xylem
Let's Solve Water

Focusing on Resilience in the Face of Emerging Contaminants

Resilience is a strong emerging theme within the water sector.

There are over 150,000 public drinking water systems in the United States and more than 80 percent of the population receives their potable drinking water from these systems. And today - according to the EPA, our water systems are faced with a growing list of challenges.

In particular, the water utility industry is facing challenges with respect to emerging contaminants, including issues of public confidence, monitoring, treatment and affordability, as regulators move to issue new water quality requirements at both the federal and state levels. This can lead to a lack of clarity both for water industry professionals, but also the public at large. These information gaps can lead to misinformation, skepticism, and even paranoia. Clear, concise, scientific driven data and directives that are effectively communicated can provide the water industry and the public with the knowledge of what the challenges are, where they exist and how to build resilience against them. We aim to achieve that for you, the reader, in the following pages.

In March 2020, America's Water Infrastructure Act (AWIA) began requiring community drinking water systems to develop or update Risk and Resilience Assessments (RRAs) and Emergency Response Plans (ERPs) if the systems serve more than 3,300 people.

In response, water technology providers are on the frontlines of helping utilities reduce their risk and improve their overall resilience through monitoring, management and treatment solutions to eliminate contaminants of emerging concern and rebuild trust with customers.

The evolving nature of emerging contaminants

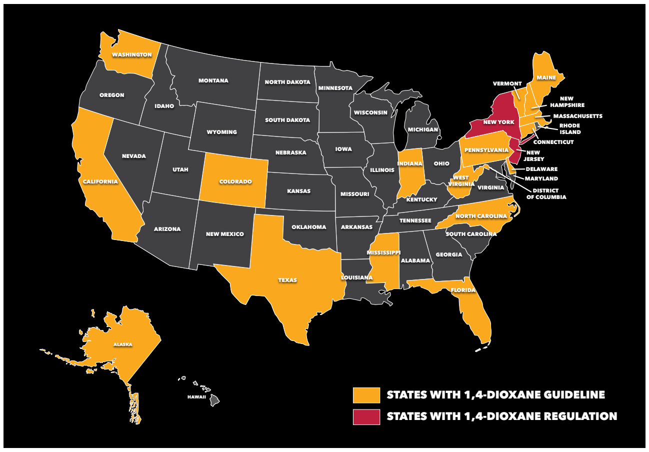
With advances in testing and health research, experts are learning of new potential dangers in our drinking water. Sometimes chemicals that had not previously been detected (or were previously found in far lesser concentrations) are discovered in the water supply. These chemicals are known as "contaminants of emerging concern" or simply "emerging contaminants."

The United States Environmental Protection Agency (USEPA) leads the federal charge to ensure our citizens' public health is protected via the Safe Drinking Water Act (SDWA). As part of SDWA, the USEPA will add emerging contaminants to their Unregulated Contaminant Monitoring Rule (UCMR) to understand the prevalence of the contaminants. If during the sampling period, the USEPA determines the emerging contaminants on the UCMR are a threat to public health, they will add the contaminants to the Contaminant Candidate List (CCL) with the intent of providing a federal regulation.

Emerging contaminants can now be detected at trace levels but even at these very small amounts can pose a chronic health risk. For the most part, they are not yet federally regulated as they move through the USEPA evaluation and rule-making process. The list includes pharmaceuticals, personal care products, pesticides, herbicides and endocrine-disrupting compounds.

Prior to the emergence of these contaminants, municipal source waters were relatively clean and, for the most part, required minimal levels of treatment followed by disinfection. Stringent new drinking water standards to address these potent compounds demand more innovative treatment approaches.

Increasing levels of micropollutants pose a significant challenge for drinking water treatment plants drawing from source waters, and often need to be removed to protect both human health and aquatic species. But many of these manmade chemicals are not found naturally in the environment and do not go away or break down, earning them the nickname – forever chemicals. We will explore two emerging contaminants that have sparked state regulations and budding interest at the federal level – 1,4-dioxane and PFAS.



1,4-dioxane

One of the most complex emerging contaminants is 1,4-dioxane, a compound that was typically used as a stabilizer for chlorinated solvents. A toxic substance, 1,4-dioxane is considered a potential threat to human health, and the USEPA has classified it as a probable human carcinogen.

The presence of 1,4-dioxane in water sources is gaining the attention of regulating bodies and the media. Recent advances in analytical tools and the requirement for public drinking water systems to test for them as part of UCMR 3 have confirmed the presence of 1,4-dioxane in drinking water sources. In fact, as part of UCMR 3 over 1,000 water systems detected 1,4-dioxane. This, along with the better understanding of the potential health effects of 1,4-dioxane, has created additional pressure at the removal of this contaminant from drinking water.

Regulations - Although no federal maximum contaminant level for drinking water has been established, the EPA has identified 1,4-dioxane as a likely carcinogen and issued a cancer risk level of 0.35 µg/L (parts per billion) in 2013. Currently, 19 states have established drinking water guidelines and New Jersey and New York have imposed enforceable regulations.

Even though there is currently no federal regulation limiting 1,4-dioxane under SDWA, many states have taken it upon themselves to protect public health and utilities have begun piloting treatment solutions to remove this contaminant from their community drinking water supply.

Treatment Options to Protect Public Health - Because its chemical makeup doesn't readily break down, most conventional technologies are not effective in treating 1,4-dioxane. As regulatory actions and public concerns about emerging contaminants grow, municipalities are exploring better, more cost-effective treatment options. The use of advanced oxidation process (AOP) has proven to be a viable approach to treat 1,4-dioxane and other contaminants. AOP is the combination of two or more processes to generate or increase the number of hydroxyl radicals (OH radicals). These OH radicals contribute to the oxidation of undesirable substances and have a considerably higher oxidation potential compared to other oxidants.

Once hydroxyl radicals have formed in water, they immediately react to virtually all existing oxidizable substances. The high degradation performance and the quick reaction kinetics of this process are the formula for success when it comes to eliminating numerous persistent contaminants.

Flexible solutions are available that combine the key components of ozone, hydrogen peroxide, UV light and chlorine in various combinations. The choice of treatment technologies depends on the target contaminant and onsite conditions, such as footprint, flow rate, and energy costs. Three proven AOP combinations for treating 1,4-dioxane include:

Ozone + Hydrogen Peroxide

In the presence of hydrogen peroxide, ozone reacts with the anion of the hydrogen peroxide, and creates hydroxyl radicals. This reaction is quicker and more effective than the reaction of ozone alone in water.

UV + Hydrogen Peroxide

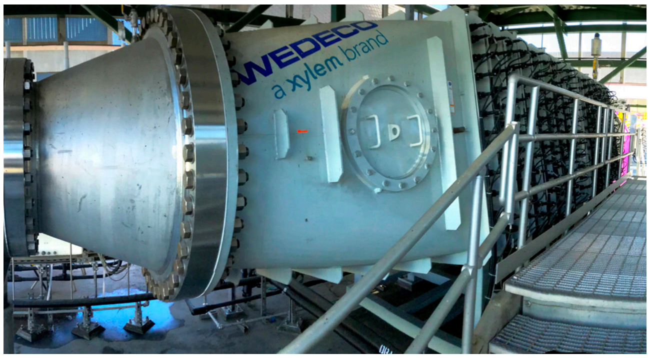
In this process, the electromagnetic irradiation (UV light) is absorbed by the hydrogen peroxide dissolved in the water. In theory, this process leads to the formation of two OH radicals, made from one H_2O_2 molecule.

UV + Chlorine

At low pH, chlorine reacts with UV to create hydroxyl and chlorine radicals. In some cases, this combination may be more cost-effective and implementable than peroxide.

Choosing the Right Treatment Option - Water technology providers like Xylem focus on a solutions-based approach that evaluates which of these combinations can deliver the performance required to address each water utility's particular challenges at the lowest possible cost.

The ability to provide an integrated solution is rooted in a strong, well-resourced applications team supported by a full laboratory and fleet of AOP pilots. This allows the technology provider to test any combination of the AOP systems mentioned in advance of a full-scale design. The next step is to custom-design the AOP process to complement the existing process and ultimately ensure maximum reliability with the highest possible efficiency. Leading water technology providers offer a comprehensive suite of AOP treatment solutions and are key partners in implementing a system – taking the project from lab testing through onsite piloting and into full-scale implementation, including process guarantees.



The key to selecting the best AOP solution is to find the right combination of these processes to most efficiently generate hydroxyl radicals that reduce the target contaminants. The best AOP for a facility's water treatment needs depends on many factors including:

- The concentration of 1,4-dioxane in the water
- Treatment target concentrations, including regulatory requirements
- The water matrix, including parameters such as pH, TOC, DOC, COD, alkalinity and more
- Upstream and downstream unit operations in the overall treatment train
- Site-specific energy and chemical costs
- Available footprint for new technologies

The Importance of Treatability Testing - Nothing is more important than proving selected AOP treatment processes will work as required. But water quality matrices are site-specific and using historical experience alone often isn't enough to provide that level of certainty. That's why laboratory, bench scale and pilot testing of processes are key tools in the design process.

In addition to providing the certainty that the chosen process will work, bench scale and pilot plant testing provide extremely valuable data regarding sizing, energy requirements, reliability, flexibility, and even ease of operation.

Bench Scale Testing

Laboratory testing and bench scale work can provide valuable data on treatability, chemical usage, UV dose, ozone dosage and selection of the right advanced oxidation process and operating parameters.

A broad array of laboratory resources and bench scale testing is available for a number of different processes to assist with process selection and design. Laboratory and bench scale applications include advanced oxidation (ozone / UV and peroxide) dose testing, biological treatability studies, UV dosage response curves, ozone treatability testing and dose response curve, and filtration studies.

Pilot Scale Testing

On-site pilot plant testing can further demonstrate the effectiveness of treatment at a facility. In particular, pilot plant testing can help ensure that a system is properly sized, preventing over-designing and wasting capital, or under-designing and risking non-compliance.

In many cases, full pilot plants can be set up on site for advanced study of a customer's particular problem. These compact units come containerized for easy transport and set up. Examples of available pilot plant testing units include UV disinfection, ozone oxidation and advanced oxidation processes, biological filtration, sand filtration, and, of course, combinations of these processes.

These pilot plants enable the engineers to confirm treatment feasibility, as well as test operating scenarios, gather data for proper sizing and fine tune the capital investment costs and operating requirements. The customer gains a better understanding of expected treatment outcomes, as well as capital and operating costs.

Expertise at work - Teaming with application experts at established water technology providers like Xylem not only offers access to treatability testing resources, but also an abundance of historical project experience to expedite the course of 1,4-dioxane remediation projects. Generally speaking, when discussing 1,4-dioxane remediation, the focus is on three areas: the ultraviolet transmittance of the water stream, the scavenging potential of the water quality matrix and the dose response of 1,4-dioxane to the AOP process applied.

Ultraviolet Transmittance (UVT)

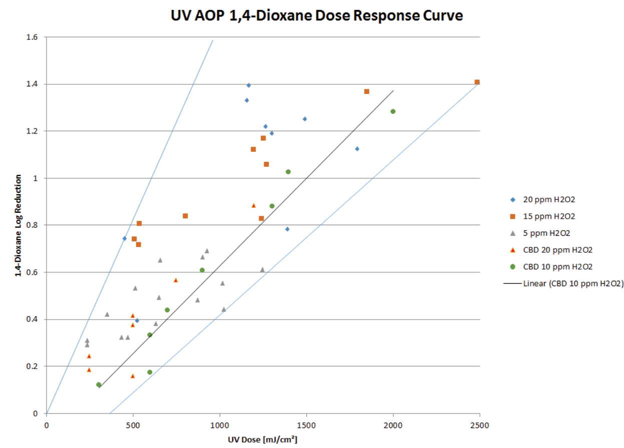
UVT is a measure of the effective penetration of UV light through the water stream. The value is represented by a percentage that indicates how much light would effectively pass through a 1 cm vial of water. By and large, the higher the clarity of the water, the greater the UVT. Water streams with very high UVTs (i.e. typically >90% and definitely >95%) are a better fit for UV AOP because of the more effective nature of UV light hydroxyl radical formation. However, in water streams with lower UVTs (i.e. <90%), it is valuable to consider both UV AOP and Ozone AOP as ozone's efficacy can be greater than that of UV in these conditions.

Scavenging Potential

The term "scavengers" is defined as "a constituent that consumes or renders inactive the chemicals in a mixture." When utilizing AOP for 1,4-dioxane remediation, scavengers do just that. They consume and compete for the attention of the hydroxyl radicals generated from the AOP process, reducing the efficiency of eliminating 1,4-dioxane. Some critical scavengers in a water stream that can require greater doses of UV AOP or Ozone AOP to remove 1,4-dioxane are dissolved organic carbon (DOC) and alkalinity. It is important to be aware if the presence of these items exist in the water stream (and if there is uncertainty, lab and pilot tests can be performed to determine the concentration of these scavengers) to best understand where on the dose response curve a project exists.

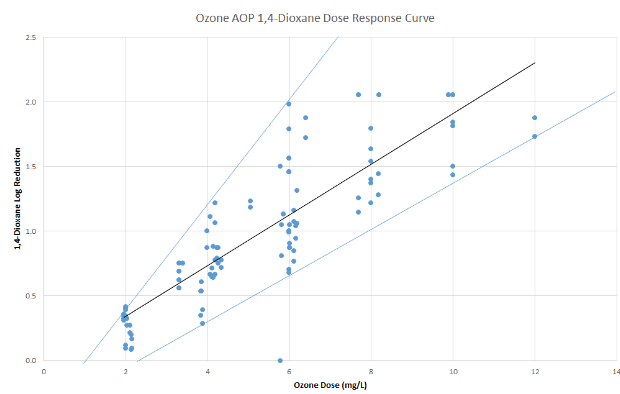
1,4-Dioxane Dose Response Curve

As mentioned above, every water stream is different and lab and/or pilot testing is suggested to best understand site-specific UVT, scavenging potential, and UV AOP and Ozone AOP dose response curves. However, with an abundance of 1,4-dioxane projects completed, Xylem has been able to compile a general dose response curve for both UV AOP and Ozone AOP. An example of a UV AOP dose response for 1,4-dioxane is shown to the right.



UV AOP dose response curve showing linear regression in the black line and band of typical dose responses in blue lines.

Again, water streams with higher UVTs and lower scavenging potential will be on the lower end of this band and systems with lower UVTs and higher scavenging potentials will be on the higher end of this band.
A general guideline for Ozone AOP dose response for 1,4-dioxane is shown below.



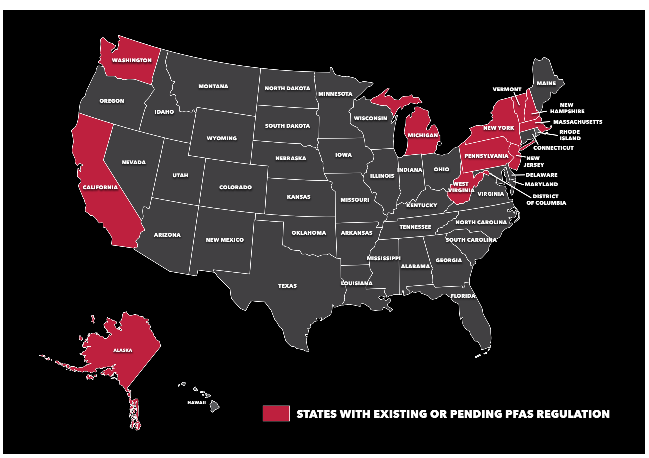
Ozone AOP dose response curve showing linear regression in black line and band of typical dose responses in blue lines.

The ratio of ozone to peroxide will allow the ability to shift up or down this band, but keep in mind that peroxide is also a consumable so just adding more peroxide may not always be the most cost effective option. This is why it's important to not only review the performance of different candidate AOPs, but also the economics of any of the candidate AOPs that demonstrate ideal performance.

PFAS

Due to their growing presence, persistence and adverse health effects, per- and polyfluoroalkyl substances (PFAS) are another family of emerging contaminants that have become major concerns for drinking water supplies nationwide.

PFAS are present in a wide range of consumer products and were once thought beneficial because of their ability to repel fire, water, oil and stains. They have been used in stain and water-resistant fabrics, non-stick products, polishes, pizza boxes, waxes, paints, cleaning products and fire-fighting foams. But many scientific studies have now linked these chemicals to various cancers, cholesterol diseases, pregnancy-induced hypertension and preeclampsia and thyroid disorders. These chronic health effects and the fact that PFAS are "forever chemicals" made it even more concerning that over 600 sites in the US identified PFAS family compounds during UCMR 3.



Regulations – The USEPA has set a guidance level of 70 ng/L (parts per trillion) for two particularly harmful PFAS chemicals – PFOA and PFOS. Furthermore, as of February 20, 2020, USEPA announced preliminary regulatory determinations for both PFOA and PFOS as part of CCL 4, which is a critical step as they plan to include regulations for these contaminants. In 2019, the USEPA released a PFAS Action Plan (EPA, 2019), thus increasing demand for the development of more efficient and cost-effective removal technologies. Additionally, many states have established guidelines and enforceable maximum contaminant levels for specific PFAS that are of concern in their area.

The Future of PFAS and Considerations to Make in Resiliency Planning – The widespread nature of these contaminants has made a strong need for identifying appropriate and resilient water treatment technologies that can be incorporated in existing drinking water facilities.

Low volatility and high water solubility makes it harder to effectively and efficiently remove these PFAS using many conventional treatment technologies. Once these chemicals have been spilled and are in the source water, they are there to stay.

Current options for drinking water treatment technologies to remove PFAS include granular activated carbon (GAC) adsorption, ion exchange (IX) and reverse osmosis (RO). Of these, GAC adsorption is the most common, with many water treatment facilities and industries already using it to remove other contaminants. Reverse osmosis and ion exchange are effective technologies, but they also are more expensive and intensive to implement. GAC as an adsorption technology is comparatively less expensive, but the media does need to be replaced once the adsorption sites are all occupied and reactivated or incinerated to fully remove/destroy the PFAS compounds.

As Xylem is a leader in both filtration technologies and water treatment application expertise, we are providing GAC adsorption solutions for water utilities now. The challenge can be that media specificity and type are very particular for the specific PFAS family compound you are trying to remove and in the event that concentrations of that compound are high, the media replacement frequency can be quite high. That is why beyond just supporting water utility customers today, Xylem is on the edge of innovation - seeking new technologies to improve the life cycle costs of PFAS removal for our utility partners for decades to come.

Ensuring drinking water resilience

As the municipal water sector becomes increasingly focused on a secure and resilient water supply, there is a growing emphasis on water quality and eradicating emerging contaminants.

Being resilient not only adds value to the public the utility serves, it also benefits the environment, gives utility owners peace of mind and has long-term economic benefits.

Xylem has the expertise and solutions to help utilities improve their resilience across the water cycle. Through implementation of innovative treatment solutions, utilities have the capacity to tackle the challenges emerging contaminants pose head-on, protecting our drinking water supplies and safeguarding the environment while lowering operating costs.

Xylem ['zīləm]

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com

XWP054 • Xylem Emerging Contaminants White Paper • 5/2020 • ACT

xylem
Let's Solve Water