration path, it contaminates the collection and conveyance system, if the original site had conveyed acutely contaminated PFAS. Source controlling those systems might look like reconstructing the whole system or lining the pipes, which can be expensive, Steets said.

Trapp said there is a lot of variability at play, with areas that have low concentrations to areas with very high concentrations. Those tend to be where this is more of a traditional point-source area. The concentrations are not typical to regions but are more based on the variability of local inputs, Trapp said.

Trapp said he foresees this changing as true source control becomes even more prioritized.

Steets, while not a wastewater engineer, said he would not expect stormwater runoff to have much negative impact on the biological treatment process. However, in a combined sewer system, he said there will be marginal treatment of PFAS if the system is not augmented for PFAS treatment. Many of which he said, are not yet.

"In equals out for those systems," he said. "Whenever PFAS is arriving at those treatment systems, they (PFAS) probably are going to be working their way through the system and discharging into receiving waters."

ALTERNATIVES TO TRADITIONAL BMPS ARE NECESSARY

While many stormwater professionals have a list of BMPs that will help them through many challenges, PFAS might need a toolbox of their own.

Steets said, for example, at a construction site, traditional BMPs will not do much for PFAS unless the site has PFAS-contaminated surface soils, and the project team is trying to control the migration of them. But for urban stormwater, traditional BMPs, including sedimentation BMPs and filtration, will have little to no effect.

Steets said treatment BMPs really need a carbon amendment, such as a compost amendment, GAC or biochar augmentation. Trapp also pointed to ion exchange resins as a treatment, one of the options Steets mentioned for active treatment.

Trapp said there are standards being discussed not only for PFAS in stormwater but for ambient water quality standards, soils, groundwater and biosolids. Trapp said a lot of what is happening right now is discussion of where the levels of concern are and if those were to be regulated, especially with the omnipresent nature of PFAS.

"PFAS is a massive family of 10,000 chemicals that are in a lot of different things, a lot of different industrial processes, a lot of consumer products and things like that, which helps drive that ubiquitous nature," Trapp said.

Once PFAS are added by each state as a priority pollutant under the Clean Water Act, such as Colorado, Minnesota, North Carolina and others have done, it is required for monitoring at industrial sites.

"I think that what makes PFAS difficult is that drinking water standards, which are going to apply to a lot of waters across the United States, are so low that, for PFOS and PFOA, you're talking about 4 nanograms per liter," Steets said. "For other regulated chemicals, you're generally talking about 10 nanograms per liter or less."

Steets said that number tends to be less than what you see in urban stormwater at a ubiquitous level, so MS4s and CSOs will have to grapple with how to deal with that responsibility — but it doesn't just fall to MS4s and CSOs. That includes phasing out PFAS-contaminated products that consumers use every day.

"Everyone has to work toward that goal of source control," Steets said.

The Race is on

In light of recent parameters set by the EPA for PFAS in drinking water, utilities are feeling the time crunch to source out the best collection and destruction methods that meet their specific needs.

By Alex Cossin

With the U.S. Environmental Protection Agency's (EPAs) introduction of Maximum Contaminant Levels (MCLs) for PFAS, there's an increasing demand for technology that can detect and destroy the contaminants.

Luckily for water utilities, there's a wide array of options. More traditional and trusted treatment techniques include reverse osmosis (RO), granular activated carbon (GAC) and ion exchange (IX). If you've been around the water industry for any amount of time, these treatment techniques probably ring a bell.

However, some lesser-known novel treatment techniques utilize breakthrough technologies to treat PFAS in drinking water and wastewater. Things like supercritical water oxidation, foam fractionation, and electro-oxidation may not be as commonly known as traditional treatment techniques, but they're quickly gaining traction in the water industry.

Although some of the technologies used to treat PFAS have been around for quite some time, RO was gaining popularity in the 1970s and 80s for example, the need to treat PFAS out of drinking water is a newer endeavor.

Water utilities have until 2029 to comply with all MCLs. While there is no clear choice to the perfect technology to treat PFAS, the rush is on to gain compliance.

PFAS REMOVAL VS. DESTRUCTION

"There's an important distinction that needs to be made," said Head of Business Development for Element Six Bruce Bolliger.

Some technologies collect PFAS, while other technologies destroy it.

"There's two different PFAS processes that have to occur. One is a separation process like activated carbons and ion exchange resins," he said. "Those don't destroy the PFAS, they just collect it and concentrate it."

PFAS removal can be thought of as collection. In removal systems, technology removes PFAS from water utilizing either a waste stream or collection in a media, such as GAC or RO.

PFAS destruction is exactly what it sounds like. This refers to technology that destroys PFAS during water treatment or after water treatment where PFAS is a byproduct. Some techniques include incineration or electrochemical oxidation.

TRADITIONAL TREATMENT TECHNIQUES FOR PFAS

Reverse Osmosis (RO)

Reverse osmosis, or RO, is a separation process that uses a synthetic thin film polymeric membrane specifically engineered to allow water to pass through.

RO systems can be used to treat PFAS from drinking water by pumping the water through the membrane which keeps small bodies like PFAS from passing through.[1]

According to the U.S. Environmental Protection Agency (EPA), RO separation is up to 99% effective at removing certain PFAS.[2] There are some drawbacks of RO according to EPA research, however:

- Higher capital costs and energy demand than other conventional treatments.
- Susceptible to fouling without pretreatment.
- Generates a concentrated PFAS waste stream that must be treated or disposed.

[1]www.watertechnologies.com/blog/does-reverse-osmosis-treat-pfas
[2]www.epa.gov/system/files/documents/2021-09/multi-industry-pfas-study_preliminary-2021-report_508_2021.09.08.pdf
[3]www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies

Ion Exchange

Ion exchange resins are made of highly porous, polymeric material that is acid, base and waster insoluble. The tiny beads that make up the resin are made from hydrocarbons.

There are two broad categories of ion exchange resins: cationic and anionic.

The negatively charged cationic exchange resins (CER) are effective for removing positively charged contaminants. Positively charged anion exchange resins (AER) are effective for removing negatively charged contaminants, like PFAS.[3]

Imagine ion exchange resins as powerful magnets that attract and hold the contaminated materials from passing through a water system.

Benefits of ion exchange according to the EPA include:

- A high capacity to capture many PFAS
- No need for resin regeneration
- No contaminant waste stream to handle
- Removes 100% of PFAS for a certain amount of time

Drawbacks of ion exchange according to the EPA include:

- More expensive than technologies such as GAC
- Incineration of media after PFAS collection

Granular Activated Carbon (GAC)

Granular Activated Carbon (GAC) may just be the most studied PFAS treatment technique. GAC is commonly used to absorb natural organic compounds, taste and odor compounds, and synthetic organic chemicals in drinking water systems.

GAC is an effective absorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb.

GAC is made from organic materials with high carbon contents such as wood, lignite and coal.[4]

Benefits of GAC according to the EPA include:

- Strong efficiency at removing PFAS for some time
- Works well on longer-chain PFAS like PFOA and PFOS

Drawbacks according to the EPA include:

- Dependent on type of carbon used, thickness and flow rate
- Shorter chain PFAS like PFBS do not absorb as well

EPA researcher Thomas Speth said in an EPA article, "GAC can be 100% effective for a period of time, depending on the type of carbon used, the depth of the bed of carbon, flow rate of the water, the specific PFAS you need to remove, temperature, and the degree and type of organic matter as well as other contaminants, or constituents, in the water."[5]

Another type of activated carbon treatment is powdered activated carbon (PAC).

PAC uses the same materials as GAC but comes in a smaller powder-like size. PAC cannot be used in a flow through bed but can be added directly to the water and then removed with other natural particulates in a clarification stage.

"Even at very high PAC doses with the very best carbon, it is unlikely to remove a high percentage of PFAS; however, it can be used for modest percent removals," Speth said in the EPA article. " If used, however, there is an additional problem with what to do with the sludge that contains adsorbed PFAS."

[4] www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies
[5] www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies

NOVEL TREATMENT TECHNIQUES FOR PFAS

Electrochemical Oxidation (EC)

Electrochemical Oxidation, or EC, is a water treatment technology that uses electrical currents passed through a solution to oxidize pollutants.[6]

EC systems can be used to treat PFAS from drinking water by pumping water through a solution, such as boron-doped diamond (BDD), to destroy organics like PFAS.

Chad Felch, technical services director for Lummus Technology, said short-chain PFAS are a pain point for utilities.

"Other technologies that we've tried have had a difficult time with short-chained PFAS compounds, whereas this technology doesn't have any issues with that at all," he said.

Felch continued by stating that the EC technology, specifically using BDD tech, has been able to destroy every type of PFAS compound that his team has been able to discover while testing.

As far as wear and tear goes, EC systems can switch polarity to reduce filing of the electrodes.

Bruce Bolliger, head of business development for Element Six, stated that in other applications outside of PFAS, the BDD tech has a lifecycle of eight to 10 years. Other than that, simple things like O-rings in the system would need to be serviced.

According to EPA research, benefits of CE include:

- Low energy costs
- Operation at ambient conditions
- Ability to be in a mobile unit
- No requirement for chemical oxidants as additives

Limitation to CE according to the EPA include:

- Potential generation of toxic byproducts
- Incomplete destruction of some PFAS
- Efficiency losses due to mineral buildup on the anodes
- High cost of electrodes
- Potential volatilization of the contaminants

[6]www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_electrochemical_oxidation_final_jan_25_2021_508.pdf
[7]cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=354238&Lab=CEMM

Supercritical Water Oxidation (SCWO)

Supercritical water oxidation (SCWO) is an existing technology that relies on heating and pressurizing water to destroy hazardous chemicals.

Although SCWO is an existing technology, it's still in early development stages when it comes to treating PFAS from drinking water.

In a 2022 EPA study, three purveyors of SCWO systems were employed to identify if SCWO could be an innovative technology to destroy PFAS. All three systems showed positive results, as indicated by the targeted analysis of influent and effluent streams.[7]

These preliminary findings suggest SCWO may be an acceptable alternative to incineration for PFAS-laden wastes.

Benefits of SCWO include:

- Previously shown to destroy hazardous substances
- Preliminary findings show more than 99% reduction of identified PFAS compounds targeted for the study
- May be an alternative to incineration

Drawbacks of SCWO include:

- Still in early development
- Requires high temperatures and pressures to work

Foam Fractionation

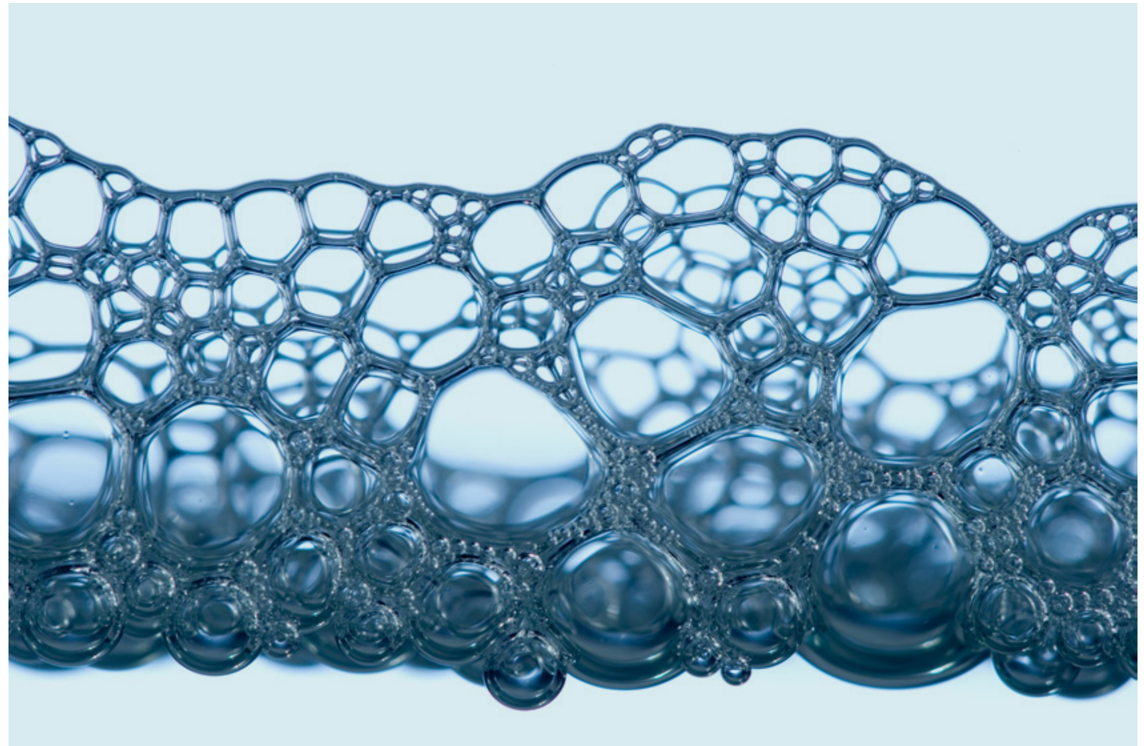
Foam fractionation is a novel treatment technique for PFAS that is currently being researched and studied by scientists.

Foam fractionation aims at separating PFAS from drinking water for later disposal.

The technology works by inserting air bubbles into water that carry proteins, detergents and fluorosurfactants like PFAS to the surface of the water to collect as foam or bubbles.

This can occur naturally in places like contaminated rivers and lakes, or as a byproduct of wastewater and landfill treatment processes.

"The PFAS molecule has head chemistry and tail chemistry. The head chemistry has an affiliation for water, and the tail chemistry has an affiliation for air. That's their most comfortable state," said Shaun Melrose, senior manager PFAS operations at Crystal Clean.



"The result of that affiliation is that they gravitate to that air-water interface in a wastewater system," Melrose added. "So if you introduce smaller bubbles into a contaminated water source the PFAS molecules will ultimately want to move to their most comfortable state."

While PFAS-specific treatment technologies applicable for landfill leachate and wastewater treatment plants are still under development, the PFAS uptake phenomenon by air-water interface (foam) may allow the foam to be skimmed off and collected for destruction.[8]

Melrose stated that the skimming of the foam is relatively straightforward, and that the science of the process really takes place in generating the foam.

This process has been studied using PFAS-impacted landfill leachate. The foam fractionation treatment method is said to be highly effective for all but the smallest and largest PFAS molecules.

Benefits of foam fractionation include:

- Effectively remove PFAS from aqueous matrices[9]
- Removal can be enhanced by optimizing setup and strategies

[8]www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_electrochemical_oxidation_final_jan_25_2021_508.pdf
[9]sciencedirect.com/science/article/pii/S0304389423024664

Drawbacks of foam fractionation include:

- Lower removal rate reported for short-chain PFAS
- Technology is still being researched and tested

CONCLUSION

These are just some of the technologies being considered to treat PFAS out of drinking water. Time will tell which proves to be the most effective. It may be traditional technology, or it may be a novel invention that is currently being tested and researched.

Costs of the technology will vary on a case-by-case basis. Large- or small-scale treatment plants, integration, volume and current technology all contribute to the cost of treating PFAS.

Table 1. Quantified Costs of Final PFAS NPDWR.

The Final PFAS NPDWR Will Cost	Annual Quantified Costs Once Fully Implemented
Water System Monitoring	$36 million
Water System Treatment and Disposal	$1,506 million
Water System Administrative	$1 million
Primacy Agency Implementation and Administration $ 5 million	$5 million

This table shows the quantified costs of the final rule. The EPA expects there are additional non-quantified costs that are not included that may result in other increased and decreased costs once the rule is fully implemented.

"The challenge is market education," said Bolliger (Element Six). "There's a lot of people making different claims and sorting through what matters and what doesn't is very important. There's no easy way to compare economics or cost in general, because application is going to be so different. People try to come up with easy metrics to compare it and I don't think those metrics work."

The PFAS molecule comes in many different shapes and sizes.

"These wastewaters that one has to deal with that are impacted by PFAS basically come from an infinite number of sources and come in an infinite number of formats," said Melrose.

Unfortunately, there's no one-size-fits-all approach to PFAS destruction, a sentiment echoed by both Melrose and Bolliger.

A medium sized water treatment plant may prefer boron doped diamond EC technology to destroy PFAS in drinking water, while a smaller utility may prefer foam fractionation to skim PFAS and send it to an incinerator to be destroyed.

Ultimately it will be up to the utilities to research the different collection and destruction methods to figure out what works best for their system and budget. ●

Table 2. Quantified Health Benefits of Final PFAS NPDWR.

The Final PFAS NPDWR Will Prevent	Annual Quantified Costs Once Fully Implemented	Number of Avoided Illnesses and Deaths Once Fully Implemented
Developmental Effects	$209 million	1,300 deaths
Cardiovascular Effects	$607 million	3,700 deaths and 15,600 illnesses
Kidney Cancer	$354 million	2,000 deaths and 7,000 illnesses
Bladder Cancer *(resulting from co-removal of disinfection by products with PFAS)*	$380 million	2,600 deaths and 7,300 illnesses

This table shows the quantified health benefits of the final rule. The EPA expects there are significant additional nonquantified health benefits that are not included but would result in a much greater number of avoided illnesses or deaths once the rule is fully implemented.

WASTEWATER DIGEST

STORMWATER SOLUTIONS

WaterWorld

ADVANCE TO TOPICS

The Dregs of Disposal

Fear of PFAS contamination established a ban of biosolids land application in Maine. Now wastewater professionals are feeling the pressure of biosolids piling up.

By Bob Crossen

A spike of shock rode up York Sewer District Superintendent Philip Tucker's spine as he read the news on April 20, 2022. Maine Gov. Janet Mills had signed L.D. 1911 into law banning land application of biosolids across the state.

This moratorium on land application was driven by fear about the latest contaminant of concern in Americans' water: per- and polyfluoroalkyl substances (PFAS). The family of thousands of man-made chemicals had become a target for U.S. EPA, resulting in a multi-year PFAS Strategic Roadmap, promulgation of drinking water regulations and research into risks of PFAS across the water cycle.

As the emotion of the moment subsided in Tucker, his mind turned to the options available for his wastewater system.

"Biosolids operate on a three-legged stool," he said. "You have incineration, land application, and landfill. But we don't have incineration in Maine, so we only had two legs on that stool, and now we're kind of balancing on one with landfill."

The issue of PFAS in biosolids is further complicated by the emotional reactions to them and the language in mass media referring to them as "forever chemicals." Those emotions compete with the reality of available and proven technologies for treatment.

WASTEWATER DIGEST

STORMWATER SOLUTIONS

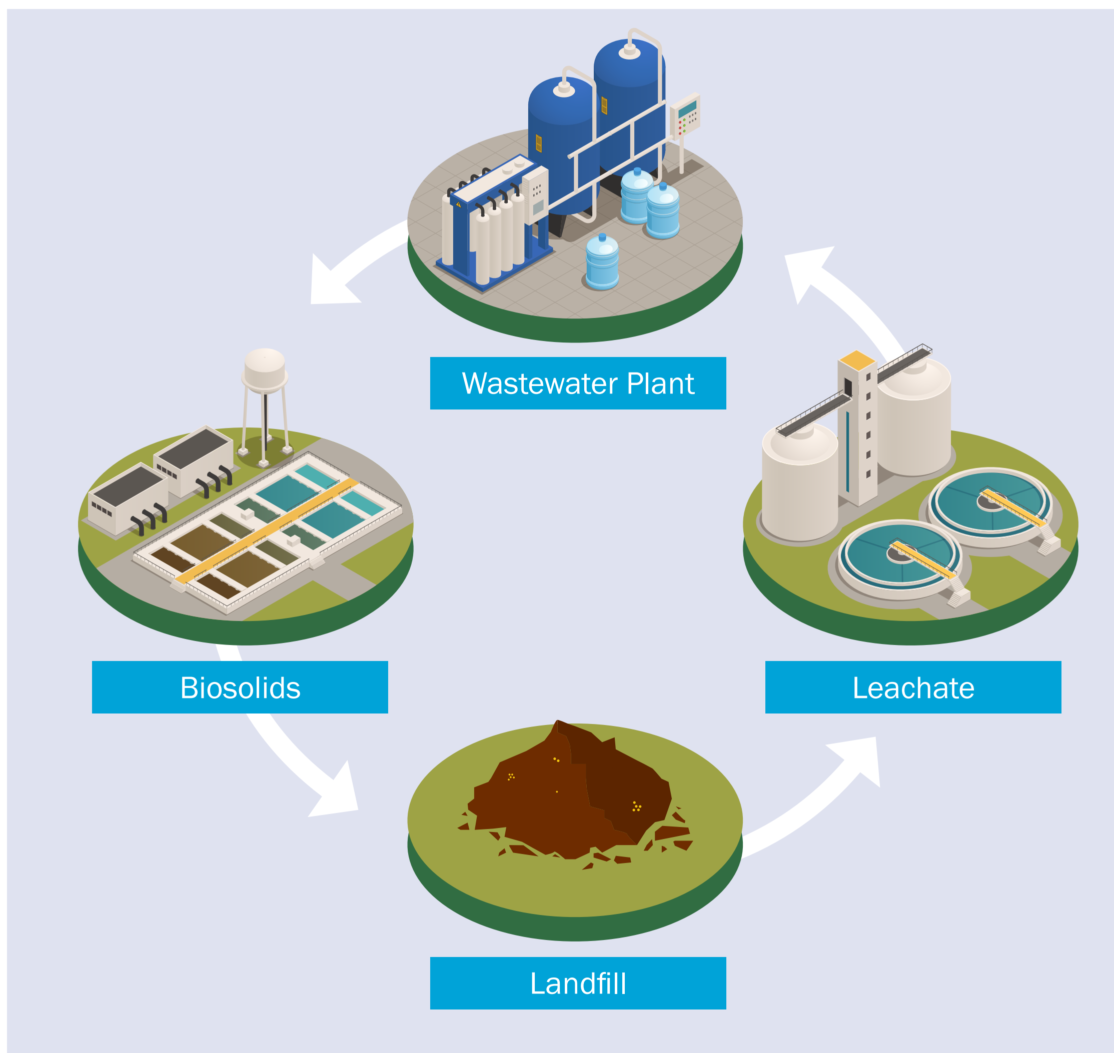
WaterWorld

ADVANCE TO TOPICS

Landfills across the state of Maine refused biosolids dumping due to liability and regulatory concerns. In fact, only one state-run landfill still accepts biosolids in Maine, but it warns of reaching capacity in 2028.

"Everybody seems to think that the crisis is over, but we've only got less than four years left," Tucker said, referring to that capacity date. "The landfill's going to be full in 2028 without an expansion. We have a big problem that's going to take a lot longer than four years to solve."

Consider also the impact of stormwater runoff at those landfills. That runoff — along with simple decomposition — creates leachate, and that leachate then enters the collection system that is diverted to the wastewater plant. It creates a cycle in which PFAS in the landfill then circle back to the wastewater system, then into biosolids, and back to the landfill.



Technology advancements and studies have shown promise for destruction of PFAS chemicals in waste streams to eliminate them entirely, but then arrives a new question: what about air regulations? While no federal air regulations exist regarding PFAS emissions, U.S. EPA did publish a test method — OTM-50 — in February of 2024, setting the stage for air quality monitoring and potential future regulation.

Combine those matters with U.S. EPA's work on a Risk Assessment of PFAS in Biosolids (expected to be published in the fall of 2024), its final rule for adding PFOA and PFOS as hazardous substances under the Comprehensive Environmental Response and Liability Act (CERCLA), and guidance on using current NPDES permitting rules to reduce upstream industrial discharges into sewer systems, and the complexity starts to make wastewater professionals heads spin.

"It's no secret. It's in the wastewater. It's in our blood streams. It's in the biosolids. Now it's really about trying to understand what is safe, what is an acceptable level, because it's not going to be practical to destroy all biosolids and not land-apply," said Eric Spargimino, CDM Smith environmental engineer.

Perhaps most surprising, the monitoring data from utilities in Maine and in Water Research Foundation studies suggest industrial discharges may not be the largest PFAS loading threat. Regardless of where the chemicals come from, they still end up in the biosolids at municipal plants.

But what happens when the biosolids have nowhere to go?

THE BIOSOLIDS CRISIS IN MAINE

While early in his wastewater career in Maine at the time L.D. 1911 was signed, Tucker said he felt shocked when the land application moratorium became law. On the flip side, Scott Firmin, director of wastewater for Portland Water District, saw the wheels had been set in motion years prior.

In 2016, Maine Department of Agriculture, Conservation and Forestry (DACF) investigated high levels of PFAS found in milk from a dairy farm in Arundel, Maine. Maine Centers for Disease Control set an action level for 210 parts per trillion (ppt) in milk in response. Thereafter, another farm in Fairfield, Maine, was identified to have elevated levels in 2020, one year before U.S. EPA would establish its PFAS Strategic Roadmap.

These two moments in Maine kickstarted a course of action to address PFAS across the state, particularly on farmland, which commonly uses biosolids as fertilizer.

"That seemed to have elevated the concern about biosolids, where it was no longer potentially implicated in the southern Maine farm; that they were starting to see other farms as well," Firmin said. "Biosolids were not the only materials land applied. There was also paper mill waste and other materials."

Firmin said the state adopted limits for PFOA in soil in 2018, but stopped short of using those limits to regulate biosolids or land application at that time.

Around one year later, Firmin and his wastewater colleagues were attending Maine Ski Day, an event in which the attendees gather to network, discuss industry issues and then ski together for teambuilding. At 3:32 p.m. on the Friday of that trip, Firmin recalled Maine Department of Environmental Protection sent an email to wastewater systems throughout the state.

"That email said until you complete testing of your biosolids and your compost, there will be no land application and no distribution of compost materials," Firmin said, noting it put a damper on the networking event and ski trip. "The tone changed at 3:32."

Maine DEP provided training on proper sampling and shared information on labs where those samples could be tested and reviewed. Ultimately, he said most utilities in Maine exceeded the standards. The Maine PFAS Task Force was commissioned by Gov. Mills in 2019, on which Andre Russo from Samford, Maine, was the voice of wastewater utilities.

By November of 2021, the state legislature had caught hold of the matter and began developing legislation that would place a moratorium on land application of biosolids across the state. This language became L.D. 1911 and was signed into law in April of 2022.

Seemingly overnight, utilities changed processes and began hauling all their biosolids to landfills. Between regulatory matters and capacity concerns, many of the biosolids at the height of the crisis were taken to Canada; a showcase of just how quickly the dominoes tumble out of control.

THE DOMINO EFFECT

According to data from U.S. EPA's Enforcement and Compliance History Online portal, land application accounted for 56% of biosolids use and disposal in 41 states across the United States in 2022. It is a long-standing, nationwide practice that provides low-cost fertilizer to farms while also disposing of the solids resulting from wastewater treatment processes in a recycled and sustainable manner.

BENEFITS OF BENEFICIAL REUSE

A 45-year review of land application of biosolids in Colorado published in *Journal of Environmental Quality* from authors James A. Ippolito and Ken A. Barbarick found biosolids land application has "led to long-term tracking of micronutrients and heavy metals in soils and revealed that plants–soil concentrations will not lead to groundwater degradation and that plants are safe for human consumption." Articles with similar findings are abundant, but there are also many studies that express a degree of caution for the practice of land application.

For example, in the article "Land Application of Biosolidsin the USA: A Review" from Applied and Environmental Soil Science, authors Qin Lu, Zhenli L. He and Peter J. Stoffella concluded that "caution needs to be exercised when biosolids are repeatedly applied or at heavy application rates as heavy metals, organic pollutants, and pathogens in biosolids, though at low concentration, may pose a threat to the environment and animal and human health with time."

Despite the potential downsides, wastewater professionals across the country recognize the importance of biosolids land application to their communities, local farmers and the wider economy. Land application allows for recycled use of a waste product and often is a cheaper alternative for farmers seeking to fertilize their land.

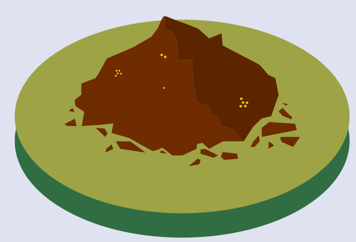
"They're just a sustainable source of nutrients for the world, a world that has a limited phosphorus supply," Spargimino said, "and with phosphorus being one of the key parts of life on Earth, it's hard to imagine destroying all our biosolids."

WASTEWATER SYSTEMS

In 2022, U.S. EPA estimated wastewater systems managed **3.76 million dry metric tons** (DMT) of sewage sludge:

- **2.12 million DMT being land applied**
- **600,000D DMT being incinerated**
- **1 million DMT being landfilled**

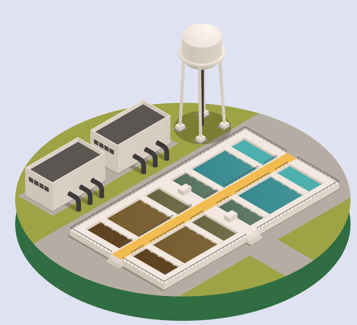
LAND CATEGORIES



The land applied tons were split into three categories:

1. **Agricultural land:** 1.17 million DMT
2. **Reclamation areas:** 39,000 DMT
3. **Others** — such as home gardens, golf courses or for landscaping use: 906,000 tons

LANDFILLED BIOSOLIDS



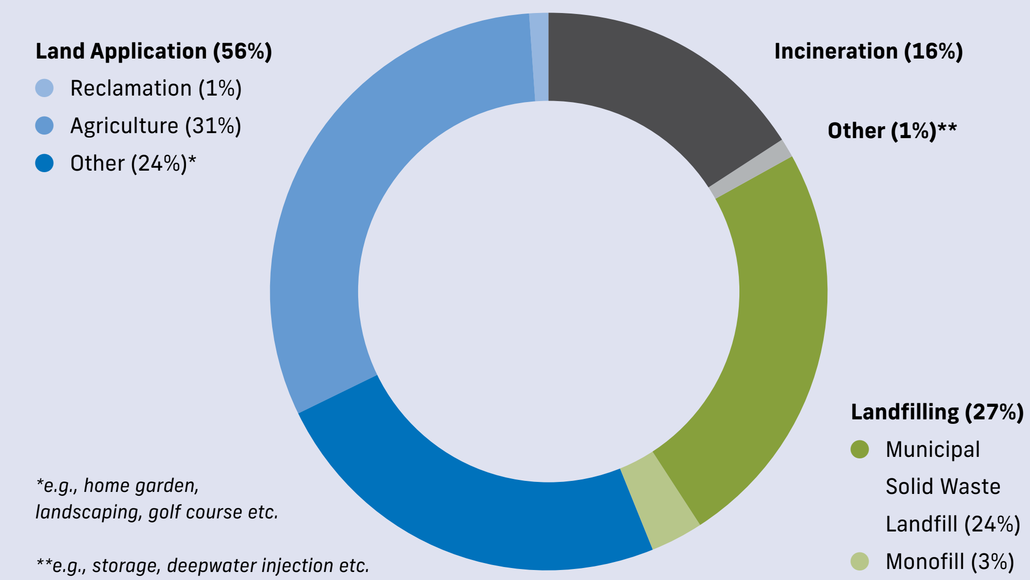
The landfilled biosolids were split between two options:

1. **Municipal solid waste landfills:** 895,000 DMT
2. **Surface disposal in a monofill:** 111,000 DMT

The data from EPA indicate that 2.12 million dry metric tons of biosolids were land-applied in 2022. By comparison, 600,000 dry metric tons were incinerated, and 1 million dry metric tons were landfilled.

Western Virginia Water Authority estimates biosolids save $350 per acre compared to fertilizer for farmland soil. A USDA report from 2022 indicates there were a total of 895 million acres of farmland in the U.S. in 2021. If every farm applied biosolids to their land and realized the savings listed per acre by WVWA, it would amount to $313.25 billion. While that is a reductive and oversimplified exercise, it nonetheless shows that the impact of a nationwide ban on land application would be greatly felt, even if only 10% of that figure were the actual realized savings.

Biosolids Use & Disposal from 2022 Biosolids Annual Reports



Source: Basic Information About Biosolids | U.S. EPA, www.epa.gov/biosolids/basic-information-about-biosolids

Were land application to be removed from the neighboring chart, the volume of biosolids now needing to be incinerated or landfilled would more than double. Biosolids provide a high supply of both nitrogen and phosphorus needed to increase farm yields, but those nutrients are a finite resource on Earth.

ADVANCE TO TOPICS

Eliminating the land-application option knocks over the first domino in a series that tumbles through issues relating to agriculture, food supply, human development and nutrition, and economies at local, state, regional and national levels.

Wastewater professionals and industry leaders have warned of this effect while also posing another major question: what else do we do with them?

MICHIGAN'S TIERED SCREENING APPROACH

Since Maine's moratorium on land application took hold, a handful of other states have taken efforts to regulate the practice of biosolids land application.

Connecticut has banned land application and Illinois has proposed a bill for a ban. Michigan, Wisconsin, New York and Colorado have source control screening levels, and 11 states — California, Washington, Oregon, Minnesota, Vermont, New Hampshire, Massachusetts, Pennsylvania, Virginia, Maryland and North Carolina — all are monitoring PFAS in biosolids or wastewater systems.

To give a better idea of source control screening, Michigan took a tiered approach for PFOA and PFOS concentrations in biosolids with four tiers.

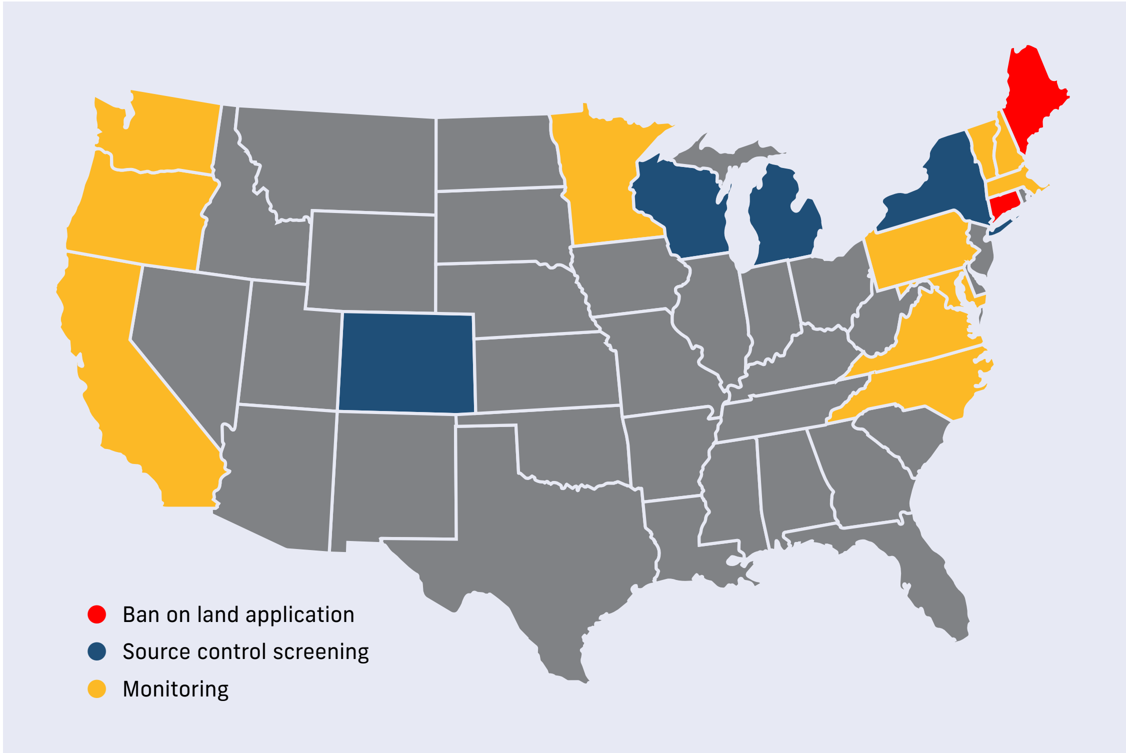
1. No land application if the concentration exceeds 100 parts per billion.
2. Source control is required, and land application is limited for concentrations exceeding 20 parts per billion.
3. No land application restrictions for concentrations lower than 20 parts per billion.
4. Biosolids may receive "Exceptional Quality" eligibility if the combined concentration of PFOA and PFOS is less than 20 parts per billion.

This model, Firmin said, is one that could be useful on a national scale following EPA's release of its risk assessment of PFAS in biosolids. Michigan tiers initially had higher concentration levels for each tier, but through source control the state was able to reduce them to the numbers listed above. This approach is one Firmin said he hopes to see U.S. EPA put forward.

"That's what we're hoping, so the whole nation doesn't have the bounce-off-the-windshield reaction that Maine had," Firmin said.

MONITORING REVEALS A UNIVERSAL THREAT

Spargimino (CDM Smith) also noted the source control efforts in Michigan that have reduced PFOA and PFOS loading into wastewater systems. Research and studying have illuminated means of identifying the compounds.



What Spargimino and others have found in studying PFAS concentrations are what he referred to as "fingerprints." PFAS are a family of chemicals, and each can have a distinct signature. Through studies and testing, Spargimino said researchers have been able to identify the signatures for certain wax papers, firefighting foams, and even dry-cleaning chemicals. When comparing these signatures to monitoring data in the collection system, utilities can lock onto industrial permitting targets.

"You can hone right into maybe a particular business," he said, noting that a conversation with that business could result in a change in chemical usage that may reduce the PFAS loading into the sewer, the treatment plant, and ultimately the biosolids at the end.

Spargimino's example points more toward industrial discharges where enforcing discharge permits can make a difference.

But for some communities, even after those enforcements, results have not moved the needle enough. Both Firmin (Portland) and Tucker (York) said monitoring data identified residential flows as a major contributor to their wastewater system's PFAS levels. This assertion is one Spargimino also noted.

"In one community where we worked on a Water Research Foundation project," Spargimino said, "almost half the load to the plant of total PFAS was from residential sources."

He said Water Environment Federation and the Northeast Regional Biosolids Association have taken charge of developing communications best practices to educate residents and communities about how they inadvertently contribute to PFAS contamination.

"We might only get halfway to solving the problem by putting in limits," Spargimino said. "The other half is going to be just educating the individuals on their consumer choices."

UTILITIES POSITION FOR THE FUTURE

Back in Maine, Firmin and Tucker each have been involved in conversations with engineers and solutions providers on options to remediate, manage and either dispose or destroy biosolids laden with PFAS.

For York, Tucker said his utility has partnered with a California company called Beyond the Dome, which offers a super critical water oxidation technology, and he expects equipment to arrive in the middle of 2026. The company is currently piloting the technology, but the science appears clear in its effectiveness.

"The technology absolutely will destroy PFAS," Tucker said. "They've been using it for decades to destroy chemical and biological weapons, and now we're trying to apply it to biosolids. The potential is there to reduce our volume by up to 90%."

Tucker said even if the figure is closer to 50% reduction in volume of biosolids, it would make a considerable difference in the utilities efforts to dispose of biosolids. He said the company is also looking into phosphorus recovery in the destruction process, which is ideal given the phosphorus need at farms.

Meanwhile, in Portland, Firmin said the utility has developed a Biosolids Master Plan, which includes investigating technology options and alternative solutions to biosolids disposal and destruction. One of the other critical components identified in the plan is the need for an on-site primary sludge mesophilic anaerobic digester, which would reduce the total mass of biosolids that need to be disposed or destroyed.

In attending conferences, Firmin also said recent information on drying and incineration has been encouraging, and the same could be said for gasification and pyrolysis. In either case, the cost is still a hurdle, but because the data show so much promise, the utility can begin to ask questions about permitting.

The utility is also looking to do right by its colleagues across the state by exploring the idea of developing a 120 ton per day facility that could provide a regional outlet for biosolids destruction with gasification and pyrolysis.

IN THE COURT ROOM

To recoup capital expenses relating to PFAS treatment, remediation, disposal and destruction, utilities have turned to lawsuits against the original manufacturers of the problem chemicals.

SL Environmental Law Group has filed a lawsuit on behalf of York Sewer District in October 2023 against manufacturers of per- and polyfluoroalkyl substances (PFAS). The suit targets 3M Company, E.I. DuPont de Nemours Inc., and other manufacturers.

In June 2024, that same law firm is also representing PWD in a suit brought against the same manufacturers.

"There aren't a lot of things we can do. This is one thing we can do that allows us to take action," Firmin said. "It gets us in line if there's a settlement but also publicly, it sets the tone."

Elsewhere in Maine, a waste management dryer is being considered in Norridgewock, Maine, which would renew an old digester facility and there also is a possibility of a pyrolysis facility in Brunswick, Maine.

CONCLUSION

There is much still left uncertain about PFAS in biosolids, their fate, disposal, and their destruction. But it has not stopped the professionals on the front line from tackling the problem head-on. They recognize the stakes at play.

Wastewater plant directors from other areas of the country see the issues in Maine and worry about the long-term approach to PFAS removal, disposal and destruction. Above all, they hope for one that does not burden a future generation with another problem as complex as the one they are dealing with today.