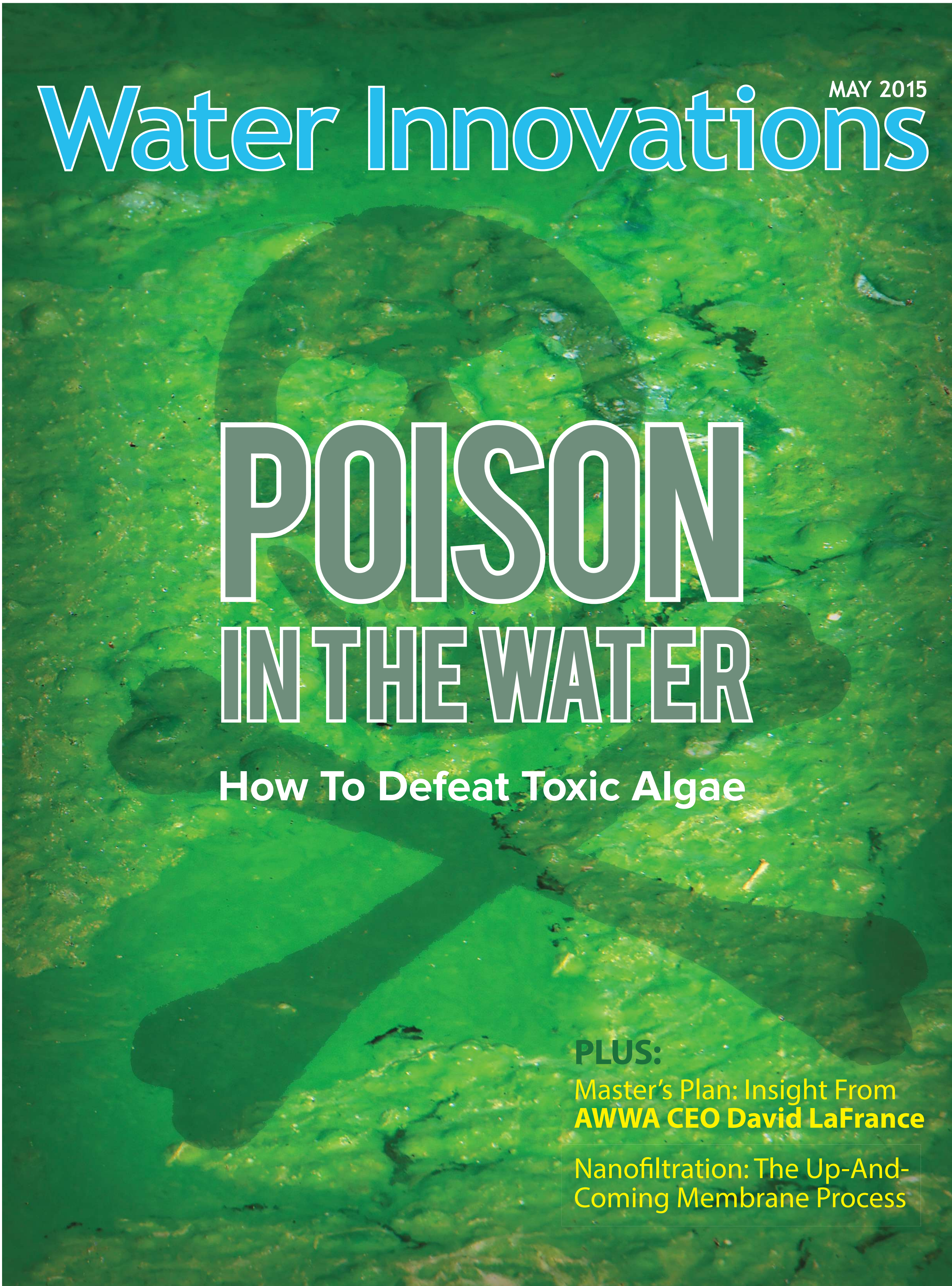
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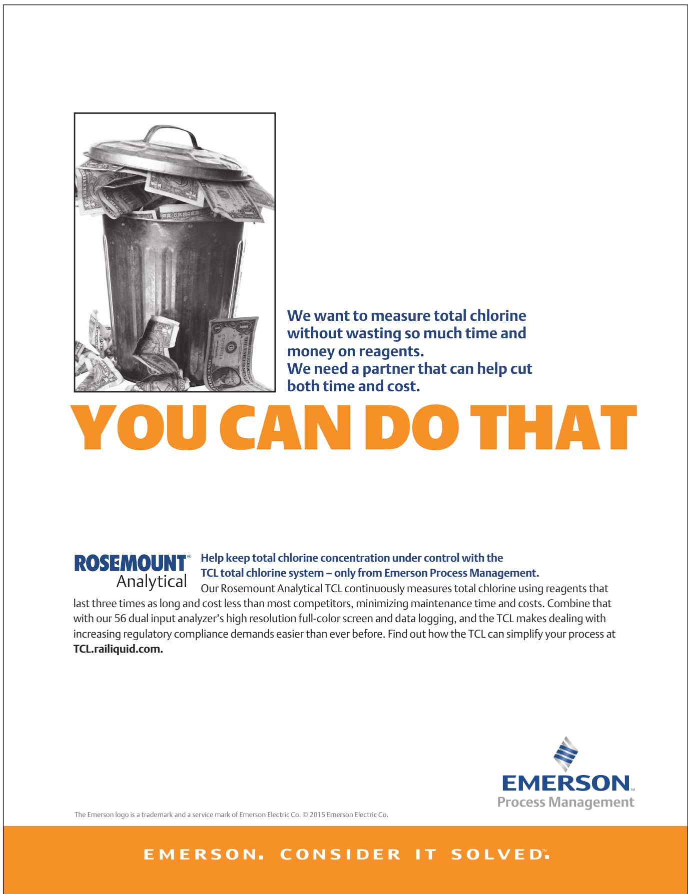

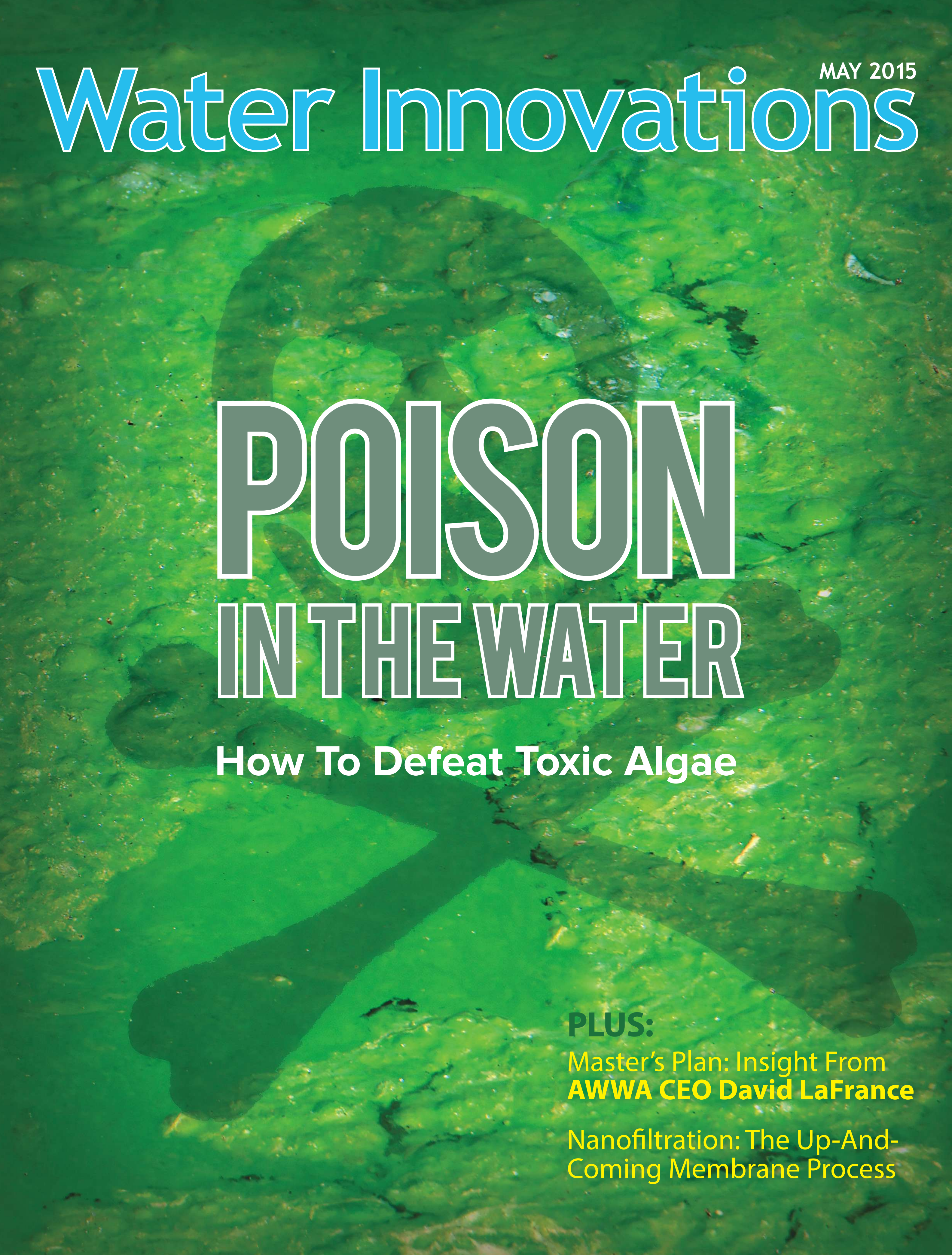

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EDITOR'S LETTER

By Kevin Westerling
Chief Editor, editor@wateronline.com

A Master's Plan For Water Industry Success

Water professionals are a rare breed. We obsess over something that most people don't consider at all, something so taken for granted as to not require thought. But water and wastewater professionals are special precisely because we know better.

Perhaps no one thinks about water more, or knows it better, than the CEO of the American Water Works Association (AWWA), David LaFrance. Obsession is part of his job, since he and AWWA are looked upon to set the agenda, and find solutions, for today's most important water issues. That authority is what drives thousands of water professionals to AWWA's Annual Conference and Exposition (ACE) each year, and what drove me to seek LaFrance's input on the current challenges and opportunities facing the industry — for those of us who think about water every day.

"Big Three" Issues

One of the foundational tools for creating the ACE program each year is the annual *State of The Water Industry* survey that AWWA conducts with its members. The latest survey revealed that the three biggest concerns for the group are the following: water availability, financing, and infrastructure.

> *"As water-quality requirements become more stringent, we're going to need more technical solutions that are innovative on how we meet those requirements."*
>
> **David LaFrance**, CEO, American Water Works Association (AWWA)

LaFrance indicated that water availability garnered additional attention for ACE15 because the host city (Anaheim) is in California, home of severe, prolonged drought. In fact, it's one of the few places in America where the citizens actually think about water — because they're running out of it. In California and many other water-scarce regions, utilities and industry are turning to conservation, desalination, and water reuse technologies out of necessity.

The remaining issues of the big three, financing and infrastructure, aren't exactly new, but a new(er) strategy for dealing with them is revolutionizing utility operations. "Asset management" has grown from industry buzzword to the recognized best practice for infrastructure oversight, upkeep, and budget planning. Municipalities, private companies, consulting engineers, and AWWA/ACE have all responded by developing programs that help utilities understand and enact formalized asset management principles.

Trend-Setting

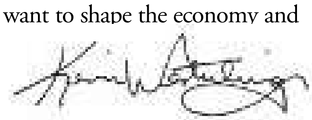
AWWA's core focus has always been potable water quality and availability, but it recently announced a more inclusive emphasis on total water solutions — "where drinking water, wastewater, recycled water, and stormwater intersect," LaFrance described. The new campaign is inspired by the need for, and trend toward, water reuse. LaFrance doesn't want us to mix the message, however. "Total" is not the same as "one." "AWWA doesn't feel that there is 'one water,'" he noted. "There are many waters, and the modern day water professional needs to understand the nuances of each of these different waters, because each has different characteristics."

State Of The Industry

Despite the industry's "big three" issues, many smaller ones, and a general lack of public awareness and support, LaFrance shared a bright outlook for the future. "I think it's probably one of the most exciting times in history to be a water professional," he said. "The challenges we're facing require solutions that are attractive not only to operators and engineers, but to people from a variety of educational disciplines — communications specialists, finance specialists, conservation specialists."

He spoke of regulations and engineering opportunity, predicting, "As water-quality requirements become more stringent, we're going to need more technical solutions that are innovative on how we meet those requirements." In summation, said LaFrance, "If you want to help your community, if you want to shape the economy and protect the environment, water's the place to be."

A great place to be, actually. Part of a rare, special breed.



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Nanofiltration:
The Up-And-Coming Membrane Process

The forgotten child of the membrane family has plenty of capabilities and potential. Learn the factors and applications that are increasing the popularity of nanofiltration.

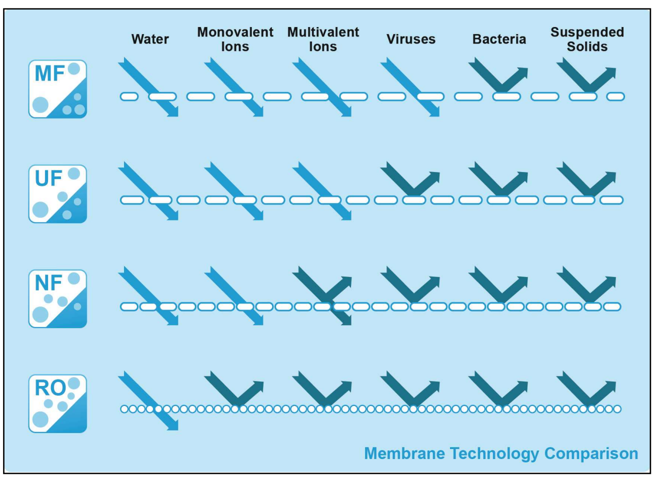
By David Paulson

Nanofiltration, a membrane-mediated process, is enjoying a resurgence of attention throughout the marketplace, including the potable, water reuse, and industrial process sectors. But misconceptions frequently appear about where it came from, how long it has been around, and even what the definition of nanofiltration is. A better understanding of how nanofiltration relates to its sibling processes of reverse osmosis and ultrafiltration, its history, and the potential that its current successful applications imply will make it even more useful.

The pressure-driven membrane processes are divided into four classes: reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). Probably because its separation characteristics bridge the salt-rejecting and salt-passing classes, nanofiltration seems to have the most confusion in the literature and among application engineers and is inconsistently defined even in written standards. Understanding how NF was developed helps understand what it is.

Brief History Of Membrane Filtration

The modern microfiltration membrane was conceived in the early 1900s, but was consistently manufactured as the artificial, polymeric membrane we know today following World War II and has become increasingly essential in medicine, pharmaceutical production, and microbiology. RO was the next class of membranes developed and was conceived in the 1950s, developed in the '60s, and commercialized in the early '70s. Its target use was making drinking water from brackish water and seawater. Soon after, UF was developed and commercialized, and UF fit nicely between the salt-rejecting RO and salt-passing, particle-retaining MF. Both RO and UF needed to run in the crossflow mode to be economically viable, which created a processing liability in some cases, but the technology was a major advance.



The filtration spectrum (*credit: Koch Membrane Systems*)

Historically, it has been understood that UF class membranes allow complete passage of ionic species, but retain uncharged solutes above 5,000 or 10,000 molecular weight through simple sieving. It was also accepted that RO membranes remove high levels of ionic species using a more complex mechanism. So, both classes of membranes removed uncharged solutes, with the "tighter" RO removing down to below 150 molecular weight (MW) while UF membranes could reliably remove solutes down to 10,000 MW for the tightest versions, and "looser" (larger pore) versions would pass such molecules but remove "macromolecular" solutes and colloids (as well as virus and bacteria).

Need For Nanofiltration

There was a tight membrane class (RO) that would remove (reject) essentially all salt ions and most uncharged organic solutes, and a group of looser membranes (UF) with smallest pore sizes from 10,000 up to 300,000-plus molecular weight cutoff (MWCO), and they worked well for many applications. But what about all those uses that both industry and science envisioned for separating one solute molecule from another in the common and valuable 500 to 10,000 MW range? And what if the purpose was not just to purify water? What membrane could a company use to desalt a protein or dye broth, to remove sugar from protein or plant matter, or to separate a mono- from a trisaccharide, etc.? An increasing need pushed the membrane manufacturers to modify their membranes to fill this gap.

A few pioneering membrane companies, especially those that focused on industrial and process applications, reacted by developing and testing what were first called "loose RO" and "RO/UF hybrid" membranes. Hence, a new category of membrane performance was realized.

Further, what if the ions (dissolved salts) that a municipality wanted removed for potable water were only the hardness ions, and the added pressure that the tight RO membranes required was an unnecessary cost? The earliest documented application of NF was a potable water application in Florida in the late 1970s and was probably the first commercial, intentional use of such NF membranes. The loose RO membrane chosen required less pressure because it allowed monovalent ions like sodium to pass through, yet still removed color molecules (and probably unrealized at the time, tri-halo-methane precursor molecules). This "membrane softening" application was born before the term nanofiltration was known.

In 1983, the first documented process NF membrane (as opposed to water treatment) I have found was commercialized for the purpose of desalting a small food-grade dye — an advantageous purification step in a critical manufacturing process. This membrane is documented well because, coincidentally, the patented use it was developed for became the basis of a major patent law interpretation case, which made it to the U.S. Supreme Court after 12 years in the lower courts (decided in 1997).

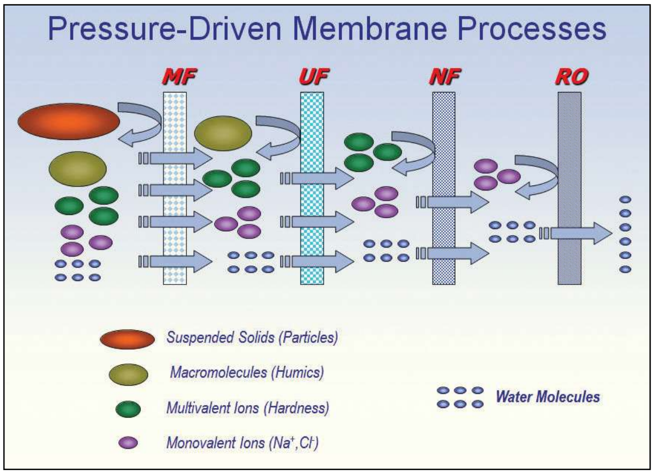
A New Membrane Class Is Born

In 1984, Dr. Peter Eriksson, in a marketing contribution to differentiate such new membranes, coined the term nanofiltration, which he based on the estimated size of the pores in a membrane with these types of removal characteristics. Thus, a fourth class of pressure-driven membranes was born.

This term and the fractionation process came into widespread use long before the "nano" materials storm that has recently swept the technology world. The only connection the NF membrane name has to nanomaterials is through the smallest size of uncharged solutes they tend to separate — a weak link.

The ability to separate some small solutes from others is a very important membrane characteristic. Keep in mind that there are two types of solutes separated by differing mechanisms: ions based chiefly on their valence state in water (charge) and sieving based on molecular weight if uncharged. This is a simplified definition that is generally not universally accepted. It seems that those industry groups that mainly purify water think only of the ionic separation performance of NF as important and often ignore the uncharged solute aspect in their definitions and common usage.

Yet some of the most creative and technical applications for NF involve removing one size uncharged molecule from a larger or smaller solute, to achieve an otherwise difficult separation. Such a process step is called "fractionation" and is employed in technical applications for food and beverage ingredients, fine chemicals, oil and gas (i.e., fracking), pharmaceutical, and biomedical



Solute rejection model (*credit: Tzahi Y. Cath*)

will undoubtedly be more applications since the interest in using membranes is growing even faster now than in the 1980s. Many of these successful fractionation applications are kept silent as trade secrets or only show up in issued patents or patent applications, reducing the public's understanding of how widely nanofiltration may be used in their everyday lives.

Nanofiltration Today

New and creative applications are driving the further development of NF membranes. While its siblings RO and UF continue to grow in importance for treating the world's potable water and wastewater, NF is helping in those areas and many others as well. The need to separate related chemicals in various production streams such as pesticides, biochemicals, nutraceuticals, flavorings, and pharmaceuticals is well understood in these industries; as a result, NF is increasingly brought into play. Today several important applications for producing, refining, and recovering fine chemicals, sugars, amino acids, food, feed additives, and medicines are well established (one illogical application, making clear beer, has gone away).

The use of NF to replace RO or develop previously infeasible applications in water reclamation and reuse in both municipal applications and in the extraction industries (oil, gas, and mining) is now economically important. The reasons include reduced energy costs; reclamation of valuable minerals, elements, and chemicals; reduced volumes of toxic pollutants for disposal or further treatment; and lower-cost process streams suitable for direct disposal.

Nanofiltration Tomorrow

Although it is unlikely to reach the total area of global, installed membrane for either RO or UF, nanofiltration may well eclipse both of these classes in the number of different applications, if it has not already. The range of separations possible is not the only reason for this. Unlike the RO membrane class, comprised essentially of only two polymers, commercially available NF membranes include those of RO (cellulose acetate and polyamide-polyimides) and also more chemically resistant polymers. And more recently, ceramics companies are claiming products in the NF range. Both these material categories extend the range of NF applications significantly.

For the acid, base, and solvent stable polymeric membranes, both published lab tests and proprietary industrial applications have demonstrated that these NF class membranes can economically recover both acids and metals from acidic solutions in reuse from mining and refining streams. Closer to the economic cusp are those used for recovering acids and especially bases from food processing, industrial and commercial laundry, and other cleaning solutions, thanks to the longer life they have in these harsh environments.

For the emerging ceramic NF membranes, the same and better resistance (and therefore lifetime) can be expected — and, given the higher probable cost, is required to be competitive. To the extent that ceramic materials can withstand higher temperatures, stronger chemicals, and higher pressure, they will eclipse the polymers as the preferred membrane in high-value applications that can afford their higher cost.

Even more and potentially bigger developments are likely in the next five to 10 years. These include improved fouling resistance and customizable separation selectivity due to the incorporation of nanomaterials, for which efforts are under way in all the membrane classes (therefore nanofiltration will still not be a term properly related to the NF membranes material of construction). Just how economically feasible and how much the benefits of this technique will be are still speculative.

But one breakthrough would be of enormous benefit, and its value is assured — the development of a hollow-fiber-style NF that can be back-flushed to clean it and therefore allowed to run in direct-flow mode instead of crossflow, as with current hollow-fiber UF. This is perhaps the chief advantage ceramic NF has now, and it is probably closer to commercialization due to more favorable existing manufacturing techniques.

However, regardless of any breakthrough in materials or configuration of the NF membrane itself, nanofiltration applications are destined to multiply at a rate equal to, or probably greater than, the other membrane classes. This potential alone justifies the attention that NF has today. ■

About The Author

David Paulson is principal partner in Water Think Tank and Prime Membrane Partners, LLC. Water Think Tank provides a variety of expertise in the membrane filtration and water treatment industries. Prime Membrane Partners aids companies in establishing and expanding media and component manufacturing capabilities, critical component sourcing, strategic partnerships, and optimum positioning in the marketplace.

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K.C. Masterpiece: Revolutionary Combined Sewer Overflow Control

Kansas City, MO, is breaking new ground in more ways than one, instituting the largest and most innovative infrastructure project in the city's history.

By Jennifer Rusch

Aging sewer infrastructure has become an issue of national concern. The U.S. EPA estimates that each year more than 850 billion gallons of combined sewer overflow is discharged into local streams and rivers. To address this public health concern, the EPA has estimated a total investment of $57 billion dollars to reduce combined sewer overflows (CSOs) across 772 communities. For the communities impacted by these CSOs, the challenge is great. In Kansas City, MO, the solution is the first of its kind.

Big Plans

Kansas City is emerging as a leader in developing strategic and data-driven solutions for the city's CSOs, which are estimated to total 6.4 billion gallons of overflow each year. In 2010, Kansas City's Federal Consent Decree became the first in the nation to receive approval from the EPA for the use of green infrastructure solutions to address CSOs. The green infrastructure solutions included in the city's federally mandated consent decree are part of Kansas City's Overflow Control Program, a $4.5 to $5 billion plan to reduce CSOs by 88 percent over 25 years. The Overflow Control Program represents the largest infrastructure investment in the history of Kansas City and has consequently received considerable attention from residents and civic leaders who are interested in maximizing the benefit of such a historic undertaking.

"Kansas City is working to leverage each dollar spent as part of the Overflow Control Program to maximize the benefit to our residents," said Troy Schulte, city manager for the city of Kansas City, MO. "The knowledge we are collecting from this work, combined with strong public and private partnerships, has enabled Kansas City to transform communities while meeting the requirements of our consent decree. The Overflow Control Program is an example of how our city has taken a challenge and used it to create smart solutions and stronger communities."

Tech To The Rescue

This year, Kansas City is scheduled to release an innovative technology initiative that will enable the city to capitalize on the investment made as part of the Overflow Control Program. The initiative is a cutting-edge Web application (app) that allows city staff and Overflow Control Program stakeholders to quickly access and utilize terabytes of the city's sanitary sewer data, largely collected as part of the city's Overflow Control Program. The application is the first to combine multiple, off-the-shelf technologies for the assessment and use of sanitary sewer data. Kansas City created the application using the Web Application Builder produced by Esri. The city's sanitary sewer data, which includes CCTV video footage, field investigation reports, smoke testing reports, and manhole inspections, are analyzed and categorized by a data-management technology called InfoMaster produced by Innovyze.

"The sanitary sewer application is changing the way our project teams serve our customers and the way we address the challenges of our aging sewer system," said Andy Shively, engineering officer for Kansas City Water Services. "Previously, this kind of data had to be accessed using specialized desktop software or would need to be shared with project teams and subcontractors using massive storage drives."

Using these analytical engines, Kansas City is able to mine more than 30 terabytes of existing sewer condition data to produce heat maps which identify portions of the sewer system that require the most urgent attention. The survey information in the app is also searchable, providing project teams with detailed information that can be accessed using smartphones or tablets from the field.

Additional sewer surveys, conducted as part of the city's Overflow Control Program, are expected to generate up to 50 terabytes of data. After releasing the sanitary sewer application, Kansas City has plans to develop a custom portal which will contain access to a series of applications such as private inflow and infiltration information, field management applications, and flow metering viewers.

"Building a legacy for Kansas City requires strategic and data-driven solutions that maximize benefits for our community," said Shively. "This leading technology initiative is important for the strategic and long-term plan for our utility, and it is paving the way for better service and smarter solutions for future generations."

Green vs. Gray

The analysis and classification of this massive amount of data is helping project teams associated with Kansas City's Overflow Control Program develop and improve upon both green and gray infrastructure solutions. Kansas City's federally mandated consent decree allows for the replacement of gray infrastructure with green solutions when those plans are

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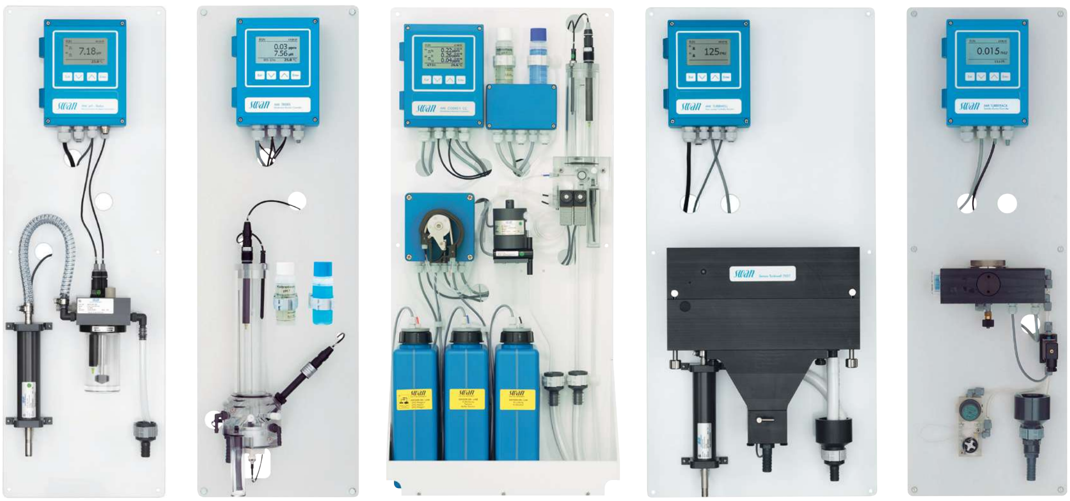

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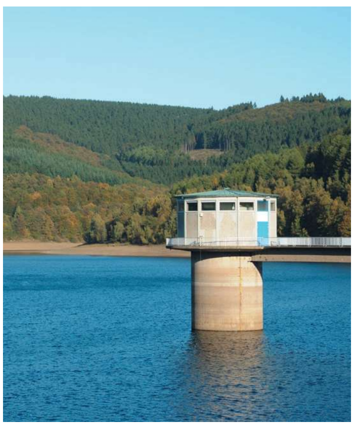

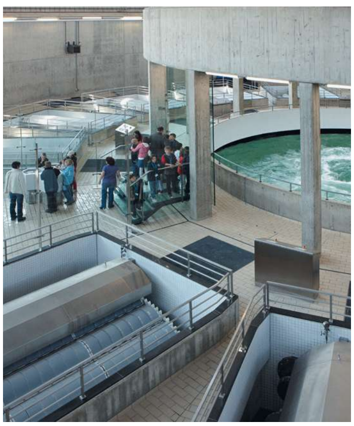

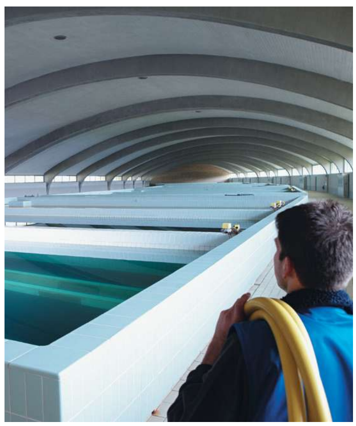

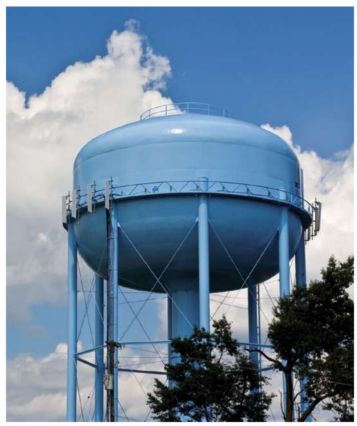

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demonstrated to be similar in both cost and performance. Because the Overflow Control Program represents the largest infrastructure investment in Kansas City's history, city officials are committed to using this investment to encourage future neighborhood investments.

In an effort to leverage this investment for the betterment of local neighborhoods, Kansas City has allocated more than $68 million for the installation of green infrastructure projects. This investment is already proving to be successful, both in the reduction of combined sewer overflows and in strengthening the local community.

Kansas City's pilot project has proven that green solutions, such as street curb extensions, are equally effective as gray infrastructure projects.

In 2012, the completion of Kansas City's nationally recognized green infrastructure pilot project showcased the community and environmental benefits of incorporating green infrastructure solutions for the on-site control of rainwater. The purpose of the pilot project was to test a wide range of infrastructure and streetscape improvements to reduce combined sewer overflows within a 100-acre area pilot project area. Before receiving EPA approval to replace gray infrastructure with green solutions, Kansas City had planned for the installation of two large storage tanks. Measured in cost-per-gallon, this gray infrastructure solution had represented one of the more costly improvements in the early years of the program.

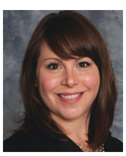
In 2013, Kansas City filed a report with the EPA confirming that the green solutions in the completed 100-acre pilot project area are successfully performing on-par with more traditional gray infrastructure solutions — but with the added benefit of revitalizing a community. The completed pilot project area achieved a total constructed storage volume of 360,320 gallons thanks in part to the installation of more than 130 best management practices (BMPs) such as rain gardens, permeable pavers, and porous sidewalks. Construction for the remaining 644 acres of green infrastructure improvements will be conducted this year.

"The green infrastructure solutions included as part of Kansas City's Overflow Control Program are transforming neighborhoods and serving as a catalyst for city and community partnerships," said Shively. "Kansas City's plan to replace gray infrastructure with green solutions was born from data and strategic planning, and it is made possible through strong partnerships with the local community."

Contagious Commitment

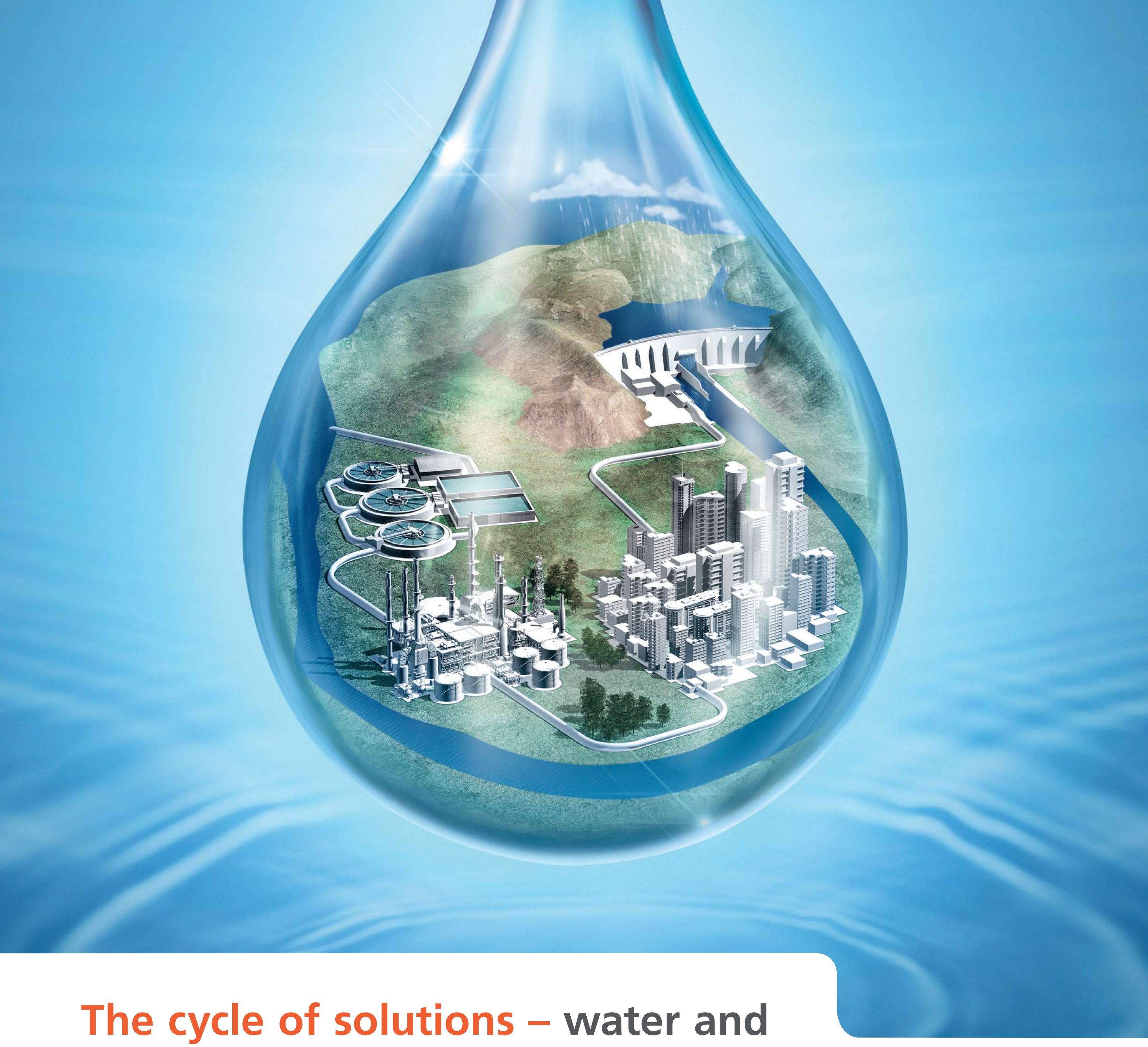
This investment and the proven success of the city's green infrastructure pilot project have instigated a citywide commitment to sustainability. In 2014, Kansas City's mayor pro tempore became one of the first elected officials in the nation to achieve accreditation as an Envision Sustainability Professional, and the program has served as a guide for sustainable practices throughout all city departments. Kansas City Water Services is leading the city's sustainable initiative by incorporating the Envision principles into project planning for the Overflow Control Program and into the long-term plan for the utility. Additionally, collaboration among various city departments has enabled the strategic allocation of city resources that will further enhance the community investment in green infrastructure solutions. Stakeholders representing the city's Parks and Recreation, Public Works, Neighborhoods and Housing Services, and Planning and Development departments convene on a monthly basis to discuss ways that resources and services in the green infrastructure project area can be improved. This collaboration has already resulted in streetscape improvements, enhanced trash services, and the reallocation of vacant properties.

In addition to pooling municipal resources to enhance the city's existing green infrastructure investment, this group has worked to assist community leaders to request public funding for enhancements to neighborhood curbs and sidewalks which will provide safe connections for pedestrians and bicyclists in the community. ■



About The Author

Jennifer Rusch is a strategic marketing professional specializing in communicating complex infrastructure programs in relatable and understandable ways to the public. She lives and works in Kansas City, MO.



Poison In The Water: How To Defeat Toxic Algae

Like many municipalities, Hamilton, Ontario, is wary of harmful algal blooms and toxic cyanobacteria. To mitigate the threat and protect drinking water, a proactive, risk-based plan was developed.

By Christopher Mills and Quirien Muylwyk

Heavy rains, environmental conditions, and nutrients from runoff have created favorable conditions in the Great Lakes to promote more frequent and longer occurrences of algal blooms. The nutrient-rich environment and warm temperatures of the Great Lakes make them the perfect incubator for algal blooms, some of which can be harmful. Algal blooms and cyanobacteria not only impact the aesthetic appearance, odor, and taste of water supplies, they also can be detrimental to public health and impact the normal operations of a water treatment plant, including loss of production capacity during high demand periods.

While several provinces and states are implementing long-term solutions to control the growth of algae, short-term solutions can minimize the impact of toxic algal blooms and avoid drastic measures like temporarily shutting off a community's water supply. Proactive planning can identify the right mix of short- and long-term solutions to prevent contamination of treated water with algal toxins, while also improving the understanding of the risk posed by algae and cyanotoxins at the plant.

Located in the western end of Lake Ontario, five kilometers from the Burlington ship canal, the City of Hamilton's Woodward Avenue Water Treatment Plant (WTP), a 900 MLD (238 MGD) facility, is a good example of a utility taking a proactive, risk-based approach to managing its algal toxin risks. The Woodward WTP treats water from Lake Ontario using conventional treatment with intake chlorination, coagulation with polyaluminium chloride filtration with granular activated carbon, and chloramination. Depending on conditions on the lake, the plant's intake can be influenced by the water of the adjacent Hamilton Harbour, a water body in which cyanobacterial algal blooms have been observed due to its eutrophic conditions.

The "filter building" at the City of Hamilton's Woodward Avenue Water Treatment Plant

Working with the City of Hamilton, CH2M HILL conducted a study to assess the potential impacts of algae and cyanobacteria on the performance of the Woodward Avenue WTP, in terms of aesthetics, public health, and plant operations. Using a proactive approach to identify risks and recommendations for both short- and long-term control strategies, the study evaluated potential control strategies and emphasizes opportunities to leverage the existing treatment plant infrastructure to address raw water quality conditions and risks.

Source Water Conditions

There are limited data available on the type and concentration of algae in the source water used by the Woodward Avenue WTP. However, monitoring data in the adjacent Hamilton Harbour are more prevalent than monitoring data in Lake Ontario.

Since 1987, the city has been reviewing water quality data in Hamilton Harbour. Long-term monitoring trends indicate an overall average increase in water transparency and a dramatic shift in algal community structure, with surface blooms becoming more frequent over the years. Also, after an approximately 10-year period of declining total phosphorus levels, there is a more recent trend of total phosphorus levels increasing. From analyzing and studying the water quality data, CH2M HILL helped the City of Hamilton better understand the potential impacts and risks associated with algae, cyanobacteria, and their metabolites observed in the source water. Previously, the city had not utilized the data to holistically identify these trends over the years.

Based on the observed water quality trends in the source water, the study helped categorize the impact on water quality and the plant's operational performance. It was determined that the predominant algal species in Hamilton Harbour had shifted towards noxious algal taxa (from chlorophytes and diatoms to cyanobacteria) over the past decade or longer. Per the literature, several species of cyanobacteria can produce algal metabolites that cause taste and odor (T&O) — specifically geosmin and MIB, which are responsible for the majority of reported T&O events — and/or toxins. The study looked at water quality data from Hamilton Harbour as a worst-case scenario, and it was also confirmed that water exchange between Hamilton Harbour and western Lake Ontario does occur through the shipping canal, though water quality at the Woodward WTP intake is rarely influenced by this exchange. In some cases, however, algal species found in Hamilton Harbour were detected at the WTP intake, but at much lower levels. Therefore, because of the limited data available, it is difficult to draw conclusions about the linkage between water quality in Hamilton Harbour and western Lake Ontario, specifically at the Woodward WTP intake.

For this study, a conservative assumption was made that algal species present in Hamilton Harbour could potentially influence water quality at the Woodward WTP intake, as this represents a worst-case scenario and is consistent with the delineation of Hamilton Harbour as Intake Protection Zone 3 for the Woodward WTP. The approach taken to assess the risk was based on deducing trends in the raw water intake data, based on groups of algae and cyanobacteria as opposed to individual algal species.

Nevertheless, in order to mitigate risk using its existing infrastructure, CH2M HILL utilized the city's risk management framework tool to interpret data and identify the components needed for managing the issue. The city had used the tool for other projects, but using the risk-management tool to study water quality in relation to algal toxins was a new application for this tool.

Treatment Schemes

Recommendations from the study included both short-term and long-term capital upgrades, monitoring practices, and operating strategies. Due to the size of the water body involved, there is no practical way to remove the risk in the source; therefore, a multi-barrier approach is required to transfer and manage the city's risk of algal events. Two areas where control can be provided include:

1. *Raw water intake* — removal of algae and cyanobacteria from the raw water (intact cells), as well as any algal metabolites (intracellular material) present in the raw water;
2. *Treatment processes* — removal of algae and cyanobacteria (intact cells), as well as any remaining metabolites (such as T&O compounds and cyanotoxins) present in the treatment process, from either the source water or from cells ruptured as a result of treatment.

Postfilter disinfection with granular activated carbon (GAC)

A multibarrier approach is necessary to physically remove intact cells (algae and cyanobacteria) before they rupture in the treatment process and remove dissolved metabolites through oxidation and adsorption. Under the multibarrier treatment approach, the inclusion of an oxidation step is implied. To manage the risks and benefits of raw water oxidation of the algae, cyanobacteria and their metabolites, a postfilter disinfection approach must be employed.

Taking this approach into consideration, the city has several options available to use and/or modify its existing infrastructure to mitigate the risk of algae and cyanobacteria, including:

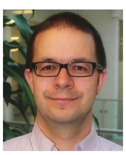
- Raw water intake prechlorination modifications to the dose
- Pretreatment modifications to operate with a higher coagulant dose, apply a polymer as a coagulant aid during algal events, or apply a powered activated carbon seasonally during algal events
- Filtration modifications to promote adsorption in the granular activated carbon filters; this may impact the frequency of the GAC (granular activated carbon) replacement. (The WTP had taken proactive steps following a 1999 taste and odor event on Lake Ontario to protect itself from water quality impairments by replacing the media in its filters with GAC and adopting a media replacement schedule of four to five years.)
- Filtration modifications to reduce chlorine residual in both filter influent and backwash water to promote biological activity
- Increase chlorine contact time to provide all primary disinfection needs downstream of the filters; alternatively, install UV downstream of the filters.
- Shut down the WTP for 12 to 24 hours during algal events to reduce the volume of water that passes through the treatment process and into the distribution system, and supply water using system storage.

Future Risk

The above list identifies the short-term solutions that the City of Hamilton can implement to manage risks associated with algae and cyanobacteria. The long-term solutions such as adding new oxidation processes to destroy toxins, new pretreatment processes to remove algae, and extending the intake pipelines deeper into Lake Ontario could not be justified for implementation at this time based on the current understanding of the risks using the available data. In the future, the City of Hamilton will continue to monitor the source water to confirm the prolonged risk profile to determine if the city should invest in the longer-term solutions for managing algae and cyanobacteria risks. In the near term, by modifying its existing infrastructure, the city is adequately managing related risks. While these solutions could impact the plant's operations, the plant currently has a surplus capacity and large reservoir storage capability. To determine the need for the higher-cost long-term solutions, the city will need to collect and analyze more water samples to confirm the raw water quality at the intake.

The City of Hamilton is leading the industry by implementing a proactive approach to monitoring algal blooms, ensuring residents continue to have access to a safe drinking water supply. In addition to reviewing and planning for algae risk and control needs, Hamilton is currently undergoing an overall study of its facility, closely examining plant performance and production, which enables the city to be pragmatic with recommended upgrades and take a multipurpose, holistic approach to managing its overall risk. ■

About The Authors



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Quirien Muylwyk is CH2M HILL's Technology Manager for Water in Canada. She has more than 20 years of experience in municipal water treatment and process engineering. Over the years, she has worked with owners and stakeholders on the strategic planning of plant upgrades, expansion projects, regulatory compliance needs, and optimization/operation of large plants. Muylwyk is active with the AWWA and serves as Chair of the Water Quality and Technology Division.

Smell Test:

A Comparison And Ranking Of Hydrogen Sulfide Emission Factors

How bad does your wastewater treatment plant (WWTP) really smell? Researchers provide a new perspective on headworks odor control and measurement.

By Amitdyuti Sengupta with Linda Daly and Bhaskar Kura

Formation and release of hydrogen sulfide (H_2S) gas from municipal wastewater is a well-recognized problem that has significant impacts on wastewater infrastructure. Impacts of generation and emission of H_2S from wastewater include corrosion and reduction in the service life of wastewater infrastructure, odor nuisance in the community, and health impacts of wastewater operations and maintenance personnel (Neilsen, et al. WEFTEC 2006). *Section 522 of Water Quality Act, 1987* mandates the U.S. EPA to study and document corrosion level in wastewater systems in the U.S. The EPA's study "Hydrogen Sulfide Corrosion: Its Consequences, Detection and Control," conducted on 89 municipalities in September 1991, revealed that 80 percent of the municipalities reported accelerated corrosion and collapse of the wastewater infrastructure.

Health Impacts: H_2S exposure is possible through various routes such as inhalation, oral, and dermal. In a wastewater treatment plant setup, operators face a high risk of H_2S exposure. Table 1 lists the potential health impacts in humans from the Agency for Toxic Substances and Disease Registry (ATSDR).

Table 1: Exposure Routes And Associated Health Impacts

	Heath Impact						
Exposure Routes	*Death*	*Systemic Effect*	*Immunological Effect*	*Neurological Effect*	*Reproductive Effect*	*Development Effect*	*Cancer*
Inhalation	*yes*	*yes*	*none*	*yes*	*limited data*	*none*	*none*
Oral	*none*	*none*	*none*	*none*	*none*	*none*	*none*
Dermal	*none*	*none*	*none*	*none*	*none*	*none*	*none*

Source: Compiled from ATSDR *(Note: "None" indicates no database found on ATSDR website.)*

Economic and Social Impact: Water Infrastructure Network (WIN) reported in the year 2000 that 50 percent of the $23.5 billion spent nationally for replacement, repair, and addition to wastewater infrastructure all over the U.S. was due to hydrogen sulfide-related corrosion. Consistent H_2S odor in a neighborhood has the potential to impact the quality of life and negatively influence property prices in the area. Strict air quality regulations and greater public concerns have led to an increased social focus on odor-related issues (Kim et al. 2007). Figure 1 shows corrosion on a sluice gate valve and bar screen at the headworks.

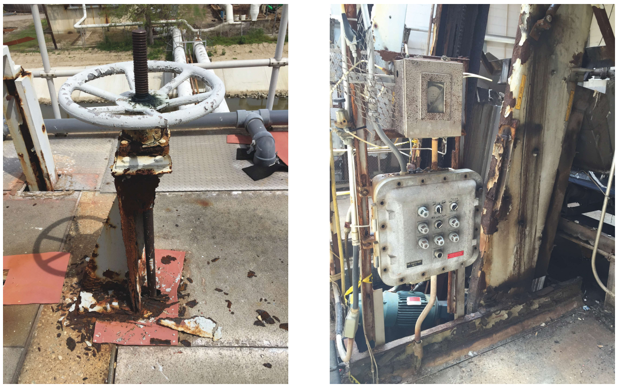


Figure 1. Corroded valve and bar screen at monitoring site headworks

Need For Research

Conventional odor control studies performed by municipalities to design their individual odor/corrosion control strategies largely depend on establishing a dilution to detection threshold (D/T) ratio and ascertaining the recognition threshold (R/T) for air samples collected from the study area. Often these samples for R/T and D/T are collected using a few grab samples (instantaneous samples using tedlar bags) over a period of a few days. Continuous sampling is rarely done since it is cost-prohibitive and time-consuming. These conventional odor studies based on R/T and D/T have a number of limitations and lead to inaccurate conclusions. Therefore, there is a demand for rapidly and economically identifying and forecasting H_2S emissions from various wastewater infrastructures.

Methodology

To reduce detrimental health, social, and economic impacts, air quality management tools such as emission factor (EF) for estimating H_2S emissions from a wide variety of sources including wastewater facilities are very useful. Per the EPA, "an air quality emission factor is the relationship between the amount of pollution released and the amount of raw material processed, or amount (number) of product (units) produced, or amount of work done." Examples of emission factors include: mass of CO_2 emitted per distance driven by a vehicle (kg-CO_2/km-driven), mass of SO_2 produced per unit amount of electricity produced (kg-SO_2 /KWH-electricity produced), and others. Determining EF is considered an important step in assessing air pollution and subsequent control.

Since 1972, the EPA has published *AP-42 Compilation of Air Emission Factors* (*AP-42*), which is a collection of EFs and process information for more than 200 air pollution source categories from a wide range of industry sectors (*Technology Transfer Network, Clearinghouse for Inventories and Emission Factors*; EPA).

In this study, the pollutant of concern is H_2S from various WWTP headworks, and the parameters to describe the "unit of measure" for normalization are: 1.) flow of wastewater processed by the WWTP, 2.) population served by a particular WWTP, and 3.) service area associated with the WWTP. EF is an average value obtained from a long-term observations study performed during normal operations of the polluting unit. *AP-42* indicates that EF formulae, which include variable parameters such as temperature, wind velocity, and pollutant unit dimensions produce a more realistic estimate. In line with the EF guidelines established by *AP-42*, this study based its EF calculation methodology on variables such as:

- H_2S emissions using continuous H_2S concentrations within the headworks' influent chamber (sampling every 5 minutes for six months);
- wastewater flow received at the WWTP;
- service area; and
- population served.

This research attempted to determine H_2S EFs for headworks at four WWTPs based on field measurements of H_2S emissions and other parameters. These EFs are expressed as a function of (a) wastewater flow (EF-Flow), (b) population (EF-Population), and (c) area served (EF-Area). Four Jefferson Parish WWTP headworks — East Bank (shown in Figure 2), Marrero, Harvey, and Bridge City — were chosen as the sites for this evaluation study/pilot project as all flows pass through these units, and it also has one of the highest potentials to generate H_2S. Based on the findings of this evaluation study, researchers could modify their methodology for any future research in this area.

Figure 2. East Bank WWTP headworks and air sampling location on top of the headworks unit

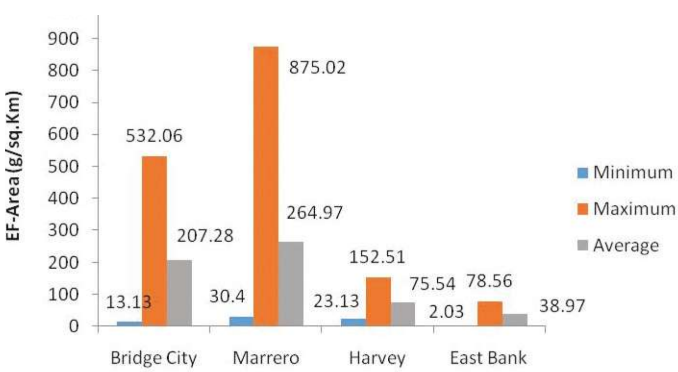
Results

Comparison Of EF Ranges Among Various WWTP Headworks: Figures 3 to 5 at right show the comparison of EF-Flow, EF-Population, and EF-Area among all four WWTPs in terms of maximum, minimum, and average EF values. It was observed that the weekly average EF-Flows calculated for Marrero and Bridge City WWTPs are 5 percent apart, whereas the average EF-Flows for Harvey and East Bank WWTP are 3 percent apart. Similarly, the weekly average EF-Populations for Marrero and Bridge City WWTP were calculated to be 32 percent apart, while the weekly average EF-Populations for Harvey and East Bank WWTP were calculated to be 72 percent apart. Finally, the weekly average EF-Areas for Marrero and Bridge City WWTP were calculated to be 22 percent apart, while Harvey and East Bank WWTP's weekly average EF-Areas were 48 percent apart.

Figure 3: Comparison Of EF-Flow Among WWTPs

Figure 4: Comparison Of EF-Population Among WWTPs

Figure 5: Comparison Of EF-Area Among WWTPs

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To reduce detrimental **health, social, and economic impacts**, air quality management tools such as emission factor (EF) for estimating H_2S emissions from a wide variety of sources including wastewater facilities are very useful.

Based on the average values calculated for the entire sampling period, Table 2 provides the preliminary ranking of WWTP (in terms of emission potential) based on individual EFs. The overall ranking was established by taking into account the individual EF rankings generated based on various EF calculations.

Table 2: Comparison Of Ranking Of Sampling Locations

Sampling Location	Individual EF Ranking			Overall Ranking
	EF-Flow	EF-Population	EF-Area	
Bridge City	*2*	*1*	*2*	*2*
Marrero	*1*	*2*	*1*	*1*
Harvey	*4*	*3*	*3*	*3*
East Bank	*3*	*4*	*4*	*4*

(Note: Rank of 1 indicates highest H_2S emissions, and 4 indicates lowest.)

In an attempt to understand the differences in the EFs from various treatment plants, attention was directed to:

1. analyzing wastewater parameters, and
2. the type of collection system.

Research was also performed to generate an empirical formula to forecast H_2S emissions. Discussions of these items are beyond the scope of this article, however.

Conclusion

Based on the literature review, it was observed that the conventional air emission studies are resource-intensive and time-consuming and typically require an outside agency to perform testing, data collection, and interpretation. Present studies also do not establish any emissions model that can be used by in-house municipal staff for predicting H_2S emissions in their respective sewer system. Discussions with Jefferson Parish municipalities revealed that an in-house air emission testing capability would serve as a great tool to identify potential locations for health risk, odor, and corrosion hot spots, particularly due to H_2S emissions. This study serves as a demonstration tool for using EFs to ascertain H_2S ranges. Based on the findings of this study, future experiments can be designed to expand this air emission tool for other closed treatment units and collection systems. Also, similar studies can be designed to ascertain concentrations of multiple gases associated with sewers.

The results of this study provide a range of EFs for four WWTP headworks based on wastewater flow handled, population served, and the service area. These EFs can be used by the Jefferson Parish personnel in understanding the day-to-day H_2S emission potential of headworks at these various WWTPs by knowing one of the variables: (a) flow rate, (b) population, or (c) service area. Emission potential at other headworks of WWTPs of similar size and scope can be estimated using the EFs presented in this paper. ■

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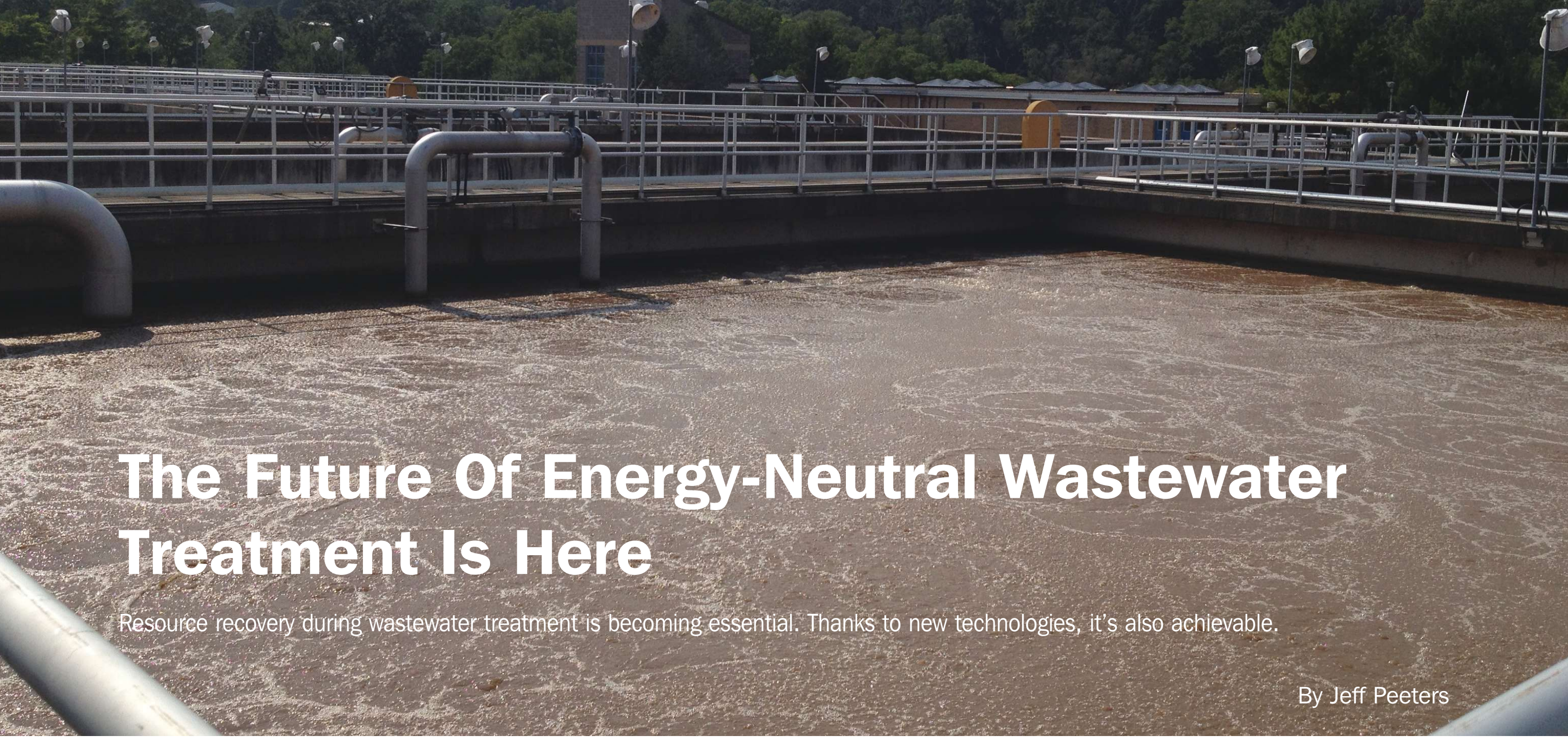


The Future Of Energy-Neutral Wastewater Treatment Is Here

Resource recovery during wastewater treatment is becoming essential. Thanks to new technologies, it's also achievable.

By Jeff Peeters

Historically, interactions between water and energy have been considered on a regional or a technology-by-technology basis. And at the national and international levels, water and energy systems have been developed, managed, and regulated independently. But more recently, the world is recognizing that water and energy are not only connected, but tightly intertwined. It's about time. We all need water and energy, and we all need to take part in the efforts to secure them for generations to come.

Water reuse, policies and partnerships, and emerging disruptive technology solutions are vital to the cause. Specifically, there is an urgent need to shift how we view wastewater treatment and move to sustainable, strategic infrastructure solutions. Wastewater treatment plants are not waste disposal facilities, but rather resource recovery facilities that have the potential to produce clean water, recover nutrients (such as phosphorus and nitrogen), and reduce the dependence on fossil fuels through the production of renewable energy.

According to the U.S. EPA, community drinking water and publicly owned wastewater systems in the U.S. use 75 billion kWh of energy per year — as much as the pulp and paper and petroleum industries combined or enough electricity to power 6.75 million homes. The EPA also recognizes energy as the second-highest budget item for municipal drinking water and wastewater facilities, after labor costs, with utilities spending about $4 billion annually on energy. Energy consumption by drinking water and wastewater facilities can comprise 30 to 40 percent of a municipality's total energy bill.

Water and wastewater utilities are highly regulated entities whose primary goals are to meet regulatory requirements for protecting public health and the environment for reasonable and fair rates. Energy efficiency has not historically been at the top of the list of priorities. Nevertheless, as populations grow and environmental regulations become more stringent, demand for electricity at water and wastewater plants is expected to increase by approximately 20 percent, according to the EPA. Moreover, as electricity rates increase, energy conservation and efficiency are issues of increasing importance for the budgets of municipalities.

The Path Toward Energy-Neutral Wastewater Treatment

The lingering effects of the global economic recession have placed additional financial burden on wastewater utilities as they strive to meet increasingly strict discharge requirements with aging infrastructure in need of repair and replacement. Energy conservation, on-site generation, and renewable energy are becoming increasingly important to wastewater utilities as energy policy, energy economics, and actions to mitigate climate change converge with the need to meet higher standards of wastewater treatment. Many utilities are beginning to reduce grid-connected energy consumption at their facilities through a variety of energy conservation and on-site energy production measures. Emerging, disruptive innovations in technology combined with operational best practices are bringing into focus the opportunity to achieve energy-neutral wastewater treatment.

On-site generation of energy is achieved by extracting the energy content of the organics in wastewater and converting it into a useable form. For example, advanced anaerobic digestion biosolids and biowaste processing systems use bacteria in the absence of oxygen to break down organic matter to create biogas; the biogas can then be combusted or oxidized and used for heating or with a gas engine to produce electricity and heat. It can also be compressed and used as fuel for vehicles or sold for use in a natural gas grid, while additional nutrient-rich effluent can be used as fertilizer. Designed to recycle biosolids into methane and valuable byproducts, the advanced anaerobic digestion systems are key to offering a cost-effective, low-maintenance way to turn sludge into electricity — generating renewable energy that can be used to power the very facility producing the waste.

The technology can also be used to treat biowaste, such as food waste, fats/oils/greases (FOG), etc. By combining the digestion of these external sources of organic matter with the digestion of organics in biosolids from wastewater treatment, the energy production potential of a wastewater treatment facility can be significantly increased. Consider this: A city of 500,000 people produces roughly 75,000 tons of household

Energy-efficient aeration and the recovery of nutrients are two key elements to sustainable wastewater treatment.

and commercial food waste and more than 14,000 tons of sewage sludge. By treating that waste with advanced anaerobic digestion, the value of the methane byproduct used in one of GE's Jenbacher gas engines would produce about 5MWe of electricity alone — enough to power 10,000 homes.

The greatest demand for energy in wastewater treatment is for providing oxygen to a biological system, which is typically achieved via forced bubble aeration. In fact, approximately 60 percent of the energy used at wastewater treatment facilities is for aeration. To achieve energy-neutral — and ultimately, net-positive — wastewater treatment, facilities require low-energy treatment alternatives to the conventional aeration, as well as methods to enhance energy generation with existing infrastructure.

New, low-energy technology solutions have become a focus of research and development activity. For its part, GE has developed a flowsheet to achieve energy-neutral wastewater treatment while removing nitrogen using the proven nitrification-denitrification metabolic pathway. Compatible with solid-liquid separation by conventional secondary clarification or membrane filtration, the flowsheet is based on a hybrid membrane-aerated biofilm reactor (MABR) process, which uses hollow fiber membranes arranged in modules and cassettes deployed in a way similar to immersed hollow fiber filtration membranes used for more traditional membrane bioreactor applications. Atmospheric air is fed down the lumen of hollow fibers, and oxygen is diffused to the biofilm growing on the outer surface of the membrane without the formation of bubbles. This technology significantly increases the efficiency of oxygen transfer, resulting in a 4x-reduction in energy consumption for aeration. This flowsheet has been compared to a conventional activated sludge system, including complete wastewater and sludge treatment with anaerobic digestion, and combined heat and power energy recovery. The results thus far are promising: with electricity consumption 40 percent lower and energy production 18 percent higher (as compared to the conventional system), leading to overall energy neutrality.

The Future Of Energy And Water

As water and energy demand and supply continue to shift, managing the two resources in tandem will help regions worldwide maintain reliable and sustainable supplies of both. This is of critical importance as the global economy continues to explore new energy and renewable energy sources. But to sustain energy production and a dependable water supply, we must all gain even more detailed understanding of the interdependencies of water and energy systems, balance the needs of all users, and continue to develop technologies that reduce water use and enable water recycling while neutralizing or even creating energy. ■

About The Author

Jeff Peeters, PE, is a senior product manager at GE Water & Process Technologies with more than 15 years of experience developing and commercializing innovative technologies, including ZeeWeed membrane technology.

Real-Time Predictive Analytics For Smarter Smart Water Infrastructure

By Sam Hatchett and Jim Uber

Are you confused by your smart water system? New tools help utilities make sense of data and finally realize the potential of smart water infrastructure.

Smart water concepts can seem confusing, at least when it comes to our sprawling buried infrastructure systems. Vendors and utilities are both trying to figure out where new technologies will make it easier to solve problems. Right now we're in the land of Big Data, and it can seem that everybody, from SCADA (supervisory control and data acquisition) suppliers to metering companies, is chanting the same mantra — more data, anywhere you want it, for less money. The assumption seems to be: If the answer is to be found somewhere in the data, then more data should equal better answers.

What's not to like? Better and cheaper sensors, more-efficient networking — these will be key for most any smart water infrastructure system. But they're just part of a complete solution for solving real operational and management problems, and, like a highway that's half finished, you might not see much benefit until the job is done. The Big Data or smart water message can be especially confusing for buried infrastructure systems, with design and operational data often stored in disparate SCADA, CMMS (computerized maintenance management software), customer billing, GIS, and hydraulic modeling databases. If you're not certain to leverage existing data for specific management and operational goals, then adding more data to the mix can seem hard to swallow.

Data Starvation Or Data Indigestion?

Water utilities, at present, seem more plagued by data indigestion than data starvation. Utilities know they need more data and better data. But it's a tough sell, until they can process those data efficiently and prove they're deriving value from investments in expanded or improved instrumentation.

Throughout the industry, it's common to find that the USB drive, the comma-separated-value (CSV) file, and the spreadsheet have been used as a stand-in for the "data integration platform." Take, for illustration, a data flow example from the hydraulic modeling arena — one that we know well. Crucial operational data are in the SCADA historian, but always need filtering or other transformations and usually have tag names that are different from their corresponding model identifiers. These data are batch-exported to a CSV file, imported into a spreadsheet, organized and transformed into something that has meaning for the infrastructure — like a water usage pattern — and then imported into modeling software. This process is repeated, as a series of one-off exercises, often by outside consultants. It's no wonder that hydraulic models are calibrated to data, on average, once every five to seven years.

Utilities can no longer afford such wasteful data management practices. We can do better, and when that happens, it will help clear the path for high-value, smart water infrastructure technologies. Data integration and management tasks need to be simple, intuitive, and meaningful. With that as a starting point, utilities will make efficient use of the substantial data sources they have today and begin to think about tomorrow.

Real-Time Predictive Analytics

"Real-time predictive analytics" can be thought of as distinct from the Big Data techniques borrowed from application areas such as finance, using unspecified methods or purely statistical "black-box" models and indelicately applied to water infrastructure. Instead of a one-size-fits-all approach, real-time predictive analytics fuses operational data streams with information about unique utility infrastructure, creating a fundamentally sound scientific basis for predicting infrastructure performance.

We're taught in school that the scientific method requires a hypothesis to predict, quantitatively, the results of new observations. Real-time predictive analytics puts this paradigm in motion — predictions of infrastructure behavior produced and updated automatically from real-time operational data. The hypotheses are proven physical laws — conservation of mass and energy — and detailed infrastructure specifications, instead of fragile statistical correlations. Complete predictions of flows, pressures, tank levels, and water quality are produced throughout the infrastructure network, evolving over time so that pump statuses, control valve settings, and water demands reflect actual system operation.

The scientific method also insists that predictions are compared to observations. Real-time predictive analytics are compared continuously to observations in the SCADA record, identifying out-of-bound conditions. The next generation of predictive analytics software will monitor these conditions as sentinels of infrastructure failure and provide the tools to identify small problems before they turn into big ones.

The Future Is Now: Next Generation Software Systems

The industry is moving quickly to address important data integration issues and bring real-time predictive analytics into mainstream utility practice as a foundation for smart water infrastructure. Turnkey configuration processes will eliminate custom software development and lower implementation costs by supporting flexible and robust methods of data access, filtering, and integration with infrastructure elements. Real-time predictive analytics will be generated automatically, using either local or cloud-based data processing, and served to the end user via Web-based, interactive dashboards on desktop, tablet, or mobile platforms. This is happening now with the CitiLogics' Polaris analytics system, which is a single solution that collates all of these functions and is based on the official USEPA Epanet-RTX real-time analytics engine.

Using such next-generation predictive analytics technologies, utility operators will practice achieving optimization goals for pressure, leakage, energy, and water quality management. Just like a pilot uses a flight simulator, utility engineers will rely on accurate infrastructure models that are continuously updated through a persistent connection to the operational record. Likewise, utility managers will review automated dashboards and periodic reports showing trends in important management goals and integrate those with past and future asset management decisions.

Early adopters of real-time predictive analytics technology are already demanding more than new sensors; they are expecting a flexible data integration platform with a real-time predictive ability that leverages their past investments in data and modeling technologies. Their experiences will benchmark the benefits from a smarter smart water infrastructure based on physics-based, real-time predictive analytics — and pave the way for the broader utility industry. ■

About The Authors

Sam Hatchett is a principal of CitiLogics and brings research-level engineering expertise and creative mathematical- and physics-based insights into designing models and building tools for large water distribution networks.

Jim Uber, Ph.D., is a principal of CitiLogics, a software technology firm located in the metro Cincinnati area. CitiLogics developed Polaris, a real-time, SaaS predictive analytics suite of tools for the water utility sector.

Optimized Decision Support For Water, Wastewater, And Stormwater Systems

By Jeffery Frey

Innovation is paying dividends for the growing list of municipalities that leverage the latest technology to optimize planning and operations decision making.

Real innovation in the water industry is a goal shared by all stakeholders — municipal and private utilities and their customers; federal and state regulatory agencies, industry organizations, and watchdog groups; equipment manufacturers and software vendors; and consulting engineers. Nancy Stoner, the U.S. EPA's acting assistant administrator for water, has stated that "technology innovation can accelerate progress toward our goals of clean and safe water. EPA and many stakeholders will strive to support technology innovation to solve water resource problems … cheaper, faster, and using less energy."

An example of true technological innovation is the development of formal optimization techniques for the planning and operation of water systems based on hydraulic simulation models. Water systems include water distribution, wastewater collection, stormwater, reclaimed water, irrigation, and even water supply and river basin systems. The simulation models include water distribution models, such as EPANET, collection system models, such as EPA SWMM, or water resources/supply models, such as REALM. This article provides an overview of this exciting technological innovation and its benefits, supported by a number of recent case studies highlighting organizations that achieved substantial results using optimized decision support (ODS) software.

Optimization And Optimized Decision Support

Everyone likes to believe they "optimize" their project-planning and system operations. Typically, their process is to identify and evaluate a number of options and then select what appears to be the best capital improvement or operating plan that theoretically meets the design and performance criteria. This is accomplished with an up-to-date hydraulic simulation model using trial-and-error and engineering judgment. This approach, however, is not the type of optimization that qualifies as technological innovation.

True technological innovation requires the use of a powerful, computationally intelligent optimization tool capable of solving both broad questions and the intricacies of complex problems. Water system problems are often highly complex with a seemingly limitless number of options to consider. These problems challenge even the smartest engineers with decades of experience using detailed simulation models. Experience and engineering judgment are invaluable in the search for the best solutions, but far better and faster results can be achieved if an engineer applies the proper optimization tool.

Software can support ODS by enabling engineers and managers to evaluate the full range of alternatives in developing cost-effective, near-optimal solutions for capital planning, operations, and long-term control plans. Software-supported ODS represents a significant advance beyond current practice by helping modelers interact far more intelligently with their simulation models as they vet numerous promising solutions for consideration by utility decision makers.

Benefits Of ODS Approach

Today, the ODS approach is becoming a recognized best practice in the water industry, with utility and consultant managers and modelers studying the appoach and being trained to utilize the software tools. The benefits and value in moving from a simulation-only approach to an ODS approach are impressive. This is evidenced by the level of cost-avoidance achieved on several projects that utilized an ODS approach (see Table 1).

Table 1. Comparison of original simulation solution vs. ODS solution

Water/Wastewater Utility	*Cost Using Traditional Planning ($M)*	*Cost Using ODS Software ($M)*	*Investment Avoided ($M)*	*% Reduction*
Fort Collins-Loveland Water, CO (System-wide plan)	*$5.9*	*$3.0*	*$2.9*	*49%*
Las Vegas Valley Water, NV (Pressure zone plan)	*$9.1*	*$7.4*	*$1.7*	*19%*
San Diego Water, Alvarado, CA (Main replacement)	*$55.0*	*$35.3*	*$19.7*	*36%*
Fort Worth Water Dept, TX (Pipes-only analysis)	*$260.0*	*$187.0*	*$73.0*	*28%*
SA Water, Australia (Desalination plant integration)	*$1,100.0*	*$403.0*	*$697.0*	*63%*
Bend, OR (Summer operations for energy)	*$1,895/day*	*$1,460/day*	*$435/day*	*23%*
South Bend, IN CSO LTCP Optimization	*$412.0*	*$299.6*	*$112.4*	*27%*
Bend, OR Sewer Master Plan Optimization	*$130.0*	*$80.0*	*$50.0*	*38%*
Texas City SSO Optimization Pilot	*$103.2*	*$82.2*	*$21.0*	*20%*

Capital improvement and lifetime O&M (operations & maintenance) cost savings are drivers for adoption of the ODS approach, particularly due to limited budgets and tighter regulations. Being able to stretch utility dollars to cover more needs and minimize rate increases can help utility managers become more efficient and effective.

Besides reductions in cost, the ODS approach offers other benefits:

- Protecting public health through the reduction of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs)
- Improving system reliability and sustainability by optimizing for specific emergency scenarios
- Improving hydraulic performance in terms of meeting design criteria
- Gaining confidence in plans developed using a comprehensive, unbiased, defensible approach
- Enabling planners to identify the critical decision choices through more powerful modeling

- Reoptimizing solutions under alternative scenarios and performing unlimited sensitivity analyses
- Finding solutions that balance capital vs. operating costs or gray vs. green infrastructure
- Staging to identify near-term projects that provide maximum value
- Utilizing multiobjective optimization to develop trade-off curves for triple-bottom-line (TBL) objectives

A 'Glass Box' Approach

Innovative technologies are often misunderstood. By definition, they differ from the current approach to problem-solving. While the ODS approach has sometimes been called a "black box" approach, this is far from accurate. If anything, the ODS could be called a "glass box" approach.

The ODS approach is transparent. It utilizes existing system simulation models, which in most cases are well understood and accepted by utility planners and managers. The ODS software instructs the system simulation model to create and evaluate many thousands of trial solutions. Trial solutions are automatically created using the range of alternative improvements it is allowed to consider, while the cost and performance of each trial solution (from a full simulation model run) are simultaneously evaluated based on the agreed unit costs and performance critieria.

The inputs into the optimization model are straightforward. Whether for a single neighborhood or a citywide master plan, there are four basic types of input required for any optimization problem:

1. An up-to-date, calibrated system simulation model
2. Range of allowable decision options to be considered such as new pipe, storage, pump, regulator and plant locations and sizes, green infrastructure and inflow/infiltration removal options, and operating set points
3. Corresponding unit costs for the decision options, including energy and O&M costs
4. List of design and performance criteria or service levels to be met, such as minimum pressures, maximum velocities, minimum drawdown for tanks to exercise, and overflow and surcharge levels

The results from an optimization run are output as the optimized plan or design that can be saved separately as a simulation model. With the ODS approach, the designs can also be modified manually, which permits the modeler to make changes based on engineering judgment and then quickly run a simulation to check and report out both cost and performance on any number of designs. The knowledge of the engineer and planner are amplified in an ODS approach, enabling a broader range of their choices to be evaluated and allowing for extensive sensitivity analyses.

Sample ODS Case Studies

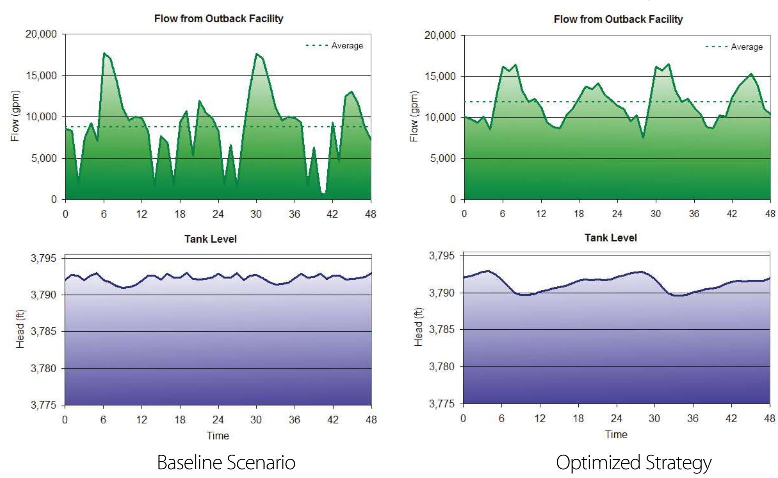
Several case studies illustrate how the ODS approach is being used by both small and large municipal utilities across the U.S. Bend, OR, optimized its Water System Master Plan in 2009-10. Based on that project's success, the city required an ODS approach be used by the consultant team to optimize its Comprehensive Sewer Master Plan in 2013-14. South Bend, IN, utilized an ODS approach in the development of its CSO Long Term Control Plan (LTCP) in 2011-12. In 2014, the Los Angeles Bureau of Sanitation and a large Texas city stormwater management group each completed demonstration studies on limited areas of their systems to better learn about the ODS approach and its ability to inform their decision-making process. The following brief descriptions highlight key aspects of these optimization projects, all of which were completed utilizing Optimatics' Optimizer ODS software tools.

Bend, OR, Operations Optimization. As part of its overall Water Master Plan, the city requested an optimization of existing system operations aimed at reducing pumping energy costs in summer and improving reservoir storage turnover in winter to enhance system water quality. Annual pumping energy costs totaled approximately $700,000, with the majority of the cost coming from pumping groundwater to supplement the lower cost surface water supply in summer.

The first step was to select typical summer and winter periods simulating the historical operation in the model and performing energy usage and cost calculations as a baseline. The ODS software was then formulated to investigate various operating options, including pump trigger levels and pressure-reducing valve (PRV) settings that might reduce costs. The optimization identified revised operating strategies that led to a 23 percent reduction in energy usage for the summer period. The operating changes included restricting flow into key reservoirs during periods of high demand to reduce peak flows in transmission lines, adjusting PRV settings to increase flow transfers from the surface water supply, and boosting surface water between zones rather than pumping groundwater at higher heads — all changes that were discussed and endorsed by the operations group.

In addition to reducing energy usage, the charts in Figure 1 illustrate how restricting flow from the Outback surface water source to the Awbrey Reservoir and forcing the level to vary over a wider range minimizes peak flows from the surface water facility and increases the overall average utilization of the lower-cost surface water.

Figure 1. Improved reservoir exercising and more constant surface water supply



South Bend, IN, CSO LTCP Optimization. South Bend's consent decree negotiations with the U.S. EPA and the Department of Justice concluded in December 2011. Prior to that, the city requested that its existing CSO LTCP be optimized using the ODS approach to see if

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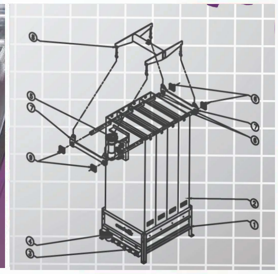

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Visit our sites at www.ovivowater.com | www.mbrcentral.com any changes were warranted. The project involved updating costs and confirming the LTCP met the four-overflows-per-year level-of-service requirement. In addition, the city wanted to know if some combination of green infrastructure or low-impact development (LID) technologies could supplement or replace proposed LTCP gray infrastructure improvements in order to reduce costs and improve performance.

Table 2 compares the existing CSO LTCP solution (column 2) with an optimized gray-only solution (column 3), the overall optimized gray-green solution (column 4), and a modified optimized solution with the effectiveness of the green infrastructure reduced by 50 percent (column 5). This type of comparison is invaluable to utility decision makers and other stakeholders involved in deciding how the city should proceed. The potential $112 million (27 percent) cost reduction certainly received favorable attention from the Board of Public Works and the mayor, who would be called on to defend the recommended LTCP plans.

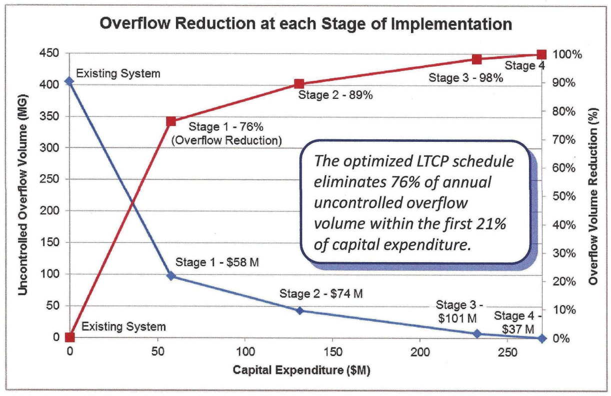
In addition to cost savings or cost avoidance, the optimized solution also demonstrated improved hydraulic performance relative to the previous LTCP. The hydraulic performance improvements included 32 percent greater CSO volume eliminated, reduced frequency of CSOs at three locations, and reduced surcharge levels resulting in fewer basement backup issues.

Table 2. Baseline CSO LTCP solution vs. optimized solution and two other scenarios

Cost Item	Baseline Solution ($M)	Gray-Only Solution ($M)	Optimized Solution ($M)	50% Effective Green Solution
Conveyance	149.83	114.40	114.40	114.40
Pump Station	0.00	1.25	1.25	1.25
Storage Tank	99.80	116.82	63.28	95.81
Linear Storage	42.66	13.96	13.96	13.96
Relining & RTC	13.04	6.18	4.85	5.34
Green Technology	--	--	27.39	19.04
Total Construction	305.34	252.62	225.13	249.80
Eng/Leg/Adm. (20%)	61.07	50.52	45.03	49.96
Total Capital Cost	366.40	303.14	270.16	299.76
Present Worth O&M	46.61	40.84	29.40	37.45
TOTAL COST	412.01	343.98	299.56	337.21
Cost Avoidance	--	$68M / 17%	**$112M / 27%**	$75M / 18%

A separate ODS analysis was also performed to optimize staging of the 18 capital improvement projects in the plan. Figure 2 shows how the first five-year stage of the LTCP can achieve an overall reduction in uncontrolled overflows of 76 percent with the expenditure of just 21 percent of the total $270 million capital cost of the optimized LTCP.

Figure 2. Optimized staging achieves maximum overflow reduction in near term.

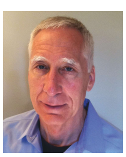


Los Angeles Bureau of Sanitation Optimization. LA BOS identified a small, but challenging problem facing their planning team. They desired to identify the best solution to augment reclaimed water supplies to one of their service areas during dry weather periods. A variety of options were identified, including construction of a dedicated pipeline between two existing plants and construction of new pipelines along allowable routes to provide additional capacity within the service area. The options were formulated in the ODS software program with new pipe and pump station upgrade costs and service level criteria. The study demonstrated to LA BOS managers and engineers the ease of the optimization formulation and its ability to quickly develop and compare near-optimal solutions that may not have been identified using the normal trial-and-error method. The estimated cost of the optimized alternatives was just 50 percent of the original dedicated pipeline plan cost.

Stormwater Optimization. The benefits of utilizing ODS for stormwater optimization have been demonstrated through finding optimal solutions on combined sewer systems which are dominated by stormwater runoff. Recently, a more pointed approach to optimization was adopted on a stormwater collection system in Texas. ODS was used to select improvement options that would eliminate flooding under the 100-year-storm design, for a portion of its stormwater network. The city provided an EPA SWMM model for an area covering 29 subcatchments. The optimization was formulated to consider 87 new pipe and 6 storage options as well as green infrastructure options to reduce surface runoff in each of the subcatchments. The project demonstrated how ODS could be utilized for stormwater applications to mitigate flooding at least cost.

ODS: A True Technological Innovation

A powerful technological innovation is changing the way utility managers and engineers approach capital planning and operations of water systems. The ODS approach is founded upon advanced computationally intelligent software tools developed, tested, and proven over the past 19 years with leading utilities in the U.S., Canada, Australia, New Zealand, the U.K., and China. As ODS is utilized by more utility and consultant planners and modelers, the ability to identify low-cost, near-optimal solutions will benefit stakeholders while providing a return on investment. ■



About The Author

Jeffery Frey, PE, co-founded Optimatics in 1996, after 15 years at Harza Engineering Company.

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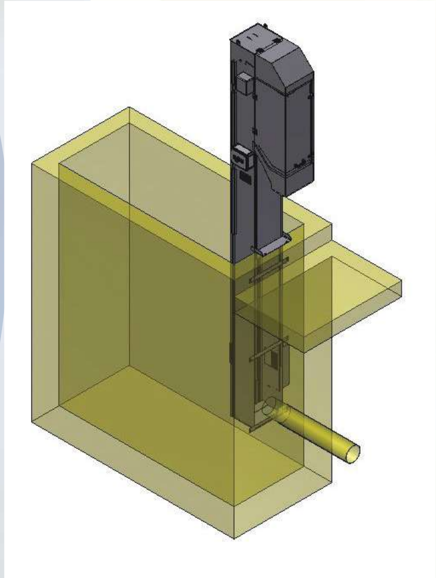

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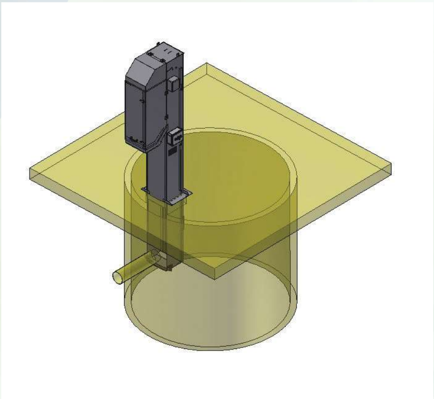

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Extreme Wastewater Treatment: Deconstructing Chemical Weapons

Can a filter save the world? Maybe not, but this application highlights the role of innovative water treatment technologies in protecting the health and welfare of the planet.

By Dean Amhaus and Thomas Ausloos

The Milwaukee region's water industry is a $10.5 billion market and accounts for 4 percent of the world's total water technology business. The Water Council, with a growing membership of more than 160 organizations, is situated here, and its members are working to address a broad range of water-related issues to tackle the goal of improving world water health — including the safe destruction of chemical weapons.

Oberlin Filter Company, a Water Council member since 2010, is a manufacturer of automatic pressure filters for solid-liquid separation located in Waukesha, WI. The company was selected to provide filtration equipment for the unique and challenging task of deconstructing U.S. chemical weapons reserves pursuant to the START I and New START treaties.

START I And New START: Strategic Arms Reduction Treaty

Negotiations for the Strategic Arms Reduction Treaty (START) ignited when President Ronald Reagan first proposed the agreement to Mikhail Gorbachev during the Geneva Summit in 1985. The final treaty was not signed and ratified until 1994 during President George W. Bush's term, mainly due to the complications and turmoil around the dissolution of the Soviet Union. The treaty outlined that Russia and the U.S. would be limited to 6,000 nuclear warheads and 1,600 nuclear delivery vehicles each. This meant both governments must destroy their stockpile of chemical nerve agent weapons, thus leading to a drastic reduction in their combined stockpiles of nuclear warheads.

In 2010, President Barack Obama's Administration signed and ratified the New START treaty, which further reduced the imposed limits. As outlined in the new treaty, both parties must meet the central limits on strategic arms by Feb. 8, 2018, exactly seven years from the date the treaty was officially executed. The new limits set deployed warheads at 1,550, significantly less than the original START I treaty, and further reduced nuclear delivery vehicles.

Dismantling Chemical Nerve Agents, One Step At A Time

The burning question now is, "How does a nation with such vast chemical weapon reserves safely and securely destroy and dispose of such dangerous arms?" The various secure locations of weapon stockpiles around the country must adopt and undergo a destruction plan of action that may employ a unique technology process, or one similar to plans conducted at other sites.

General Atomics, a specialized contractor for the government, located in San Diego, was tasked with deconstructing reserves located at the Blue Grass Army Depot, outside of Richmond, KY. They were in search of a prefilter that would provide a nearly suspended-solids-free water solution before feeding into their posttreatment process. After General Atomics developed a proprietary process named SCWO (super critical water oxidation), designed to perform the final destruction of the organic components, they selected Oberlin as the solution to their prefilter need to provide a less-than-one-micron, suspended-solids-free solution before feeding their SCWO treatment reactor for the final treatment step. One of the big challenges was the large swing in total suspended solids (TSS) concentrations. The filter needed to be:

- mechanically reliable with high, online operating time
- automatic, to minimize operator exposure
- flexible, in case the feed conditions changed and media had to be modified.

Oberlin came to General Atomics' attention through a recommendation from one of their consultants and through previous testing/report recommendations done for a similar technology. General Atomics and Oberlin began working together initially with a five-year development process agreement, which eventually led to the two entities forming a partnership to dispose of the weapon reserves at Blue Grass Army Depot, where Oberlin's automatic pressure filter is still currently installed.

Underneath the levels of personnel and environmental safety protections, the process of destruction is relatively simple and takes only a few steps:

Destruction: The nerve agent is drained from the missile and

neutralized in caustic. The energetic (fuel) is also drained and neutralized in caustic. This process is known as hydrolysis, and the resulting chemical compounds are known as hydrolysates. Another parallel step is that the aluminum missile body needs to be thinly sliced and dissolved in caustic. The three hydrolysates are then held to ensure agent destruction before being transferred to the next treatment step.

Neutralization: The next step is the neutralization of the hydrolysates. This involves using a special mixture of HCl, H_2SO_4, and H_3PO_4 acids. The neutralization step is very exothermic and results in a solution that contains a high level of aluminum hydroxide, precipitated salts, and unquantified substances. A good portion of this chemistry was developed and filter-tested at Oberlin's headquarters.

Filtration: This step is accomplished by the automatic pressure filter, which was chosen for its simplicity in mechanical function, its need for minimal operator intervention/safety due to its automatic dry-solids discharge operation, and its ability to provide flexible media selections. The clean filtrate is expected to have TSS around 8 to 20 mg/L (0.45 micron membrane) and an NTU (nephelometric turbidity unit) of 3 to 20. The filtrate was visually clear. The media selected was a 1-micron absolute DuPont Soloflo. The solids filter cake is 25-mm thick with a moisture content of 45 to 50 percent.

Organic Destruction: The final step utilizes the SCWO process, taking the filtrate from the automatic pressure filter and breaking it down into the basic components of CO_2, water, and salts. This is accomplished by operating above the supercritical point of water at >3200 psi and >700°F where water exhibits unique properties and where organic compounds are quickly converted to carbon dioxide and water in the presence of oxygen.

Milwaukee's Water Cluster: A Global Health Steward

The role that Oberlin Filter plays in the deconstruction and disarmament of chemical nerve agent weapons is crucial in providing a safe, reliable, and precise filtration step during the destruction process. It also exemplifies the work that Water Council members are doing to create a safer environment for all, addressing a broad range of global water challenges through the development and deployment of innovative technologies — such as filters that disarm chemical weapons. ■

About The Author

Dean Amhaus has served as the first president and CEO of The Water Council since March 2010. The Council seeks to grow the Milwaukee region into a world hub for water research, education, and economic development. Amhaus holds an MBA from the University of Wisconsin-Whitewater and a B.S. in business from the University of Wisconsin-Platteville.

Thomas Ausloos has spent the last 28 years at Oberlin Filter Company, where he is currently VP of marketing and product development. He holds a B.S. in chemical engineering from the University of Wisconsin-Madison.

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