JULY 2025

Water Innovations

A NEW GOLD STANDARD IN WATER TREATMENT

How Oxidation-Reduction Potential (ORP) Monitoring Improves Disinfection

PLUS:

PFAS Policy In 2025

Advances In Bioremediation

TABLE OF CONTENTS

JULY 2025

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Editor's Insight

Articles

Advertiser Index

FROM THE EDITOR

By Kevin Westerling
Chief Editor, editor@wateronline.com

A New Power Paradigm For Wastewater Utilities?

Renewable energy is great for the environment. Are power purchase agreements great for wastewater treatment operations?

Among the main (and many) challenges facing wastewater treatment utilities are keeping costs down and keeping operations online, while doing so in the most environmentally friendly way possible. One potential consideration to tackle all three is a power purchase agreement (PPA). PPAs are an increasingly popular mechanism for financing and developing renewable energy projects across a range of well-suited facilities, but wastewater treatment plants are especially ideal candidates. Perhaps most attractive, particularly in terms of feasibility, is that it comes without capital cost for putting the equipment — namely solar panels — in place.

To help explore the idea further, I interviewed Sage McLaughlin, business development manager at REC Solar, a 15-year energy industry and decarbonization veteran with previous experience at Trio (formerly Edison Energy) and Duke Energy. She earned a B.S. in communication studies from the University of Idaho and a certification in energy innovation and emerging technology from Stanford University, putting both to good use in the following Q&A.

Sage McLaughlin
REC Solar

What is a power purchase agreement, or PPA, and what are the benefits compared to traditional power supply?

A power purchase agreement is a contract between an independent power producer and a buyer, like a company or municipality. PPAs make it easier for organizations to adopt clean energy solutions by offering predictable energy costs without the complexity of system ownership or large upfront costs. Beyond design and installation, the energy provider may continue to manage the system throughout the agreement — REC Solar does so for 25 years — so customers can stay focused on their business while getting energy resilience and savings over the long term.

On top of that, pairing renewable energy with storage can reduce reliance on the traditional grid, thereby helping facilities to better manage demand and avoid costly energy peaks. For organizations with around-the-clock responsibilities, such as wastewater treatment utilities, it can be a long-term operational strategy that helps them control their costs and improve energy reliability.

What conditions must exist for a wastewater facility to be a good candidate for solar energy in particular?

Wastewater facilities are great candidates for solar when they have available space that can be creatively used for an array like rooftops, land, or parking areas. A supportive policy environment can always help, but with REC Solar's PPA model, customers don't actually need to navigate policy themselves. For example, in California specifically, pairing solar with storage is a no-brainer under Net Energy Metering 3.0, formally known as the Net Billing Tariff [governing how solar energy systems interact with the electrical grid]. And for many facilities, the value goes beyond saving money and into meeting sustainability goals, like California's 2045 target for carbon neutrality or the reduction of Scope 2 emissions [indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling].

The environment and community obviously benefit, but can you highlight with an example?

A previous project in California with the Central Contra Costa Sanitary District (Central San) on a 2.16-megawatt (MW) solar array eliminated 1,865 metric tons of carbon dioxide emissions annually, equivalent to removing 444 gasoline-powered vehicles

from the roads yearly. By shifting to this financing model, Central San is projected to save nearly $6 million in electricity costs over the system's lifetime.

What approvals or steps are typically necessary for the municipality to proceed with a PPA?

The process varies from city to city, but because PPAs are $0 down, municipalities typically have an easier time getting budgetary approval than for large capital projects. That said, we do look at current energy data and rates to make sure the process makes financial sense over the span of 20 to 25 years and that the customers see savings. We also want stakeholder engagement and buy-in, which we enjoy in California because we're based there and have been around for so long. Beyond that, we want to make sure the area is feasible, the interconnection can work, and that we take advantage of net energy metering (NEM) where available. Specific to California, Government Code Section 4217 allows California public agencies, including cities and special districts, to enter into contracts for energy conservation, generation, or purchase without a full formal competitive bidding process, cutting down time and administrative expenses on getting clean energy.

Are there any pitfalls to be aware of to ensure success?

There are a few things to be aware of as a company looking to implement solar into your operations that can get very confusing. First, we recommend working with a consultancy group and with partners who are in business for the long haul because projects run smoother with someone who is familiar with the local policy landscape and procurement processes. Also be aware of growth plans for the site. If you're moving tanks, growing, or need to do any cleaning or crane operations, you want to make sure those plans are taken into consideration with where panels will be, how much energy you'll need, and when you'll need it. Ultimately, solar often makes sense for many organizations with substantial energy loads and available land or rooftop space. ■

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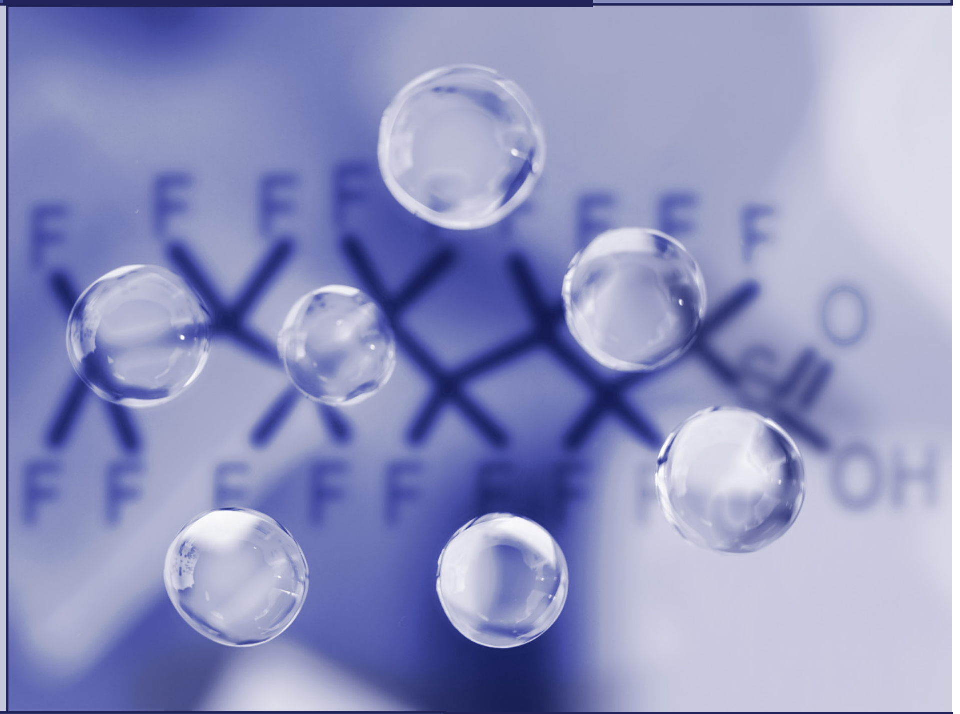


PFAS Policy In 2025: Why It's Time To Go Beyond Remediation

The most common techniques for disposing of PFAS may no longer be good enough.

By Simon Gatcliffe

In recent years, the phrase "forever chemicals" has become near synonymous with water contamination itself. Per- and polyfluoroalkyl substances — also known as PFAS — were once a popular additive to industrial and consumer goods thanks to traits such as resistance to stains, water, and heat. However, they have since become a key target of the U.S. EPA and other groups.

Much of this attention can be attributed to the powerful carbon-fluorine bond at the heart of all forever chemicals — one of the very strongest in nature — meaning that PFAS do not break down naturally. Throw in decades of widespread usage, and PFAS can be found at every stage of the water cycle — including 45% of the nation's drinking water[1] and maybe even your favorite beer.[2]

Combined with a growing bank of evidence linking PFAS to decreased fertility, developmental delays, and even cancer,[3] it's easy to see why PFAS are now such a hot topic in the water industry. However, with an increasingly complex legislative landscape — including some relatively recent changes — it can be hard to see the wood for the trees. What's more, with the total cost of cleanup settlements constantly on the rise, water operators need to be aware of the stakes at play.

The only way to be truly assured that a PFAS is not a risk is to destroy it.

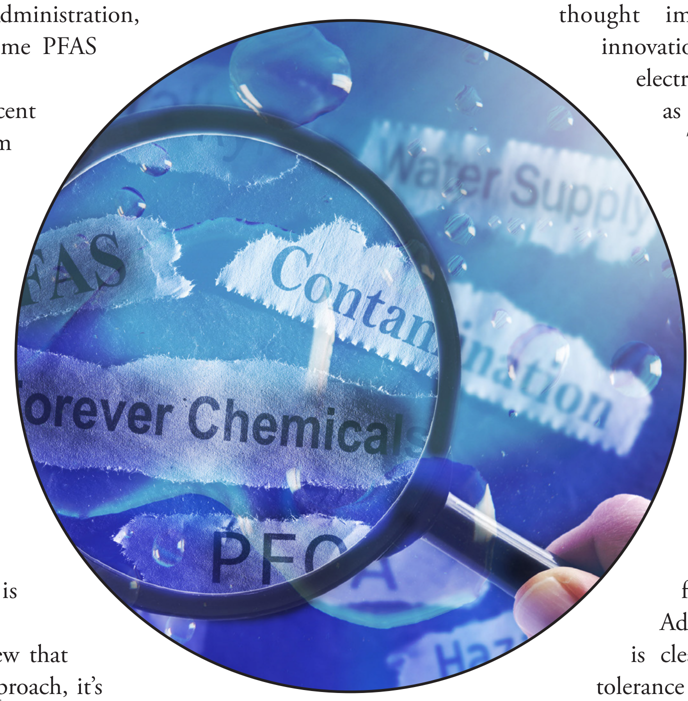
PFAS Under The Microscope

In April 2024, the Biden-Harris Administration introduced some of the most stringent PFAS regulations in the world in a landmark effort to tackle PFAS pollution in drinking water. Most notably, the EPA imposed maximum limits of four nanograms per liter for two of the most well-researched and widespread compounds under the PFAS umbrella — perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS).[4] This is the equivalent of just four parts per trillion.

Given that this is the lowest possible level at which PFAS can be physically detected, and coupled with a maximum contaminant level goal (MCLG) of zero, this demonstrates a zero-tolerance policy for PFAS, and that there is no level of accepted risk for these contaminants.

However, many readers with one eye on the news will be sure to note that this executive action has recently been subject to revisions from the Trump Administration, with a decision to maintain some PFAS limits but adjust others.[5]

This includes a wave of recent revisions that saw the maximum contaminant levels (MCLs) for PFOA and PFOS retained, but the compliance deadline for public water systems pushed back from 2029 to 2031.[6] The limits of 10 nanograms per liter set by the Biden-Harris Administration on four other chemicals — GenX, PFHxS, PFNA, and PFBS — have been rescinded and will be reconsidered, though this area is still recognized as a bipartisan issue and is broadly supported.



While some may take the view that this represents a softening of approach, it's important to note the wider context. Amid a wave of rollbacks on environmental policy from the Trump Administration, the fact that the limits for PFOA and PFOS have remained is significant in and of itself. These are still among the strictest PFAS regulations in the world, and the long-term outlook for these chemicals remains very much zero tolerance.

Act Now Or Pay Later

Regulations aside, the growing number of PFAS lawsuits may be enough to make anyone in the industry reconsider their position on forever chemicals. In the U.S. alone, nearly 10,000 court cases related to PFAS exposure have been filed in the past 25 years, with settlement fees already amounting to $16.7 billion and growing.[7]

And it's showing no signs of slowing down just yet. In just the past few months, a major farm in Maryland has been hit with a sizeable lawsuit,[8] while PFAS manufacturer 3M recently agreed to settle for an eye-watering sum of $285 million in this year alone, with the total possibly reaching $450 million over the next 25 years — the largest single clean-water settlement in New Jersey's history.[9]

Combined with a tightening regulatory landscape, there is now a renewed incentive to get ahead of the curve on PFAS management. However, it should be recognized that current PFAS remediation techniques may no longer be up to scratch.

For example, landfill and incineration — two of the most common techniques used to dispose of PFAS — simply move the problem from one place to another. Inevitably, this will lead forever chemicals to reenter the water cycle at a later stage, posing a significant risk of compliance.

Given the stringent limits on PFOA and PFOS in particular, such narrow margins for error cannot be left to chance. The only way to be truly assured that a PFAS is not a risk is to destroy it.

This is something that has, until recently, been thought impossible. However, years of innovation have led to the creation of electrochemical oxidation reactors, such as the Florenox™ range from Arvia Technology, that can destroy PFAS from concentrates. Florenox reactors feature a patent-pending advanced inert electrode material (Nyex.3™) that promotes the formation of highly reactive hydroxyl radicals that are capable of targeting and breaking the carbon-fluorine bond.

In this lies an opportunity to provide the best defense against tightening regulation and possible legal action. While further action from the Trump Administration may yet follow, it is clear that, despite some rollbacks, tolerance for PFAS is only heading in one direction and demands action. ■

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Simon Gatcliffe, CEO of Arvia Technology, has led the commercial growth and innovation of Arvia's solutions since 2020. In his role, he has provided guidance to organizations in life sciences and agrochemicals, and frequently participates in major industry conferences such as Aquatech, World Water Tech, and WEFTEC. He regularly advises businesses in the U.K. and internationally on navigating the challenges of water treatment.

Building Tomorrow's Water Infrastructure:

Insights From The Pacific Northwest's Largest Water Conveyance Program

A decade of collaboration and toil creates a pipeline to enduring water security.

By Erik Peters, Mike Warriner, and Scott Gibson

As water utilities across the country grapple with aging infrastructure, population growth, and increasing climate uncertainties, a major infrastructure initiative in the Pacific Northwest demonstrates effective approaches to meet these challenges. The Willamette Water Supply System (WWSS) — spearheaded by the WWSS Commission, a partnership of the Tualatin Valley Water District and the cities of Hillsboro and Beaverton, Oregon — is a $1.6 billion investment in resilient water infrastructure.

The Willamette Water Supply Program (WWSP) addresses multiple water system challenges through integrated planning and design. The system will deliver water from the Willamette River to the rapidly growing Tualatin Valley through a network of seismically resilient infrastructure. The system's cornerstone is a state-of-the-art, 60-MGD water treatment facility, designed with expansion capabilities to 120 MGD. This scalability enables the facility to meet both current demands and future growth without significant retrofits.

In addition to the water treatment facility, the program encompasses 13 major projects, including:

- More than 30 miles of large-diameter pipelines (66-inch and 48-inch) built to modern seismic standards
- A modified intake on the Willamette River
- A 15-million-gallon terminal storage reservoir on Cooper Mountain
- Ancillary facilities designed to enhance system reliability

When complete, the WWSS will be one of the most seismically resilient water systems in Oregon, engineered to withstand natural disasters, protect public health, and speed regional economic recovery by restoring critical services following natural disasters faster than ever before.

The project's scale and complexity required sophisticated construction-management approaches.

Managing Construction Challenges

The project's scale and complexity required sophisticated construction-management approaches. Carollo Engineers, in partnership with Stantec, provides both program-management and construction-management services, having secured the construction-management contract in 2017.

The construction-management scope includes oversight of the intake, treatment facilities, reservoirs, and large-diameter pipelines through a variety of jurisdictions. Some system components, including the reservoir and major pipeline segments, were constructed and tested up to three years before final system integration. Others, such as segments of pipe built to correspond with planned roadway construction — known as "opportunity projects" — were completed as much as eight years in advance. This phased approach allows for thorough testing and validation of each component while maintaining overall program momentum and limiting public disruption.

Community Buy-In

To mitigate community concerns about construction impacts such as traffic, noise, ground movement, and site access both during and after construction, program partners sponsored a coordinated public outreach program. A significant portion of the pipelines was originally routed through farmlands with no roadway access. By partnering with local government agencies such as Washington County, the Carollo/Stantec team modified the routing of some pipe reaches to parallel planned roadways to new developments. This significantly improved buy-in from local growers by minimizing impacts to their farms, while providing access during pipeline construction and for future maintenance.

To keep costs in check, maintain a rigorous schedule, and avoid potential rework the program employed specific contract language, and a detailed construction-sequencing plan aimed at seamlessly transitioning the work from one contractor to another.

A Focus On Local Participation

To boost the local economy, WWSP offered opportunities to as many local businesses as possible. Rather than hire a team of consultants and builders from outside the region, WWSP placed a high priority on giving those who live and work in the community the opportunity to contribute to this seminal project and share in its economic benefit. Efforts have included significant outreach to recruit local trades, contractors, and other businesses.

Bringing It All Together

Coordinating a major construction program so all components come together smoothly takes planning and skill. Key to success is implementing policies and procedures to streamline the construction process. For the WWSP, the strong emphasis on local business involvement resulted in participation of a larger than usual number of contractors. To keep costs in check, maintain a rigorous schedule, and avoid potential rework, the program employed specific contract language and a detailed construction-sequencing plan aimed at seamlessly transitioning the work from one contractor to another.

The commissioning process presented unique challenges, including testing a 15-million-gallon reservoir for leaks, connecting and flushing more than 30 miles of large-diameter pipe, and managing the associated water disposal. With construction completion now in sight, a comprehensive plan to address all interrelated program elements is more critical than ever. The commissioning team meets at least monthly to monitor construction and refine the plan to adjust to evolving issues.

> "This joint effort between contractors, program staff, and operators from three different owners is all coming together just as planned, with the first water deliveries to customers scheduled for early 2026."
>
> *–Tim Tekippe, Carollo Program commissioning and startup manager*

Measuring Success

Despite the program's complexity, it has evolved to adapt to shifting technical, regulatory, and economic issues over its 11-year duration, and work remains on track to meet the original 2026 completion date established in 2015. Plus, the overall program-change orders for the work currently stand at just 1%. This achievement is a testament to the discipline and technical acumen of the program participants. It reflects the soundness of the program objectives and the leadership of those dedicated to achieving them.

When complete, the system will provide exceptional finished water quality, improved water conservation measures, enhanced system safety, and greater source reliability and redundancy for the region's growing population. ■

About The Authors

Erik Peters is Carollo Engineers' director of construction management and operations. With more than 20 years of experience, he has overseen construction of more than $1 billion in water and wastewater facilities in the last five years, including the Willamette Water Supply System and large construction projects for San Diego, Nashville, and El Paso.

Mike Warriner, PE, CCM, is a senior vice president and a chief construction manager at Carollo, with experience in more than $2 billion in water and wastewater construction. As principal-in-charge for construction management of the Willamette Water Supply System, he offered lessons learned from working for project owners and construction contractors for more than 15 years prior to joining Carollo.

Scott Gibson, PE, is a vice president with Carollo, with 34 years of experience in the planning, design, and construction of water and wastewater projects. As design manager for the Willamette Water Supply Program, he is overseeing quality programs, design review, status reporting, plant operation, and change management.

From Theory To Precision:
ORP Monitoring As The New Standard In Water Treatment

On numerous levels, oxidation-reduction potential (ORP) outperforms the presently predominant metric for evaluating disinfection performance.

By Emma Flanagan

Ensuring microbiological safety in water systems is a top priority for municipal utilities, healthcare facilities, food processing, and industrial operations. Two widely recognized methods for assessing and controlling disinfection performance are the CT (concentration times time) method and oxidation-reduction potential (ORP) monitoring. While the CT method has long served as a regulatory benchmark, ORP monitoring offers a more dynamic, real-time, and integrated approach to managing water quality — especially in systems where precision and adaptability are critical.

Understanding CT Monitoring: Strengths And Limitations

For many years, operators have relied on the CT method to evaluate the success of their disinfection efforts. CT is determined by multiplying the disinfectant concentration (C) in mg/L by the contact time (T) in minutes. This product yields a numerical value used to assess whether the water treatment process meets established regulatory thresholds for pathogen inactivation. These thresholds vary depending on variables like water temperature and pH. For instance, achieving a 3-log (99.9%) reduction of *Giardia* at pH 7 and 10° C with free chlorine typically requires a CT value around 90 mg-min/L.

While CT remains foundational and regulatory in nature, its limitations become increasingly pronounced in dynamic or complex water systems. CT assumes steady-state conditions and requires detailed hydraulic modeling. It produces only a momentary snapshot of water quality based on periodic measurements. These values don't reflect how real-world water chemistry, such as organic load or fluctuating pH, can weaken or neutralize the efficacy of disinfectants. CT calculations also involve several interdependent variables, such as temperature, flow rate, and baffling factors, many of which may not be stable or accurately measurable in live systems. Because CT values must be evaluated after the fact, they offer little support for immediate decision-making or timely corrective action.

The method is inherently static. It reflects water quality conditions at the time of sampling but fails to capture fluctuations in flow, disinfectant residual, or temperature between data points. These information gaps can lead to inaccurate conclusions. Moreover, CT relies on complex calculations and precise instrumentation. Operators must assess effective contact volumes, system hydraulics, and baffling efficiency to derive meaningful CT values. Even with accurate data, this process is time-consuming and not well suited to real-time decision-making. CT is also pathogen-specific. Different organisms require different CT thresholds for inactivation. Operators must constantly adjust for potential threats, complicating the disinfection strategy. Finally, CT does not account for the strength of the oxidative environment or the presence of organic matter that can consume disinfectants before they contact pathogens.

Reading The Water's Pulse: ORP Fundamentals For Smarter Monitoring

ORP offers a radically different and more modern approach. Measured in millivolts (mV), ORP quantifies the water's tendency to either donate or accept electrons. In practical terms, it assesses the water's ability to oxidize contaminants such as bacteria, viruses, and protozoa. Unlike CT, which only captures theoretical dose and time exposure, ORP integrates the full range of oxidative and reductive influences in a water system. It reflects changes in pH, disinfectant type, temperature, and organic load — all of which influence disinfection strength.

Higher ORP values correspond with stronger disinfection potential. Research consistently shows that ORP levels above 650 to 700 mV are sufficient to inactivate a wide array of pathogens, including *E. coli* and *Legionella* pneumophila. Whereas CT calculates disinfection performance using indirect inputs and assumptions, ORP delivers real-time, direct feedback about actual water-quality conditions. This immediacy enables operators to make timely adjustments to chemical dosing, detect contamination risks as they develop, and maintain stable disinfection performance even in systems with variable water conditions.

What distinguishes ORP is its ability to reflect the total oxidative condition of the water. This is not limited to the presence of disinfectants — it also includes the impact of organic contaminants and reducing agents, such as ammonia, iron, and manganese. If these substances begin to deplete available oxidants, ORP will drop, alerting operators to diminished disinfection efficacy. CT monitoring offers no such real-time alert. Its reactive nature often results in problems being discovered only after the fact, when test results fail to meet standards.

ORP is also simpler to implement. It eliminates the need for manual CT calculations, complex modeling, or laboratory analysis. ORP sensors continuously stream data to digital interfaces and can be integrated into automated control systems. When ORP levels fall below a predetermined set point, chemical dosing can be automatically adjusted to restore optimal disinfection. This closed-loop feedback mechanism is ideal for facilities that require consistent and adaptable water-quality control.

Operationally, ORP offers several other advantages. It requires no calculations — operators simply read the sensor value. There is no need for contact tank modeling or estimation of baffling factors. This reduces training burdens and the risk of user error. ORP is also highly compatible with automation. Sensors can communicate with control systems and chemical dosing equipment, dynamically responding to spikes in contamination or changes in water chemistry. This precision reduces the need for over-dosing, conserves chemicals, and limits the formation of disinfection byproducts. In terms of microbial control, ORP provides a more predictive indication of performance. Research has shown that ORP levels reliably correlate with microbial inactivation across various disinfection agents, not just chlorine. Pathogens like *Legionella* respond more consistently to the oxidative strength of the environment than to calculated CT exposure, especially when biofilms are involved.

CT vs. ORP: Side-by-Side Comparison

FEATURE	CT MONITORING	ORP MONITORING
Data Type	Calculated (intermittent)	Measured (real-time)
Pathogen-Specific	Yes	No (general oxidative capacity)
Considers Water Chemistry	No	Yes (pH, temperature, organic load)
Requires Hydraulics Modeling	Yes	No
Ease of Use	Complex	Simple
Automation Ready	Limited	High
Response Speed	Delayed	Instantaneous
Disinfection Optimization	Reactive	Proactive

Time To Set A New Gold Standard — Here's Why

Although CT still dominates regulatory frameworks, particularly under the U.S. EPA Surface Water Treatment Rules, many facilities are shifting toward ORP for operational control. Hospitals, food production plants, and cooling-tower systems are increasingly using ORP thresholds as either a supplement or replacement for CT, particularly in environments where disinfection must be uninterrupted and highly effective. ORP's real-time nature is particularly valuable in systems prone to biofilm development or where oxidant-resistant pathogens may be present. *Legionella*, for example, often thrives in conditions where CT values suggest adequate disinfection, but oxidative strength is insufficient.

The ability to measure actual oxidative power rather than theoretical exposure time also supports better chemical management. CT-based disinfection often leads to overdosing as a buffer against uncertainty, which raises costs and increases byproduct formation. ORP-driven dosing strategies can maintain disinfection reliability while improving efficiency and sustainability.

In a side-by-side comparison, CT provides a retrospective, theoretical assessment based on ideal assumptions. ORP offers a forward-looking, real-time measurement grounded in actual water chemistry. For operators focused on preventing outbreaks, meeting compliance targets, and modernizing water-system management, ORP represents a superior method of monitoring.

Though CT remains embedded in regulatory protocols, ORP is increasingly recognized as the gold standard for practical, continuous monitoring. Facilities managing cooling towers, reclaimed water systems, and healthcare plumbing are setting ORP thresholds — often above 650 mV — as operational targets that ensure water remains disinfected regardless of CT data availability or variability.

In modern water systems where flow rates, temperatures, and contaminant loads can shift unpredictably, operators need more than theoretical models. They need real-time, integrative data to ensure water safety. ORP provides that insight. It empowers operators to respond with precision, manage risks proactively, and reduce reliance on outdated assumptions.

While CT monitoring has laid the groundwork for water disinfection standards, ORP delivers the clarity, speed, and adaptability that today's systems demand. Its adoption marks a shift toward smarter, more resilient, and data-informed water-treatment practices — ones that align with both operational efficiency and public health protection. ■

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Designer Microbes:

Can Synthetic Biology Supercharge Wastewater Treatment?

Exploring the potential of bioengineering as a pathway to pollution remediation.

By Christian Bonawandt

An ever-evolving number of challenging chemicals are entering the environment each year. While commercial and municipal wastewater technologies continue to advance as well, many of these chemicals continue to be difficult to treat and remove. These include long-standing industrial pollutants such as heavy metals (e.g., chromium, cadmium, lead, copper, zinc, nickel), various dyes, and hydrocarbons (like phenol, benzene, toluene, and more), as well as emerging contaminants including pesticides, pharmaceuticals (e.g., diclofenac, enrofloxacin, β-estradiol), microplastics, polychlorinated biphenyls (PCBs), and so many more.

Conventional physical and chemical treatment methods, such as sedimentation, filtration, and chemical precipitation, often fall short in effectively treating new and diverse pollutants. Meanwhile, traditional biological methods like microbial remediation and aerobic/anaerobic treatment processes struggle with incomplete breakdown of organic pollutants and limited suitability for many of these contaminants.

As such, many researchers are investigating the possibilities with synthetic biology. In the past few years, researchers have engineered microbes, including varieties of bacteria and algae, that can break down or neutralize specific pollutants such as heavy metals and hydrocarbons. For instance, *Pseudomonas veronii* — a generally harmless bacterium commonly found in soil and water — has been shown to reduce cadmium concentrations[1] by 100%, and *Pseudomonas putida*, a similar bacterium, can reduce phenol concentrations by 92%. Genetically modified *Pseudomonas putida* has demonstrated a 75% pollutant removal rate compared to 40% for its wild counterpart[2]. Meanwhile, *Bacillus subtilis*, a harmless bacterium so common that it's often found in human and animal guts, can be engineered to degrade 85% of aromatic compounds and 70% of aliphatic hydrocarbons. Similarly, *E. coli* can be enhanced to degrade a range of organic pollutants.

Bioengineering Technologies Are Expansive

As the field of bioengineering continues to evolve, so too is the variety of methods and technologies for producing environmental remediation and wastewater treatment solutions. Synthetic biology, in particular, is changing how researchers approach these challenges by allowing biological systems to be redesigned for specific tasks.

At the heart of many bioengineering solutions are genetically modified microorganisms, such as bacteria like *E. coli* and *Bacillus subtilis* and yeast like *Saccharomyces cerevisiae*. These "chassis" organisms are chosen due to their rapid growth rates and ease with which scientists can manipulate their genetic code to serve new functions.

The ability to precisely control gene expression is crucial to bioengineering solutions. Genetic circuits regulate cellular functions like light switches, while transcription factors activate or repress gene activity. Tools like CRISPR-Cas[3] allow for highly precise modifications to DNA, enabling the deletion, correction, or insertion of genes. This is vital for enhancing metabolic pathways that degrade pollutants. For instance, CRISPR-Cas9 has been used to improve biotransformation efficiency in *Bacillus licheniformis*[4]. Other tools like zinc-finger nucleases (ZFNs) and transcription activator-like effector nucleases (TALENs) can also target DNA modifications.

Some of the ways that researchers are "upgrading" microorganisms include:

Optimizing degradation pathways. Using the tools mentioned above, scientists can build or optimize new ways for microorganisms to digest and break down pollutants. They do this by introducing genes that encode specific enzymes to target specific chemicals. Computational tools and databases are used to help predict effective decomposition pathways and identify the most suitable enzymes.

Enzyme engineering. Enzymes themselves can also be customized to help convert toxic compounds into harmless ones. Recombinant DNA technology can be used to modify and produce large quantities of enzymes (e.g., laccase) with improved activity and stability, making them ideal for onsite bioremediation.

Synthetic microbial consortia. Instead of relying on a single organism, synthetic microbial consortia[5] combine cultures of multiple microbial species. Each species contributes to a part of the degradation process. This allows them to break down complex chemicals that a single strain could not. For example, one such study used engineered *Rhodococcus erythropolis* OSDS1 to make hydrocarbons more soluble and bioavailable, while a combination of four other microorganisms produced unique enzymes that targeted various parts of the hydrocarbon mixture.

Beyond treating and remediating pollutants, synthetic biology can also be used for pollution monitoring and control through the development of biosensors[6]. These are genetically engineered microbes or other biologics that can detect certain environmental signals and convert them into measurable outputs. In addition, biofilms, which are aggregated microbial communities encased in an extracellular polymeric substance, have been used in wastewater treatment for many years. Biofilms can survive harsh environmental conditions and enhance pollutant degradation due to increased bioavailability to degrading organisms.

Limitations To Commercialization

Despite these advancements, bioengineered solutions face an uphill battle to full-scale implementation. For example, the risk of synthetic genes transferring to the environment raises ethical concerns, due to the potential to disrupt existing biospheres. In addition, researchers in many of the studies cited above found it difficult to maintain consistent performance amidst fluctuating environmental conditions, such as pH, temperature, nutrient availability, and competition with native microbes. While laboratory efficiency of synthetic biology can be enhanced, most studies show these solutions still struggle to outperform natural strains in real-world conditions. Other limitations include the high cost of production and deployment for some technologies, the time-consuming nature of biological processes compared to some alternatives, and the complexity of fully understanding microbe-pollutant and microbe-microbe interactions in complex environments. Still, this is a field of study with tremendous potential for wastewater treatment and pollution remediation. ■

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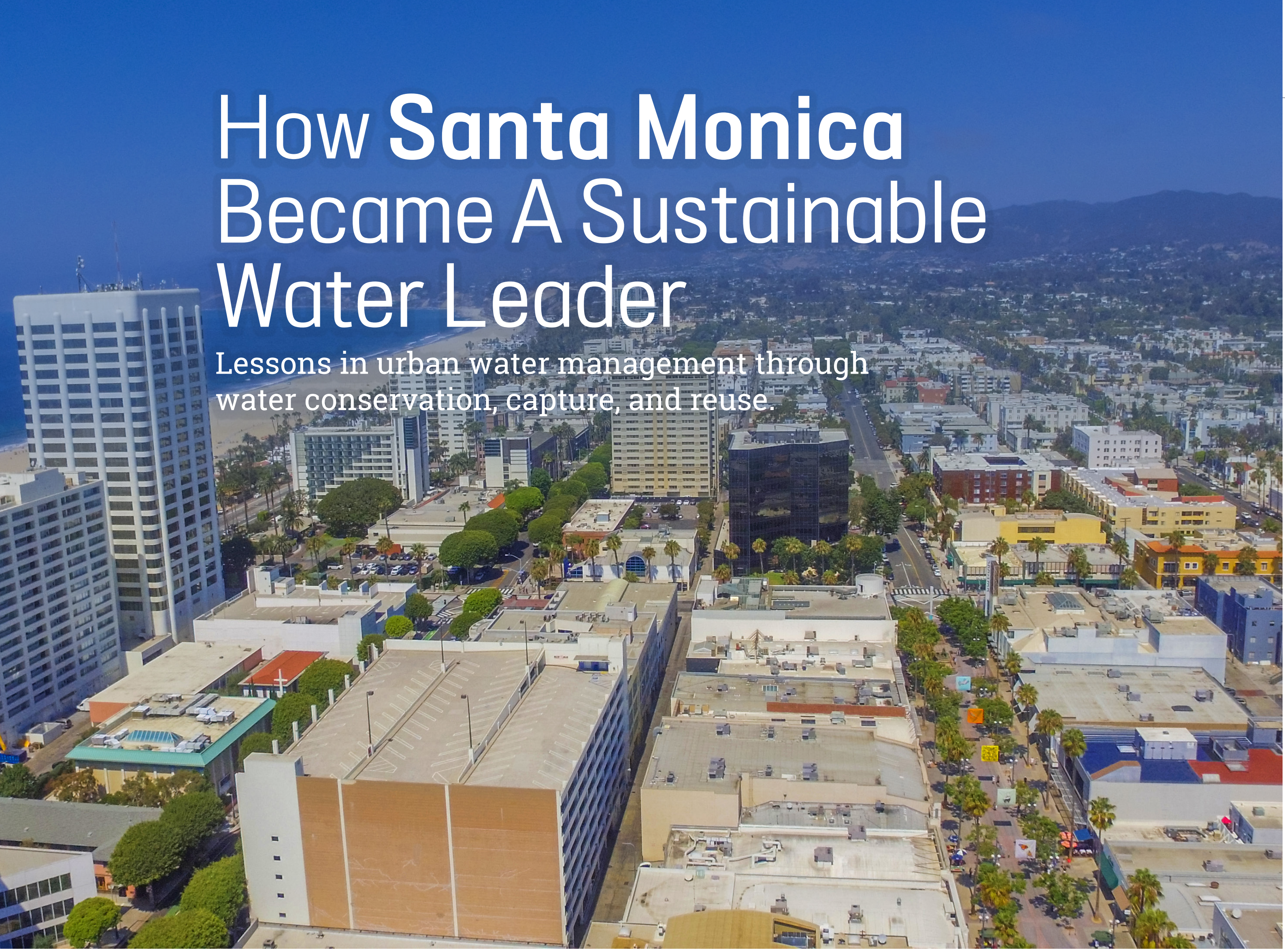

How Santa Monica Became A Sustainable Water Leader

Lessons in urban water management through water conservation, capture, and reuse.

By Katie Peach

California's ongoing water challenges have pushed cities and municipalities to seek innovative solutions for sustainable water supplies. The city of Santa Monica's pioneering sustainable water master plan[1] aims to secure water resources, reduce the city's energy footprint, and provide long-term cost benefits for ratepayers. The plan's three main elements include increasing water conservation efforts, creating sustainable alternative water supplies, and expanding local groundwater production.

One component of that plan, the Sustainable Water Infrastructure Project[2] (SWIP), has emerged as a blueprint for other local governments to emulate, representing a significant shift in urban water management and reuse.

SWIP combines several components to maximize local water resources and reduce reliance on imported water. The project's centerpiece is the advanced water treatment facility (AWTF), an underground facility processing 1 million gallons daily, California's first permitted groundwater augmentation project using a membrane bioreactor.

Complementing AWTF is the Santa Monica Urban Runoff Recycling Facility (SMURRF). It produces up to 500 acre-feet of Title 22 diluent water per year for groundwater replenishment, marking another first for California as the state's first stormwater direct injection project.

The third key component is a new 1.5-million-gallon stormwater harvesting tank at the city's Civic Center to complement the existing 1.6-million-gallon Clean Beaches Initiative Tank, which helps capture stormwater and manage urban runoff to contribute significantly to the city's water recycling capacity.

By integrating each of these components, Santa Monica has created a system that captures and treats stormwater, urban runoff, and wastewater, allowing the city to harvest rainwater and urban runoff that would otherwise go to waste and purify it to surpass drinking water standards.

The city of Santa Monica caters to the daily water needs of over 93,000 residents and 2,700 commercial customers, delivering 10 million gallons daily of high-quality drinking water; SWIP aims to reduce Santa Monica's reliance on imported water by 10%. SWIP also showcases Santa Monica's commitment to cutting-edge environmental practices and ensures climate resilience in the face of drought by reducing dependence on imported water and maximizing the use of local resources.

How The Advanced Water Treatment Facility (AWTF) Was Built

AWTF's groundbreaking solution incorporates a multi-barrier approach, pushing the boundaries of water treatment technology. The treatment steps include a LEAPmbr system[3], cartridge filtration, reverse osmosis (RO), ultraviolet disinfection, and free chlorine disinfection.

Veolia Water Technologies & Solutions partnered with the city to provide the membrane bioreactor (MBR) system as the core of the facility. The system produces high-quality effluent to send to the downstream advanced treatment technologies and marks a significant milestone as the first MBR granted log removal values (LRVs) for virus, *Cryptosporidium*, and *Giardia* removal in California.

Following the MBR, water passes through cartridge filters, another first in California to be granted LRVs. The subsequent RO system operates highly efficiently and further purifies the water by removing dissolved solids and contaminants.

The team quickly realized that in the world of advanced water treatment, analyzers aren't just tools — they're the eyes and ears of the entire operation.

Post-RO, an advanced oxidation process using ultraviolet light and free chlorine (UV/Cl2) destroys remaining pathogens and breaks down trace organic compounds. A final free chlorine disinfection step provides residual protection.

What sets AWTF apart is its integration of these technologies into a cohesive system with multiple critical control points that monitor parameters like turbidity, conductivity, UV transmittance, and free chlorine residual, ensuring consistent water quality throughout treatment.

These innovations collectively enable SWIP to produce water that exceeds drinking water standards. By housing the entire AWTF underground, Santa Monica minimized the facility's urban footprint and provided additional protection for the treatment processes. Additionally, Veolia has completed a greenhouse gas (GHG) emission analysis for the AWTF that demonstrates that the city is able to reach its goals of water independence while also achieving a similar GHG emission or less when compared to the emissions from importing water.

Keys To Success

From the outset, the city adopted a design-build-delivery model to streamline the project's execution and ensure accountability. This approach gave the contractor and engineer a single point of responsibility for performance, fostering a sense of shared purpose and aligning interests toward the project's success.

The team quickly realized that in the world of advanced water treatment, analyzers aren't just tools — they're the eyes and ears of the entire operation. This revelation led to a deep appreciation for the nuances of water chemistry and the importance of selecting the right analytical methods for processes like UV-chlorine advanced oxidation.

When traditional methods of monitoring cartridge filtration proved inadequate, the city created new parameters like temperature-corrected specific flux and normalized differential pressure. They also discovered that operational flexibility could be a powerful tool in balancing cost and risk and developing a hybrid "threshold mode" for the UV-AOP system to find a sweet spot of oxidant dosing that maintains water quality and protection while optimizing operational costs.

As the project neared completion, the multiple barrier treatment system proved its worth with its array of critical control points. Extensive sampling revealed no maximum contaminant level exceedances in the product water.

Capturing Urban Runoff For Groundwater Injection

Leading the way for water recycling is nothing new for Santa Monica, where the SMURRF has been operating since 2000. Originally designed and operated to collect and treat stormwater runoff to provide non-potable water for irrigation and toilet flushing, the SMURRF system also uses ZeeWeed membranes to meet Title 22 recycling requirements. The facility has undergone recent upgrades as part of SWIP, including the addition of reverse osmosis to further purify the water, and it is the first facility in California to directly inject treated stormwater into the groundwater basin.

As other cities and water agencies look to chart their own paths toward sustainable water infrastructure, they should heed these lessons from Santa Monica's journey. The experience planted the seeds of future innovations and successes in the quest for sustainable urban water management. ■

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BALANCING COST TRANSPARENCY and CONTRACTOR QUALIFICATIONS in COLLABORATIVE DELIVERY

While contractor qualifications guide early-phase selection in collaborative delivery, cost considerations take priority during guaranteed maximum price development. Navigating this shift requires strategic procurement approaches to uphold project value, strengthen contractor engagement, and reduce risk.

By Bryan Canzoneri

Owners typically select design-build and construction manager at risk (CMAR) contractors based on qualifications, experience, and project-specific approach. A contractor's ability to deliver hinges on demonstrated capabilities and available resources. The value of these delivery methods is rooted in early-phase communication and collaboration. During design, contractors provide critical input through early cost estimates, aligning with project budgets, while constructability feedback optimizes design for cost and schedule efficiency. Contractors are chosen based on their record of successfully delivering these early-phase services. While this phase sets the foundation for project success, execution remains paramount. Though owners often prioritize qualifications and construction quality in contractor selection, the focus usually shifts to cost transparency when developing the guaranteed maximum price (GMP). This transition can introduce challenges that must be strategically managed.

Most of the time, contracts include requirements for bidding on any work that's to be self-performed — offering assurance that the amount in the lowest responsive bid will be used for the work. Typically mandated by legislation or procurement regulations, this process mirrors the competitive bidding approach used by public entities. While it promotes transparency and structure, it can discourage contractor participation and limit a design-builder or CMAR contractor's ability to assemble the most qualified team for project delivery.

Challenges Of Public Procurement Requirements

One of the primary challenges with a GMP is that it is often established before the design is complete. While contractors may use internal estimates as a baseline, the GMP typically incorporates some level of competitive market pricing. This pricing serves a dual purpose — providing owners with confidence that the GMP is not artificially inflated while giving contractors assurance that the project can be delivered within the agreed cost. The complexity arises in how this market pricing is obtained. Bidding on incomplete drawings leads to inherent risks — either an underestimated cost that lacks necessary details or an inflated bid to account for design evolution. To mitigate this, contractors typically conduct scope reviews with bidders to confirm alignment. However, strict procurement processes, originally designed for traditional delivery methods, can limit this flexibility, making it difficult to validate scope coverage before finalizing pricing.

Strategic Considerations For Self-Performed Work

In the water sector, contractors typically self-perform critical project elements, including water-bearing concrete, process equipment installation, and mechanical piping. This approach enhances control over the critical path and key cost components. Most design-build and CMAR contractors in this sector have extensive experience in these disciplines, making them valuable partners for clients seeking specialized capabilities. Many contractors also continue to deliver projects through traditional methods, leveraging their construction background to provide consulting services during phase one.

A recurring challenge in self-performed work is maintaining competitive pricing against market rates. Since contractors develop scope packages and integrate directly into the design process, they often have a deeper understanding of project details than external bidders. This knowledge gap can result in significant pricing discrepancies. Additionally, while general conditions, overhead, and profit for self-performed work are defined, general contractors can often realize efficiencies unavailable to outside bidders. Their ability to access and manage project contingencies further influences pricing strategies. These dynamics can discourage market competition, making it a critical factor for project owners to consider when structuring procurement strategies.

Managing Risks In GMP Development And Contractor Selection

The challenges previously outlined can create significant obstacles for a project team. In a limited market, both the owner and the contracting community may lose confidence in the procurement process, raising concerns about whether the GMP reflects true market value and whether the contractor made a rigorous effort to engage the market. From the contractor's perspective, they are accountable for overall project delivery, including subcontractor performance and its impact on outcomes. Selecting the lowest bidder based on incomplete drawings introduces risk rather than mitigating it. Similarly, engaging a design-builder or CMAR based on qualifications but then restricting its ability to manage construction undermines project success. The objective remains clear: selecting a qualified partner who can deliver value to the owner.

Optimizing Procurement Strategies For Collaborative Delivery

When developing requests for proposal (RFP) and procurement guidance, it is essential to define the rationale behind selecting a collaborative delivery approach. If a project is highly complex and requires a contractor capable of planning and executing critical work components, the selection process must confirm that the chosen contractor can self-perform those elements. The goal is to establish a structured method for the owner to validate that the GMP reflects fair and reasonable costs for the contractor's self-performed work.

> **When developing requests for proposal (RFP) and procurement guidance, it is essential to define the rationale behind selecting a collaborative delivery approach.**

Introducing competitive bids for these critical work elements later in the project can create unintended consequences. If pricing is solicited solely to validate the CMAR or design-builder's self-perform costs, it misrepresents the intent to the broader contracting community. If the objective is purely to reduce costs, the risk emerges that another contractor — not the CMAR or design-builder — executes the work, undermining the original justification for selecting collaborative delivery.

There is no universal solution to these challenges. While collaborative delivery methods have advanced significantly over the past two decades, further refinement is needed to optimize processes and maximize value. As the industry continues to clarify legislation and procurement standards, owners and practitioners can enhance project success by developing RFP and contract requirements that fully leverage the intended benefits of collaborative delivery. ■

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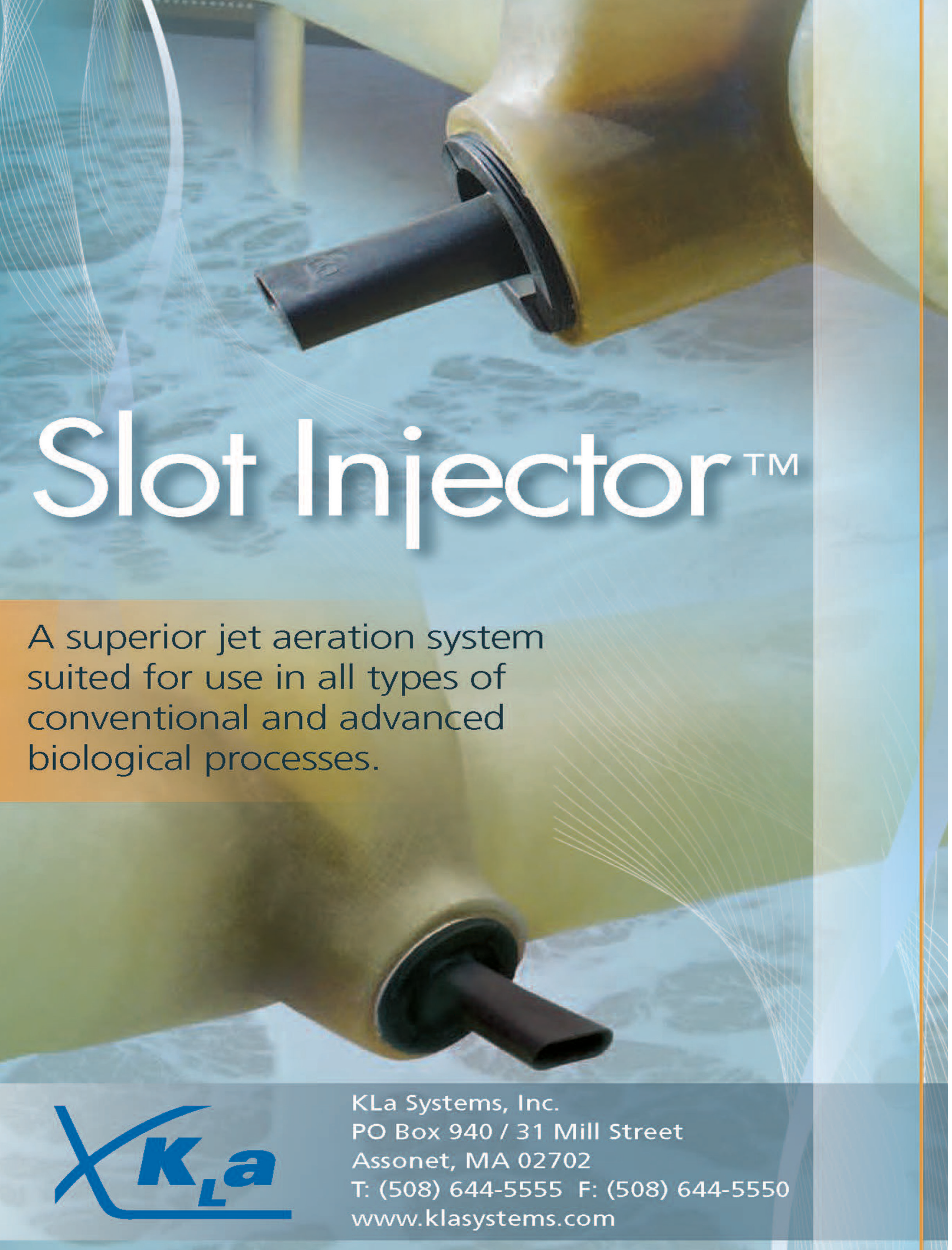
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