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EDITOR'S LETTER

By Kevin Westerling
Chief Editor, editor@wateronline.com

'Seize The Day'
On New Water Technology

When the time comes, will you be ready?

Timing is everything. It's a painful adage sometimes, used to point out the slim divide between success and failure. Fate notwithstanding, we are often presented with opportunities to "seize the day" and help dictate future outcomes. For utilities, the opportunity may come in a short window of time, with repercussions that affect operations, consumers, and the environment for decades — or the amount of time a large equipment purchase stays in operation.

Most treatment systems are financed over a projected lifespan of about 20 years. As the useful life of a piece of equipment comes to a close, an important decision-making process begins: Replace the model with a very similar technology, essentially stagnating progress for 20 more years, or make the leap to a new technology. While the latter may hold the promise of across-the-board improved performance, there is no guarantee — and thus an understandable wariness develops. George Hawkins, CEO and general manager of the District of Columbia Water and Sewer Authority (DC Water), explains: "When you have very tight budgets, it's natural to go with what you know, or be very careful and certain that something new is going to work before you spend the money. You have to be right, because you don't have extra money to retool if it doesn't work."

That said, Hawkins and DC Water are strident trailblazers in the water/wastewater industry. When the window of opportunity opens, DC Water seizes the day and opts for leading-edge solutions — but not without due diligence. In line with this "Best Practices" edition of *Water Innovations*, Hawkins shared three keys for implementing new ideas and technologies, based on considerable experience in doing so.

A Strong Business Case

DC Water recently invested $470 million in discretionary funds to employ Cambi's thermal hydrolysis process (THP) for sludge treatment at its 370-MGD Blue Plains Wastewater Treatment Facility — an expensive proposition even for a utility with an annual operating and capital budget of nearly $1 billion. But the business case became evident when numbers were crunched; THP projects are both cheaper and more efficient than traditional digestion and biosolids removal over the (literal) long haul.

Hawkins described 1,200 wet tons of sludge, or Class B biosolids — "about 60 very large tanker trucks a day" — that needed to be hauled away from Blue Plains. "Each one of those truck drivers and trucking companies has to be paid," he noted. "There's air pollution being generated; there are all sorts of costs going into that system. And our other worry was that Class B biosolids could always be regulated more tightly, to make it more expensive to handle them."

Moreover, the current system had reached its useful end and would require up to $150 million just to maintain the status quo. Instead, DC Water's new THP installation is generating Class A biosolids, which the utility can sell as fertilizer. Hawkins added, "Truck traffic is cut in half ... and we're generating up to 9 MW of net power that we can use at our facility rather than buying power off the grid. [THP] is absolutely saving funds, it's reducing liability, and there are all sorts of opportunities we haven't even realized yet."

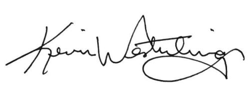
Research

Though financial projections were favorable during the vetting process, questions around the technology's efficacy remained because Blue Plains would be the "first adopter" in North America. However, Hawkins and staff conducted "many, many years of research," including numerous field tests and the analysis of an estimated 40 peer-reviewed papers to prove that, yes, it would (and does) work. In operation since October 2015, "It is functioning better than anticipated," Hawkins proudly reported.

Readiness

DC Water has what Hawkins described as "a system and a scheme for how we identify and evaluate innovative ideas," including a renowned Innovations Chief (Dr. Sudhir Murthy) and a robust R&D program. While that's a luxury not available to all utilities, Hawkins emphasized that "an innovative idea can come to anybody, anywhere."

Innovation is obviously ingrained and ongoing at DC Water, but the notion of *anybody, anywhere* should be universal among utilities and their personnel. A single idea, well-timed and thoroughly researched, can change the fate of many. Start by keeping abreast of what's available, be mindful of when new systems will be needed (timing being everything), and seize the day when the opportunity arises.



Water Innovations

101 Gibraltar Road, Suite 100
Horsham, PA 19044
PH: (215) 675-1800
FX: (215) 675-4880
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Membrane Fouling And Prevention: What Works And What's New

An overview of the current state of pretreatment technology is presented alongside the latest advances and innovative techniques in the pipeline.

By David Paulson

This article is a status review of the industry's efforts to control membrane fouling, including the current standard approaches (briefly outlined) and new and emerging technology. These efforts fall in two categories: pretreatment steps and "in-device" — a loose term to denote that the technology is incorporated within the membrane media, element, machine, or system. This in-device category is further categorized into physical embodiments and operating process steps. Common examples for each of these are the so-called "fouling resistant" variants of commercial reverse osmosis (RO) membranes and the backflushing step now nearly universal for operating hollow fiber ultrafiltration and microfiltration systems (HF-UF/MF).

Everyone reading this article probably understands that fouling of pressure-driven membranes is a constant and pervasive challenge. The biggest controversy on the concept is how to creatively label fouling as a membrane process issue, such as "fouling is the major shortcoming, processing hurdle, ever-present challenge, market-limiting factor, nemesis, albatross, curse, plague, or bane of membrane processing" (or perhaps the "opportunity" for techno-entrepreneurs?). This article does not explain why fouling is bad or the benefits of preventing, mitigating, or reversing it. There are now thousands of articles and papers to reference for that information. But how can the current situation of fouling mitigation be summarized, and what emerging fixes are in the pipeline?

Consistent Approaches Predominate Prefiltration

The old axiom that every system design situation is different because every feedstream and every user's objectives are different is only partly true. Beyond the typical pretreatment steps, diminishing returns are quickly reached for investing in more fouling prevention, so most membrane systems installed today use a fairly standard pretreatment scheme, differentiated by a few major categories of "systems." The following descriptions are generalizations and, as such, are simplifications.

For POU (point of use) residential and small commercial systems, pretreatment typically includes a 5- or 10-micron pre-filter and AC (activated carbon) filter to protect the polyamide membrane from chlorine attack. Both are disposable, like the membrane element itself, simplifying consistent operation and providing an ongoing revenue stream to component suppliers. A post-RO AC cartridge is not pretreatment but removes off-taste from the storage tank's rubber bladder. In the more rare small POU UF system, there typically is no pretreatment.

While larger commercial and light industrial systems may be installed in a business, they do not have trained operators assigned and typically use the same POU pretreatment scheme, sometimes adding a softener where hard water and/or a desire for high recovery (less water to drain) occur.

Large commercial and industrial membrane systems usually justify maintenance by trained technicians and often use a backwashing particle filter (or, increasingly, the backflushing HF-UF/MF technology discussed later, which is more expensive but more efficient). Chemical feed of an oxidant (usually chlorine) is common to precipitate iron and manganese ahead of the filter. Chlorine and its siblings can also be fed to keep biological growth from occurring both in the pretreatment media and on the membrane surface, but this is actually not a common practice. Also common is feeding an antiscalant chemical to prevent precipitation of salts and silica. This pretreatment scheme has been popular for decades now.

The most elaborate and most studied/published membrane pretreatment practices are in the municipal water treatment category. A century-old cohort of high-communicating professionals (i.e., noncompetitive) have shared their efforts to develop and adopt water treatment technology, aided by municipal, state, and (as of 1972) federal government support. When RO, UF, and then NF (nanofiltration) membranes became available, this group's collaborative attitude about improving technology sped both its acceptance and refinement, including pretreatment. Further, they are experts in the pretreatment unit processes required, including oxidation-precipitation, coagulation/flocculation, backwashing bed filtration, dechlorination, etc., that define the standard pretreatment regimen today. Those not on the cutting edge of the technology or its use should look to this civil engineering pool to learn the best large-scale pretreatment techniques.

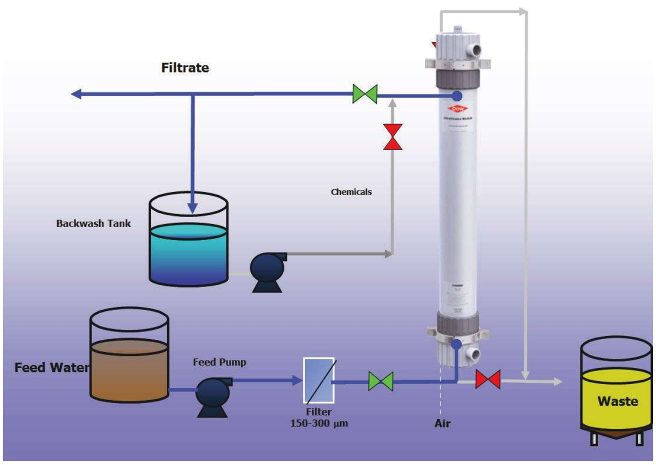
This is not to imply that one should not analyze the feed and consider the best pretreatment scheme. However, once accomplished, the results often look the same. Also, some industries/applications do have other, more nuanced approaches. But they comprise a small minority of installed membranes.

The "extraction industries" of oil, gas, and mining are areas of intense interest for membrane processing and have more difficult feedstreams. Thus, new and more elaborate pretreatment and in-device prevention techniques have been tested in this area. Due to competitive reasons, the system owners do not publish the test results, and their status is currently opaque in the marketplace.

Pretreatment norms are also under development in water reuse/reclaim, especially from municipal wastewater and extraction industries. Here, the value of the water reclaimed is growing, and the difficulty of fouling mitigation is higher due to a tougher foulants profile not yet addressed over past decades. Expect some advances to emerge, due to both the bigger technical hurdles and the market segment excitement that brings more funding and motivation.

Backflushing Hollow Fiber Technology — A Step-Change Breakthrough

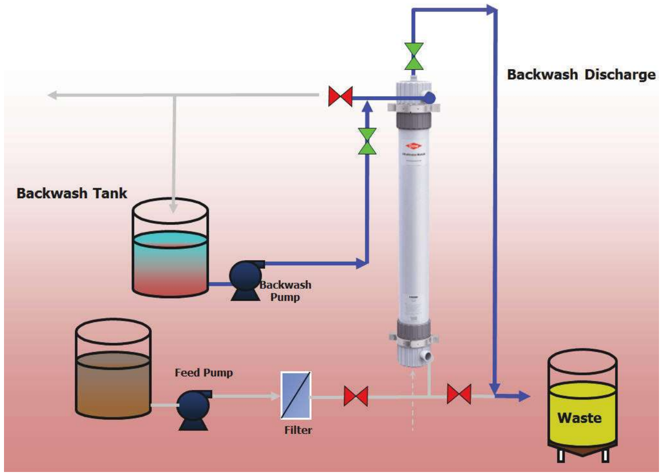
The biggest improvement in membrane fouling mitigation since the concept of crossflow operation is the backflushing of hollow fiber membranes. This was a game-changing benefit that, although two decades old, is still extending its reach. A periodic step, but applied continuously and frequently (typically every 15 to 30 minutes), it is a process operation like chemical addition or high-crossflow velocity. For applications where ultra- and microfiltration (UF/MF) provide adequate removal (think particles, colloids, and microbes), backflushing paved the way for economic operation in large-scale water purification plants as the final filtration.



Hollow fiber UF system in filtration mode *(Credit: DOW)*

Its use as a pretreatment to RO and NF systems was immediately recognized, but its higher cost than backwashing bed filters limits its use. Seawater systems, usually larger and always more expensive, employ this method on 15 to 20 percent of new systems. Where fouling prevention is most crucial, such as for military operations, arid oilfields, mines, or shipboard purification systems, UF/MF's better quality effluent is also often justified.

But backflushing has proven difficult to apply to spiral-wound elements, so RO and NF membrane systems presently do not benefit from this technique. However, the fouling mitigation



Hollow fiber UF system in backwash mode *(Credit: DOW)*

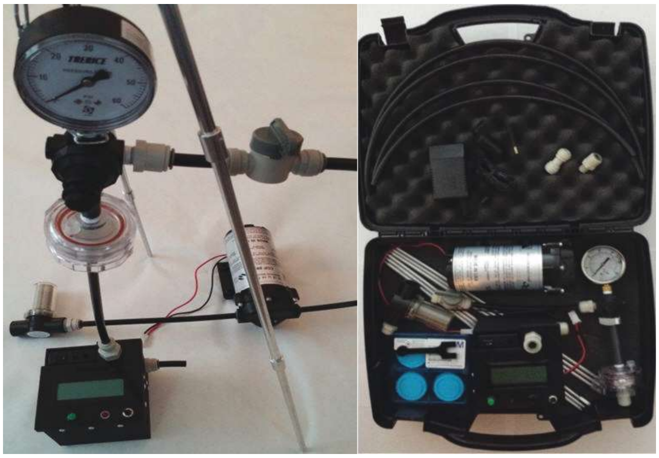
value alone makes hollow fiber RO/NF membranes a very attractive proposition. Should they be developed, they would be another step-change development and viewed as more of a holy grail than even the elusive chlorine-resistant RO/NF membrane.

Measurement Of Pretreatment Effectiveness

To gauge the effectiveness of pretreatment beyond the membrane fouling experienced, there are actually few common measures in use, especially for the most common uses of the purified water. These few measures are widely applied. For large systems with closely monitored operations (e.g., municipal potable water), there is turbidity to measure particle removal, and total organic carbon (TOC) as a broad gauge of organic foulants remaining after pretreatment. The next two techniques pertain only to the salt-rejecting membrane classes, RO and NF. Feedstream pH is monitored to keep salt from precipitating if it exceeds saturation while concentrated in the system, the tendency of which is pH-dependent.

The measure most directly related to fouling potential of water, a direct indicator of pretreatment effectiveness, is the Silt Density Index or SDI test. This direct measure of fouling potential is decades old and used widely across the membrane marketplace for the RO and NF membrane class systems. It is an established warranty requirement for membrane elements, meaning that short membrane life due to fouling will not be an honored claim without proof that SDI values lower than the vendor's benchmark have been maintained.

Although limited in which foulants it indicates and its repeatability, the SDI test is the most accepted measure of pretreatment effectiveness and has been long codified by the ASTM standards organization as Standard Method D4189. Although now in its seventh iteration, the method has not changed much and so has not improved much over its life. New and expanded methods are in development but still in very limited use. The benefits, history, and shortcomings of SDI could easily provide chapters in membrane books (and do). For example, an inherent shortcoming of SDI is that some foulants will pass through its 0.45 micron test membrane, run in the dead-end mode; meanwhile, all RO, NF, and some UF systems are run in crossflow mode. Limitations more easily



Automated SDI system assembled and in carry case

addressed include variation in the membrane discs required, lack of user friendliness and repeatability, and lack of normalization software. These last shortcomings are being addressed by more sophisticated automated systems, the most useful of which come with normalization software (to standard conditions) and teaching documentation.

The SDI test method is already complicated; attempts at improvement have complicated it further. New methods touted as improvements include the Modified Fouling Index (MFI) using either UF or NF class membranes, so-called MFI-UF and MFI-NF tests. The more elaborate Crossflow Sampler — Modified Fouling Index Ultrafiltration (CFS-MFI-UF) test in theory is more predictive of real-world fouling. However, the SDI test is well-established in the marketplace, and change occurs slowly in the world of ASTM standards. The MFI and CSI-MFI-UF methods seem to have not yet broken out of the academic acceptance phase.

Emerging Pretreatment And In-Device Technology Improvements

So, besides improved SDI testing, what products and technologies are emerging to help reduce membrane fouling? The answer: Some in every category are coming; most are only incremental improvements, but a few could be step-change or even game-changers.

Steady Incremental Improvements

Improvements in bed filtration (AKA "pressure filters" or "multimedia backwashable filters") are incremental but continuous, with refinement of both the media used and processing steps. The same can be said of chemical feed treatment, mainly refined antiscalants targeting certain bad actors. These have proved themselves on silicates and are expanding to target other specific scaling solutes. Alternate chlorination chemistry (chloramines, chlorine dioxide, etc.) have been known for longer than membranes themselves, but their use is a slow-moving development. Other alternatives for bacterial fouling control, such as mixed oxidants and UV light improvement, can also be characterized as incremental. This same slow evolution characterizes verifiable antifouling membrane properties, although most RO/NF manufacturers label some products as FR or "fouling resistant." Despite the best efforts of marketing departments, neither disciplined comparisons nor marketplace success has proven that these areas have produced real step-change breakthroughs in fouling mitigation.

Major And Potential Step-Change Improvements

But some exciting changes are emerging now, too, and these are ones to watch closely. They include reduced-cost, backflushable ceramic MF membranes that might improve the economics of both large-scale final filtration but also could expand the use of backflushing HF-UF/MF for small and midsize system prefiltration. The recent entry of all PTFE (polytetrafluoroethylene) hollow fiber UF/MF membranes and modules also improves the selection of membrane that can be back-flushed and will allow harsher cleaning chemicals and higher sanitation temperature, improving economics in high-fouling applications. The established polymeric hollow fiber UF/MF suppliers are already looking at this small-scale market.

The concept of ultrasound on a continuous basis, an example of induced energy disruption of fouling, has been known for some time. But now it is being actively developed by a startup company determined to overcome significant cost hurdles to create products that are economically justified and expected to be widely applied within the next five to 10 years.

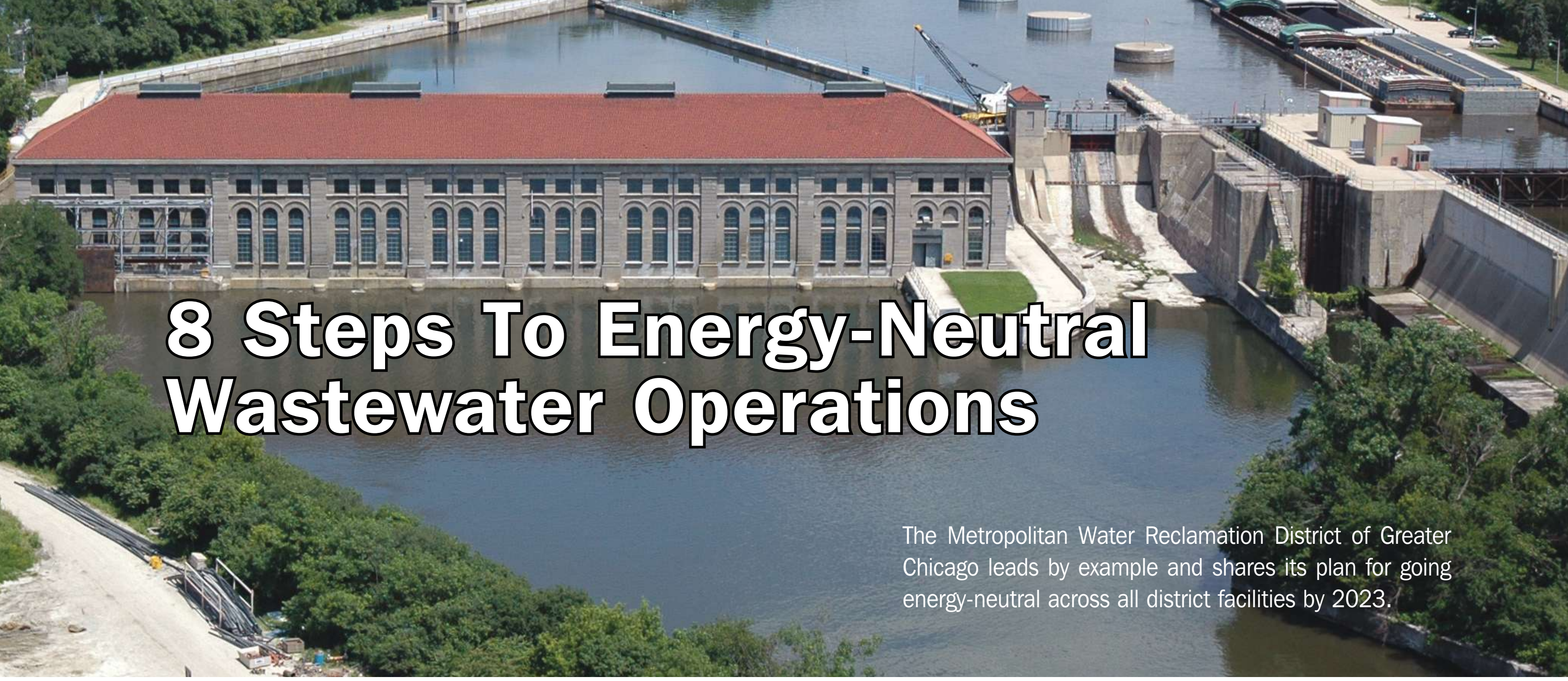
Another possible step-change is the very real and ready-to-test technology arena of nanofiber media. Development is well along on nanometer-scale, fibrous media technology with substantially reduced pressure drop at MF- and even UF-range separation. Making this more interesting is the ability to charge the media for select removal of some contaminants by sorption, while removing others by sieving while maintaining a low pressure drop. Products made with this media will be very useful at the POU level for membrane pretreatment (and final filtration as well). Depending on cost, both midsize and large systems could also benefit from such enhanced pretreatment, and if these can be made cleanable (by backflushing or otherwise), their cost will come down and acceptance will move way up.

An "elegant" technical advance (the combination of efficiency and simplicity) to watch closely is mechanically imprinted nanoscale patterns in the membrane itself. These increase feedstream turbulence at the micron level and thereby reduce all categories of fouling. This technique has been proof-of-concept proven at the lab level, is under further development, and could be commercially available in a few years. Incorporated into the membrane itself, it does not require chemical modifications, which usually prove to be temporary; it would serve its anti-fouling function in every use and is an example of a potential game-changer. ■

About The Author

A four-decade technology developer and market builder in the membrane filtration industry, David Paulson has deep expertise in membrane application stemming from 20 years as director of corporate R&D for Osmonics/GE Water and nine years of consulting. Paulson has authored 40-plus papers in addition to peer reviews for the *Journal of Membrane Science* and the U.S. EPA. He contributes to AWWA, ASTM, and NSF International works and was chosen by the American Membrane Technology Association as a Membrane Pioneer. Currently, he is partner in the Water Think Tank, LLC, and Prime Membrane Partners, LLC.

8 Steps To Energy-Neutral Wastewater Operations



The Metropolitan Water Reclamation District of Greater Chicago leads by example and shares its plan for going energy-neutral across all district facilities by 2023.

By Allison Fore

When the Metropolitan Water Reclamation District of Greater Chicago (MWRD) was created in 1889, street lights were gas-lit, and waste flowed freely into Lake Michigan, the source of the area's drinking water. Advances in technology have helped achieve the mission of protecting the lake, which is done primarily by operating seven water reclamation plants (WRPs). While the MWRD designs and operates treatment processes with an eye toward energy efficiency, the agency aspires to become energy-neutral by 2023. This accomplishment will provide a return on investment that will benefit taxpayers and the environment.

Across the country, water and wastewater collection, treatment, and distribution accounts for 35 percent, on average, of a municipality's energy budget. The MWRD consumes approximately 600 million kWh per year of electricity to operate the treatment plants and 22 pumping stations. To meet the 2023 target, the MWRD is pursuing a range of actions to reduce energy consumption while increasing production of renewable energy.

Energy-Reduction Projects

Building Audits

The MWRD hired an energy services contractor to audit and identify opportunities for energy reduction at its facilities through operational changes and/or replacement of outdated equipment or materials with new, energy-efficient equipment. Several recommendations are being implemented, such as upgrading LED interior lighting and controls, insulating steam blankets, and replacing boilers. Once completed, the MWRD will realize energy savings of approximately $800,000 a year.

Energy Curtailment

MWRD electricity draws have a noticeable impact on the local power grid. When the grid experiences peak demand, the MWRD voluntarily curtails electricity usage by turning down or shutting off equipment and storing sewage in the interceptors in order to assist the local power company with managing the load. In exchange, the power company provides a cash rebate offsetting the cost of operations. For the 2015-2016 program year, the MWRD will receive $1.9 million in curtailment revenue.

Biosolids Drying

The MWRD produces 165,000 dry tons of biosolids each year and is working to diversify the biosolids management portfolio, which consists of beneficial reuse of biosolids by application on farmland, use of dried biosolids on parks and golf courses, and a pelletizer facility producing pellets for commercial fertilizer usage. The MWRD is installing a composting facility that requires less energy than heat drying. By using tree debris as a bulking agent, the composting process raises the temperature of the biosolids and wood chip mixture, killing off pathogens to create a Class A biosolids product. The MWRD has a goal of producing 10,000 tons of composted material in 2016.

New Process Technologies

Excess nitrogen in the form of ammonia discharged to waterways can contribute to water quality degradation. Traditional removal of ammonia from wastewater via aeration is energy-intensive. New approaches to ammonia removal focus on manipulating the presence or absence of oxygen in the wastewater to allow certain types of beneficial bacteria to grow. These bacteria convert the ammonia to less environmentally degrading forms of nitrogen. Called "deammonification" and "short-cut nitrification," less aeration is required for these approaches; therefore, less energy is consumed. The MWRD is constructing a deammonification process called ANITA™ Mox on the centrate sidestream at the Egan WRP in Schaumburg, IL. It will be operational in the spring of 2016.

ANITA Mox is a single-stage nitrogen removal process with low carbon footprint based on moving bed biofilm reactor (MBBR) technology. The ANITA Mox process is specially developed for treatment of streams highly loaded in ammonia, such as centrifuge centrate at the Egan WRP. The process is designed to achieve ammonia removal higher than 90

With the reduction in electricity usage comes a reduction in greenhouse gases.

percent and total nitrogen removal in the range of 75 to 85 percent, without external carbon addition and at a low energy cost compared to conventional nitrification-denitrification. The process at the Egan WRP utilizes existing dissolved air flotation tanks that are repurposed for this application. The Egan WRP treats the solids from both the Egan (50 MGD) and Kirie (72 MGD) WRPs. Because of process limitations, however, the centrate has had to be diverted from the Egan WRP to the O'Brien WRP, about 15 miles away, which exacerbates odor and corrosion in the collection system. The ANITA Mox process will allow centrate treatment to remain on-site at the Egan WRP in an energy-efficient manner.

The MWRD is conducting research to apply deammonification to the mainstream treatment process. If successful, this process will completely change the way nitrogen is removed from wastewater. It will reduce energy usage by 40 percent, saving 120 million kWh annually, the equivalent energy provided by 15 utility-scale wind turbines or enough energy for 4,500 homes.

In another application of leading-edge technology, the MWRD is working with GE Water and Process Technologies to evaluate the performance of a new membrane-aerated biofilm reactor (MABR) technology called ZeeLung™. The MABR process employs a gas-transfer membrane to deliver oxygen to a biofilm that is attached to the surface of the membrane. The technology is being evaluated for its potential to increase existing aeration tank capacity by providing nitrification in a smaller tank volume than that required by conventional activated sludge (CAS). This will expand the existing aeration tank capacity to institute enhanced biological phosphorus removal (EBPR) to meet future effluent phosphorus limits without the need to construct additional infrastructure. The MABR also improves performance for total suspended solids (TSS) and ammonia removal during stressed conditions (specifically cold-temperature peak-flow periods). A significant benefit of this MABR technology is the potential to reduce the energy consumption required for aeration by about 40 percent compared to the current CAS mode of operation.

The study involves deploying a full-scale ZeeLung gas-transfer membrane cassette in a sidestream configuration at the O'Brien WRP in Skokie, IL. The goal of the pilot project is to determine and optimize the nitrification rate, oxygen transfer rate, and aeration efficiency of the MABR technology. Results from this year-long pilot test will be used for projecting the performance and installation costs of a full-scale configuration at the O'Brien WRP, which treats nearly 250 MGD of water typically and up to 450 MGD during wet weather or peak times. Initial projections show that electricity usage will be reduced by 15 million kWh per year if the technology is fully deployed at the O'Brien WRP. With the reduction in electricity usage comes a reduction in greenhouse gases.

Green Roof Installation

A 33,000 sq. ft. roofing system was installed at the Racine Avenue Pumping Station (RAPS) in 2014. The roof consists of two parts: a 29,300 sq. ft. reflective, "Energy Star"-rated aggregate surface with a solar reflective index of 86 and a 3,700 sq. ft. vegetative roof system incorporating eight plant varieties. A reflective roof reduces energy demand by lowering air-conditioning loads through reduction of the amount of heat absorbed through the roof. The vegetation reduces heat transfer through the roof during the summer and acts as an insulator during the winter. The vegetative green roof also reduces stormwater surface runoff, removes air pollutants, filters water pollutants, and creates microclimates for insects and birds.

Careful consideration: MWRD is piloting GE's ZeeLung membrane-aerated biofilm reactor.

Renewable Energy Generation

Hydroelectric Power

In 1899, the MWRD constructed the Lockport Controlling Works on the new Chicago Sanitary and Ship Canal (CSSC), a 30-mile-long canal designed to convey stormwater and sanitary sewage away from the city of Chicago. In 1907, the MWRD constructed the Lockport Powerhouse at the confluence of the CSSC and the Des Plaines River to take advantage of the 38-foot drop in water elevation from the canal to the river. Over the years, this hydroelectric power plant has produced clean, renewable electricity. Today, the Lockport Powerhouse has two 6 MW turbines that produce 40 million kWh per year of hydroelectric power, which is sold to the local power company.

Co-Digestion And Methane Utilization

Organic material removed from the wastewater streams at the MWRD's WRPs is stabilized and biologically broken down

Anaerobic digesters produce biogas for energy production at the Calumet facility.

in reactors called anaerobic digesters. The MWRD has 46 anaerobic digesters at four of its WRPs to handle the organic solids from all seven WRPs. A byproduct of the anaerobic digestion process is called biogas, containing about 60 percent methane, 35 percent carbon dioxide, plus small amounts of other compounds such as sulfur and siloxane. Because of the high methane content, biogas is a valuable fuel the MWRD uses to fuel boilers that produce steam or hot water used for heating buildings and processes at the WRPs. The MWRD is increasing the use and production of biogas.

To boost this production, the MWRD is importing organic waste produced in industrial and commercial processes into the anaerobic digesters as feedstock. Organic wastes may be either liquid wastes high in organic content from food processing plants, breweries, dairies, and biodiesel plants or from oils and greases produced at restaurants and rendering plants. This organic feedstock can be added to the anaerobic digesters along with the organic matter removed from the wastewater streams in a process called "co-digestion." The MWRD is designing a receiving station at the Calumet WRP for tanker trucks hauling liquid organic wastes. The additional organic feedstock can increase biogas production in the Calumet WRP's 12 anaerobic digesters up to 75 percent more than current production. The MWRD also plans to build a facility that will clean and transform the biogas into biomethane for conversion into compressed natural gas (CNG) fuel for vehicles, thus reducing gasoline use and the resulting greenhouse gases. The revenue from biomethane sales and tipping fees collected from the liquid organic waste feedstock will help reduce the MWRD's operating costs.

A similar co-digestion operation at the Stickney WRP in Cicero, IL is under way. The 24 anaerobic digesters at the Stickney WRP have the capacity to receive up to one million gallons of organic feedstock per day. The MWRD is investigating the possibility of collecting food waste from local restaurants and grocery stores. This food waste, or "source separated organics" (SSO), has a higher biogas yield than liquid organics and could increase biogas production 100 percent. If successful, the MWRD could produce up to three million decatherms of biomethane per year or the equivalent of 20 million gallons of gasoline.

Thermal Energy Projects

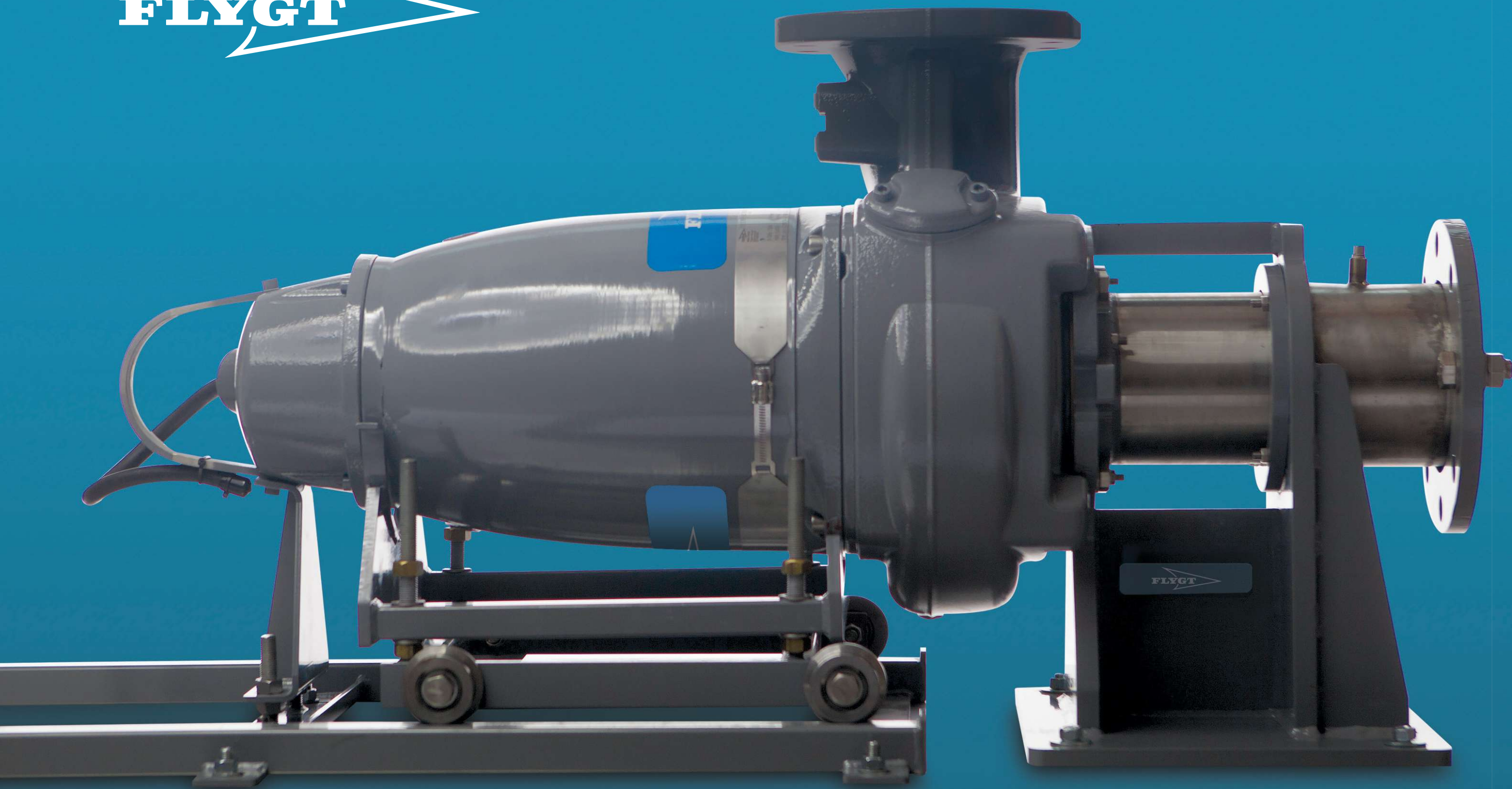
In 2012, the MWRD began converting solar heat into usable hot water at the Egan WRP. The MWRD installed roof-mounted solar panels that generate 2,040 therms annually. The system provides preheated boiler makeup water, hot water for solids treatment, and other hot water needs at the plant. The treated water leaving a wastewater treatment plant runs at a near constant 55°F, making this a potential heat source for heat transfer. The MWRD installed heat pumps at the Kirie WRP in Des Plaines, IL, using the plant water as a heat source in the winter and a heat sink in the summer. Staff dubbed this evaporation-condensation system of energy production as "sewerthermal." This system is used to heat and cool a portion of the Kirie WRP administration building; as a result, electricity usage was reduced by 50 percent for heating and cooling needs for that building unit.

Conclusion

These exciting innovations in renewable energy and energy savings provide another illustrious chapter in the MWRD's history in which no small plans are made. Working toward a goal of energy neutrality will reap major benefits, but, more importantly, will reduce greenhouse gases and promote a cleaner and more sustainable environment for the entire region. By exploring and embracing technology, the MWRD is taking control of its energy future and moving toward its next technological adventure. ■

About The Author

Allison Fore has served as the Public & Intergovernmental Affairs Officer at the MWRD for more than four years. She has 20 years' experience in government communications, having also worked for the Illinois State Treasurer, Illinois General Assembly, Indiana Secretary of State, and Indiana Department of Environmental Management. She received her bachelor of science degree from Indiana University's School of Public and Environmental Affairs and master of arts degree from University of Chicago's School of Social Service Administration.



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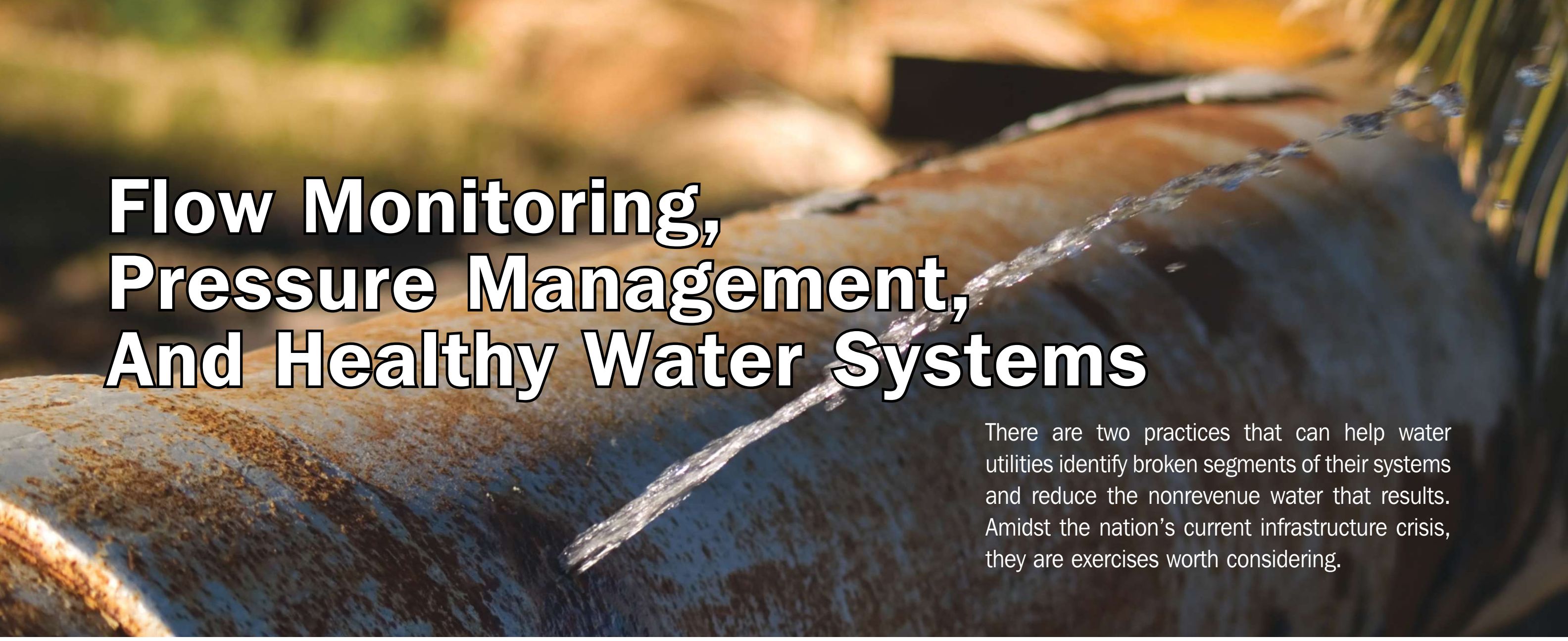

Flow Monitoring, Pressure Management, And Healthy Water Systems

There are two practices that can help water utilities identify broken segments of their systems and reduce the nonrevenue water that results. Amidst the nation's current infrastructure crisis, they are exercises worth considering.

By Peter Chawaga

The Uni-Bell PVC Pipe Association estimates that every day, 850 water main breaks occur in the country. Since the turn of the century, there have been nearly five million such breaks, resulting in over $649 billion in total corrosion costs. The U.S. EPA announced a $271 billion price tag for upgrading and maintaining wastewater infrastructure over the next five years. The AWWA puts the investment needs for buried drinking water infrastructure at more than $1 trillion over the next 25 years.

That's all to illustrate a well-known truth in the water industry: Pipes are breaking down and putting water and revenue at risk.

Going With The Flow

By flow monitoring, also known as district metering, a utility examines the pattern of water use in a system (usually between 11 p.m. and 5 a.m. when customer demand and flow are low) and can identify potential leaks by watching for elevation.

"Flow monitoring is a concept that has been around but slow to penetrate the U.S. market," said David Hughes, the water research manager for the Innovation and Environmental Stewardship Department of American Water. "It evolved in Europe, in part because customer metering was lacking, and quantifying leakage was difficult to determine."

American Water is a utility composed of over 300 distinct systems. It serves 15 million people from California to Ontario. As the nation's largest publicly traded water utility, it's as susceptible as any to the perils of the country's aging infrastructure and the resulting revenue loss. Hughes and other researchers have conducted studies in flow monitoring and have found that the practice reveals crucial, often anomalous, information about a system.

"Through our research on flow monitoring, we have found some unexpected events," said Hughes. "For example, one system appears to have accurately recorded what we believe was the theft of water from a fire hydrant during consecutive summers, indicated by a sudden, brief increase in flow with a volume that corresponded to the size of a tanker truck."

Hughes has studied system flow in combination with pressure monitoring and found that the two can provide even more insight into a system when paired together.

"With flow and pressure monitoring, we found an unexpected jump of pressure in a zone caused by a mechanical defect or operator error, followed quickly by evidence of elevated flow," said Hughes. "The operators were alerted and fixed not one but two leaks. The second leak was detected because the night flow did not return to conditions before the event after the first repair."

Under Pressure

During last December's North American Water Loss Conference in Atlanta, Hughes shared his interest in pressure and what it can mean for system leaks in a presentation titled "Leakage Control in Small Systems and Pressure Zones." His presentation was focused on a practice meant to take place after flow monitoring, once leaks are identified. It's known as pressure management, effectively reducing pressure in a system with altering pumps

Managing pipe pressure minimizes long-term stress, thus reducing breaks and repairs.

or pressure reducing valves (PRVs) to divert water away from defective pipes.

"Flow and pressure in a water-closed system are clearly interrelated," Hughes said. "Adding flow without water demand to offset it or tanks to store it will increase pressure, and a lack of adequate flow will drop pressure."

Through pressure management, leak flow can be minimized, and water can be saved. Primarily this is because less water will be streaming toward and out of broken areas of pipe. Secondarily, reducing pressure minimizes the long-term stress on pipes and keeps them intact for longer. Thus, even systems with relatively low leakage can benefit from pressure management.

"Operators need to better understand the merits of pressure management and the potential savings of reduced pressure in portions of their water systems," said Hughes. "Reducing pressure that still satisfies customer expectations has been shown to reduce leakage and stress on pipe that causes future breaks. This implies that pipe under less pressure will perform longer."

Hughes invokes a rule of thumb that dictates 1 percent reduction in water loss will result for every 1 psi drop in maximum pressure in a pressure zone.

Still, he is quick to point out that there is no blanket approach to leak detection and prevention that is right for every utility. It's a notion he sticks to, even while projecting the future of water treatment and how flow monitoring and pressure management will fit within it.

"The industry is already moving toward what is described as the 'intelligent water system,'" said Hughes. "Flow monitoring and pressure management … are more tools to put in the box. The challenge going forward is to sift through the various approaches and find the best one for each utility operation. But with an aging infrastructure, the push for more efficient operations will drive these techniques to more implementation down the road." ■

About The Author

Peter Chawaga is the associate editor for *Water Online*. He creates and manages engaging and relevant content on a variety of water and wastewater industry topics. Chawaga has worked as a reporter and editor in newsrooms throughout the country and holds a bachelor's degree in English and a minor in journalism. He can be reached at pchawaga@wateronline.com.

Best Practices For Flow Meter Calibration

Get to know the basics, best practices, and importance of flow meter calibration from an industry expert.

By Philip S. Stacy

Flow measurement is integrated into every aspect of modern life, from the measurement of water flow in power plants to the metering of household water. Accurate measurement is vital in both these examples, as well as in other scenarios. Specifically, the power plant must measure correctly for safety, efficiency, and revenue, while the homeowner is interested in being charged correctly. With water supplies being affected by global weather, water measurement is integral to conservation plans. Accurate flow measurement has a positive impact on energy conservation. One of the most expensive problems in environmental control is the handling and treating of potable water distribution.

Flow meters need to be calibrated when a defensible accuracy is required. Sometimes, as in the case of the petroleum industry, meters may be calibrated every day against a built-in calibration device. At the other extreme, some meters may never be taken out of service during the life of the meter — for example, the flow meters found in homes across America. Meters used in the manufacturing and power industries are often subject to periodic calibrations as part of quality assurance programs. In these cases, unless the user maintains a calibration facility, the meter is typically sent to an independent calibration laboratory.

The following discussion reviews the best practices for water flow meter calibration.

Traceability

A calibration is a comparison of the instrument (meter) and a standard. This comparison must be made by measuring the same quantity (e.g., mass versus flow), and the standard used must be accurate. Flow meter calibration is unique; whereas there can be a 1" gauge block for the calibration of a machinist's micrometer, there is no "gallon per minute" or "cubic meter per hour" test artifact that can be run through a flow meter in order to perform the calibration. Instead, large-scale flows are most often calibrated by the gravimetric method, which uses scales and timers and temperature measurement to determine the flow through the meter under test (MUT). The calibration instruments measuring these parameters must show traceability to higher-level measurements and to national and international standards.

Accuracy Or Uncertainty

Although often used, accuracy is not a term that should be used to quantify calibration results. Accuracy is a qualitative term that should only be used for indicative purposes. Uncertainty is the correct term to express the "accuracy" of a calibration result.

The uncertainty in the result of a measurement generally consists of several components. An uncertainty value is applied to each measurement taken during the calibration process. These are based on instrument calibration data, manufacturers' data, and laboratory experience. For example, in the case of volumetric flow measurement using the gravimetric method, the uncertainty of the lab flow is directly related to the measurement of these primary parameters and the instrumentation used for their measure; all must be traceable to a recognized international standard and must have an associated uncertainty budget, or allowance. The individual measurement uncertainties are combined to provide a confidence level in the flow measurement result.

In addition, the user should evaluate the final "as-installed" uncertainty of the meter, which may include differences in the piping between the calibration piping and installed piping as well as the ancillary instrumentation, which likely carries with it a different uncertainty value than the equipment used in the laboratory. In the case of clamp-on style ultrasonic meters, for example, the calibration is almost always performed by attaching the meter's transducers to laboratory pipe. As such, the end user should budget some additional uncertainty when the transducers are later installed on plant piping.

Accreditation

Laboratory accreditation provides the consumer seeking meter calibration with reassurance that the laboratory has been independently evaluated and has demonstrated competence in the field. At the time of this publication, the ISO/IEC 17025 is a quality, internationally recognized standard for calibration laboratories, to which accreditation demonstrates technical competence for a defined scope of work and adherence to a laboratory management system.

Fluid Properties

Understanding the fluid properties of water at both the operating and calibrating conditions is critical to providing useful calibration data. The interaction between the flow meter and the water is affected by the water temperature, density, operating pressure, Reynolds number, and conductivity. Reynolds number is a nondimensional value based upon the viscosity and velocity of the fluid through the meter. For differential-producing meters such as flow nozzles, Venturi meters, and orifice plates, it is desirable to calibrate at the operating Reynolds number


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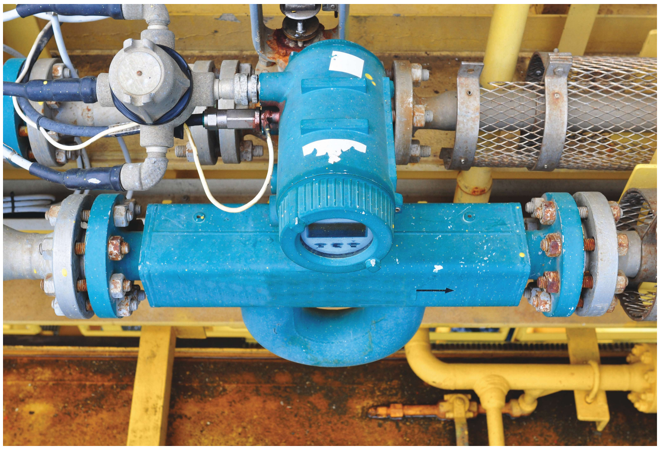
Coriolis flow meter

of the meter. In general, meter calibration should be conducted using a fluid having properties as close to the actual operating conditions as possible to reduce errors associated with using the incorrect fluid properties. Often it is impossible to achieve the operating conditions in the laboratory, and extrapolation of the lab data is required. Extrapolation of calibration data is a subject worthy of its own paper, but an incorrect application of fluid properties during the calibration process can result in a significant error when using the meter in its final installation.

Simulated Installation Conditions

The velocity distribution of the flow as it enters a meter can affect a meter's response. The goal of any meter installation is to provide the best possible piping conditions upstream and downstream of the meter; the American Society of Mechanical Engineers (ASME) and International Codes provides guidance for meter installations. Ideally, the flow entering a meter should have a fully developed velocity profile. This is dependent on the internal pipe diameter, pipe roughness, Reynolds number, and length of pipe; it is achieved by providing many diameters of upstream pipe free from disturbances such as elbows, valves, and diameter changes. It should be noted that, although some types of meters are less affected by the adjacent piping, it is generally recommended to provide long, straight lengths of pipe upstream and downstream of the meter. If the site installation is not compliant to that guideline, it is recommended that the piping during calibration be arranged to simulate the site installation configuration as closely as possible. ASME codes provide allowances (added uncertainty), which may be added to a meter calibrated in the (ideal) laboratory setting. Interestingly, the additional installation uncertainty can be large enough to overshadow the calibration uncertainty. In cases such as this, it is prudent to reproduce the plant conditions during the laboratory calibration.

Cost Of Calibration

There is a cost to the consumer associated with providing the best possible meter calibration. The cost of calibration is typically a function of the size and number of test points recorded. Differential-producing meters are nonlinear devices in which the signal varies with the square of the flow, and these often require more data points to characterize the meter performance. These meters can have multiple sets of piezometers, or "taps," which add to the cost (laboratory instrumentation is costly to maintain under typical quality programs).

A base price is often determined as a function of meter diameter and includes a predetermined number of taps and data points. For example, the base price for a 12-flow-point calibration of a 16" diameter meter will be approximately $2,500, with additional tap sets adding about $1,000 each and additional data points adding about $50 each. Most differential-type meters are calibrated with two tap sets to provide redundancy. Electronic flow meters such as magnetic, ultrasonic, and Coriolis are often calibrated by recording six "as-found" and then six "as-left" data points if the meter requires adjustment to bring its performance to the customer's specification. There may be several iterations of data required to adjust these meters before finalizing the as-left data. A 6" magnetic flow meter would cost approximately $1,300 for a 12-point calibration of this type. Accredited calibrations, to ISO/IEC 17025 for example, require additional data and analysis, which can more than double the cost of the 6" meter in the example above.

The major costs of calibrating an existing meter are related to its removal, shipping, and reinstallation after calibration. These costs are highly dependent on the meter's location within the plant, which affects the cost of its removal and reinstallation, and the geographical location of the plant with respect to the calibration facility. A facility with a meter bolted to upstream and downstream piping that is located at the ground level will likely cost less to remove than a welded-in-place meter located on the ninth level over open space. Those costs are estimated to range from $5,000 to $75,000.

Summary

Water is an important resource, and its measurement is crucial in determining the operational efficiency of power plants and no less important in conserving supplies of drinking water. Meters used for water flow should always include a statement of the meter's measurement uncertainty. When this uncertainty must be determined by calibration, many factors contribute to an accurate flow calibration, and an oversight or error in any of these factors can contribute to significant uncertainty in the results. Meticulous attention to detail (e.g., fluid properties, piping, and appurtenances configuration) and collaboration with a traceable calibration facility are recommended to provide a useful flow meter calibration. ■

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About The Author

Philip S. Stacy, director of calibration services at Alden Research Laboratory, is responsible for all flow meter testing performed at the company's flow measurement facilities. He provides technical and administrative supervision of Alden's flow measurement department to ensure the highest standard for calibrating fluid meters to an accredited certified uncertainty of 0.1 percent in accordance with ISO/IEC 17025:2005.

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Solving Sewer Overflows: Green Or Gray, WERF Shows The Way

A leading research organization investigates wet weather strategies to help municipalities make informed decisions about stormwater management.

By Kimberly Davis

The Water Environment Research Foundation (WERF) has been researching issues related to combined sewer overflows (CSO) for nearly 20 years. The scope of WERF's research portfolio has spanned from assessments of emerging technologies, to improved wet weather treatment, to more recent examinations of the response of fish to hypoxia and CSOs in the field. Notable among the projects have been:

- *Best Practices for the Treatment of Wet Weather Wastewater Flows (00CTS6)*
- *Characterizing the Quality of Effluent and Other Contributory Sources During Peak Wet Weather Events (03CTS12PP)*
- *Decentralized Stormwater Controls for Urban Retrofit and Combined Sewer Overflow Reduction (03SW3)*

Going Green

Recently, WERF and water resource recovery facilities (WRRFs) have been striving to better understand how green infrastructure (GI) can complement conventional gray infrastructure such as piping, wet weather technologies, and treatment refinements. A recent WERF report, *Institutional Issues for an Integrated "One Water" Approach* (SIWM2T12), identifies green infrastructure as infrastructure that works with and mimics nature. GI enables a built environment that supports the natural environment.

In the SIWM2T12 research, approximately 30 case studies evaluated a variety of "one-water" approaches. Several of them focused on CSO management. In particular, the research illustrates how Philadelphia Water undertook a comprehensive initiative to establish the optimal ratio of gray-to-green infrastructure projects and a standard unit of measure to quantify the GI benefits. Effectiveness of measures evaluated included:

- Stormwater fees
- Daylighting streams
- "Green Street" blocks
- Removal of impervious paving
- Green schools and green roofs
- Park transformations for GI features
- Engagement with private businesses for greening projects

The resulting Philadelphia Water Evaluation and Adaptation Plan incorporating these demonstrated techniques is due in fall 2016. Transferable actions from the initiative included findings such as:

- Remain open and adaptable to public feedback, and work to find solutions that address stakeholder concerns.
- Adopt standardized, measurable units so that all institutions and stakeholders have a clear understanding and baseline from which to plan.
- Emphasize multiple benefits (economic, environmental, and societal) to encourage monetary feasibility of project adoption.
- Create watershed partnerships and stakeholder networks to assist with community outreach and more easily identify, receive, and appropriately allocate funds for a project.

Communication And Collaboration

The research also highlights the Atlanta CSO long-term control plan (LTCP), which included a public education and involvement program for citizens for its CSO Remediation Plan under its federal consent decree. Atlanta sought better understanding by the public, in particular regarding actions with significant cost — and sometimes temporary infrastructure disruption — including:

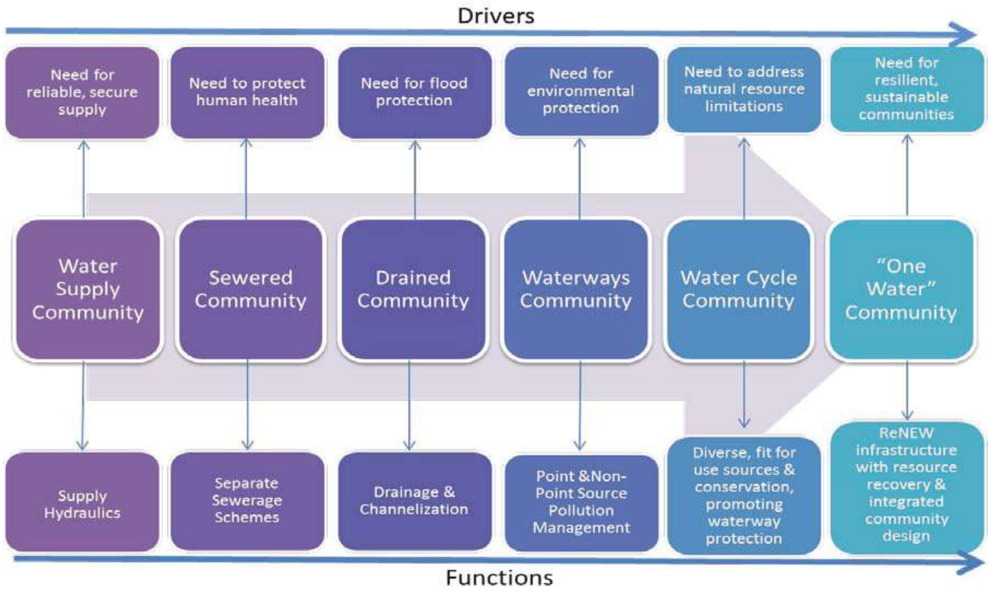
- Separation of sewer basins to increase Atlanta's separate sanitary sewer network to 90 percent
- Construction of a deep-rock tunnel storage and treatment system to capture and store combined flows for two quadrants of the combined sewer network
- Reduction of the number of permitted, wet weather overflows from the combined sewer system from 360 per year to an average of four per year

Northern Kentucky Sanitation District #1 (NKSD#1) was also studied. They sought to maximize the impact of expenditures for CSO/SSOs, as required by a U.S. EPA consent decree, given restrictive state and federal regulations about options. NKSD#1 had 1.8 billion gallons in CSOs annually and another 240 million gallons in SSOs. However, an assessment found that failing septic systems and the loss of riparian corridor contributed more pollution to the receiving waterbody than did the SSOs.

To address the CSOs/SSOs, customers experienced rate increases annually for all but two of the previous 14 years. NKSD#1 sought to evaluate measures that could be more cost-effective. But state and federal regulations did not permit "pollution trading," nor did they recognize the efficacy of local land use regulations in

reducing pollution. Yet involving measures relying on such intergovernmental collaboration would permit greater nonpoint pollution reduction for the smallest fee increases.

NKSD#1 (which is both the sanitation and the stormwater district) approached the Northern Kentucky Water District and the Northern Kentucky Area Planning Commission for collaborative discussion, assessment, and identification of successful strategies. The result was a series of local agreements encouraging GI solutions, along with a targeted regional plan. Finally, the necessary state law was enacted, requiring regulators to consider affordability, GI, and effectiveness when enforcing the Clean Water Act (CWA) and in working with local entities to develop compliance programs.



Sustainable integrated water management continuum *(Source: WERF report number SIWM2T12,* Institutional Issues for Integrated 'One Water' Management. *Published in 2015.)*

The innovative work from this project can be replicated. The U.S. Conference of Mayors is developing informational documents to address policy concerns with the EPA, highlighting more adaptive management approaches in context of the difficulty in implementing creative solutions due to regulations. Ideally, these efforts will ultimately lead to the modification of the CWA.

Data-Driven Solutions

In 2015, WERF also released a report known as the *NYCDEP Metering Pilot Study* (WERF2P13). There, the New York City Department of Environmental Protection (NYCDEP) evaluated improved flow monitoring telemetry to improve the accuracy of predictions and for more robust modeling of gray-to-green alternatives for cost-effectiveness in its Long-Term Control Program. The resulting comparative analysis provided a holistic look at the CSO drainage area and allows for a better understanding of the interrelationship between drainage area characteristics and overflow discharge volumes.

In addition to an updated calibrated model, the study identified improvements necessary in instrumentation and triggering, due to the flow characteristics of high tides and tide gates. Adjustments to instrumentation will be used in both the hydraulic model and for real-time controls.

Perhaps WERF's best-known work supporting WRRFs large and small in CSOs, *The Sustainable Infrastructure Management Program Learning Environment* (SIMPLE), was based on their partnerships, case studies, and collaboration with WRRFs such as those mentioned previously. SIMPLE, a knowledge base on strategic asset management (SAM) in Web format, was designed specifically for the wastewater industry. SIMPLE incorporates wastewater-specific asset management tools, graphics, guidelines, templates, interactive training aids, a glossary of terms, Web links, and relevant wastewater references.

SIMPLE breaks asset management into seven concepts:

1. Asset inventory
2. Data standards
3. Level of service
4. Risk/failure analyses
5. Capital improvement plans
6. Life-cycle costs
7. Maintenance programs

SIMPLE also includes "Forums and Support" which allow users to ask questions to facilitate interaction among utility staff across the country. This approach encourages a sharing of knowledge and experiences to avoid "reinventing the wheel."

In 2016, WERF will seek to further refine understanding of the cobenefits of GI for communities. WERF researchers will be asked to find the actual and hidden life-cycle costs of green and gray infrastructure projects — particularly when used to prevent combined sewer overflows. Many municipalities have commissioned their own studies to identify the full costs and benefits (via triple-bottom-line assessments) of conventional versus green infrastructure options for controlling CSO events. By building on work such as *21st Century Water Asset Accounting,* WERF will produce research that will result in increased confidence in comparisons of both the costs and benefits of green infrastructure alternatives to manage CSO challenges. ■

About The Author

Kimberly Davis is an environmental compliance analyst and researcher in urban infrastructure planning, with a systems approach to water, wastewater, stormwater, and renewable energy. Kimberly is a graduate of Trinity University in San Antonio, TX, and received a master's in Urban Planning from New York University.

Baffled Bioreactor – A Small Community Wastewater Solution

Recently developed baffled bioreactor technology promises decentralized wastewater treatment that is cheaper, more effective, and easier to own than existing solutions.

By Jianmin Wang, Guoqiang Liu, and Robert Tucker

Baffled Bioreactor R&D

The baffled bioreactor (BBR) technology has developed since 2008 through multiple projects in partnership with the U.S. Army. During the Iraq War, the U.S. Army deployed different wastewater treatment technologies for military bases overseas. However, the majority of those technologies failed to work properly, mainly because of their high O&M needs — the U.S. Army is interested in simple solutions for wastewater treatment. The treated effluent needs to be safely discharged to the environment (to avoid wastewater hauling cost and improve the base environment and soldiers' health). With clean, treated water, there is also the probability of beneficial reuse, which reduces the freshwater needs from off-base sources and related monetary/human costs. In addition, the mobility and the energy use of the treatment system are significant considerations for the U.S. Army due to the nature of the application — military bases are usually temporary, and low energy use is critical to reduce fuel delivery convoys to the base.

Frontier Environmental Technology (Frontier) has answered those Army requirements by developing an easy-to-use and high-energy-efficiency BBR technology. In principle, the BBR technology is an extended aeration process. However, with the special arrangement of baffles within the reactor, its operation is much simplified and its performance greatly enhanced compared to other available technologies. The entire process function is driven by air. The U.S. Army has invested $2.3 million on the BBR development in the last several years. The reactor developed in the most recent project has been successfully demonstrated in the Naval Surface Warfare Center-Carderock (Maryland), Contingency Basing Integration Technology Evaluation Center (CBITEC) at Fort Leonard Wood (Missouri), Fort Devens (Massachusetts), and Fort Bliss (Texas). Small communities can take advantage of this BBR technology, originally developed to meet future military needs, to conduct advanced wastewater treatment at a cost lower than the wastewater bill paid by city residents where centralized treatment plants are employed.

BBR Technology Description

The BBR technology has been extensively tested and demonstrated in Missouri since 2008 at pilot- and full-scales. One deployable BBR (dBBR), constructed using a 20' standard shipping container, has the capacity to treat up to 15,000 GPD of municipal wastewater, equivalent to wastewater from 40 to 50 homes. This capacity is about 30 percent greater than a membrane bioreactor (MBR) unit that is constructed using the same 20' shipping container. This is because the MBR uses a larger space to house complex equipment and controls, while the BBR only needs a small space to house two blowers (one regular and one small) and a small control box. As a result, the BBR allows significantly more volume for wastewater processing.

It employs a group of uniquely arranged baffles that separate the unit into several functional zones: an anoxic zone for denitrification, an aerobic zone for organic matter oxidation and nitrification, an internal settler for concentrating and returning biomass, and a final polishing clarifier for removing solids carried out of the internal settler. The newest version of the BBR unit requires only one influent pump, two blowers, and one timer-controlled solenoid valve to be functional. Due to the very high biomass concentration it can maintain (6,000

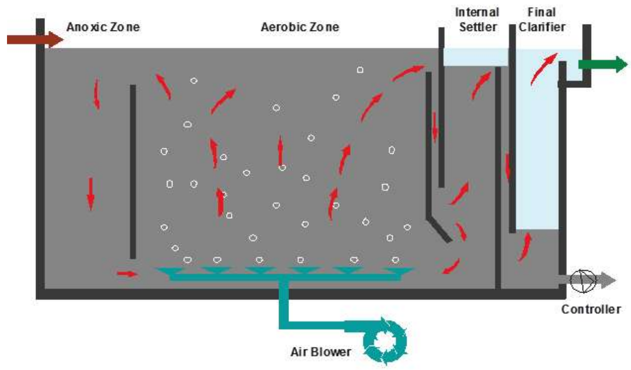


Figure 1. Process schematic of the BBR

Using a BBR can save more than 85 percent of the O&M cost. The cost savings is mostly from its high operational reliability, low maintenance needs, low power use, and no chemical additions.

to 8,000 mg/L), it is very compact (thus it has low construction cost for the same treatment requirement). In addition, due to the elimination of most mechanical moving parts used by other technologies, the O&M needs are very minimal, and mechanical energy-wasting was eliminated. The electricity use rate is 3 to 5 watt-hours per gallon (Wh/gal), equivalent to a $10 to $15 electricity bill per person for an entire year. This energy use rate is within the range of that for large, centralized treatment plants, but is only a fraction of that used by other small packaged plants. The total maintenance labor is less than two hours per month. Furthermore, there is no chemical use for the BBR technology, although it can achieve significant denitrification.

The BBR is very simple to set up. Once the site is prepared (requiring a wet well, a leveled foundation to support the treatment unit, and a power outlet), one only needs to connect the pipes of BBR influent, effluent, and drain to appropriate locations and connect power. The entire process takes less than 4 hours. The startup process is also simple. After installation, the unit needs to be turned on as if it is in normal operation, without using any seeding sludge. This natural startup option allows the BBR to be deployed in remote locations and military bases where seeding sludge is not readily available. It will take one to two days to allow the effluent to meet the federal secondary effluent standard. More time, up to a month, is needed to achieve complete nitrification, depending on the temperature of the water. However, if there is seeding sludge available nearby, using the seeding sludge will enable the BBR to perform complete nitrification within a day.

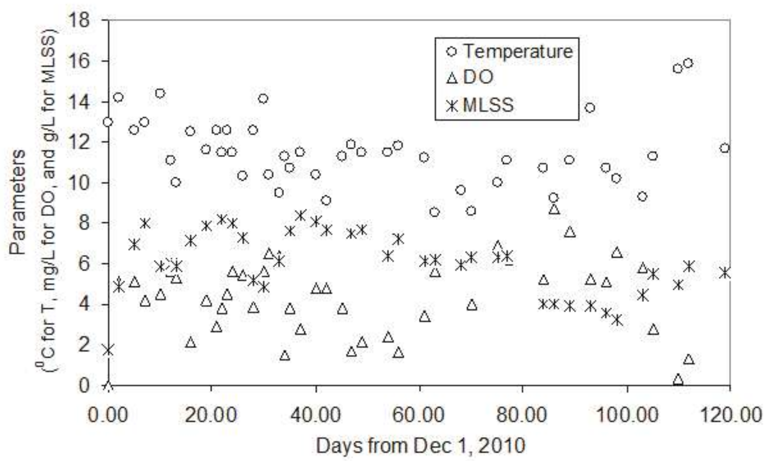


Figure 2. 20' BBR operation parameters

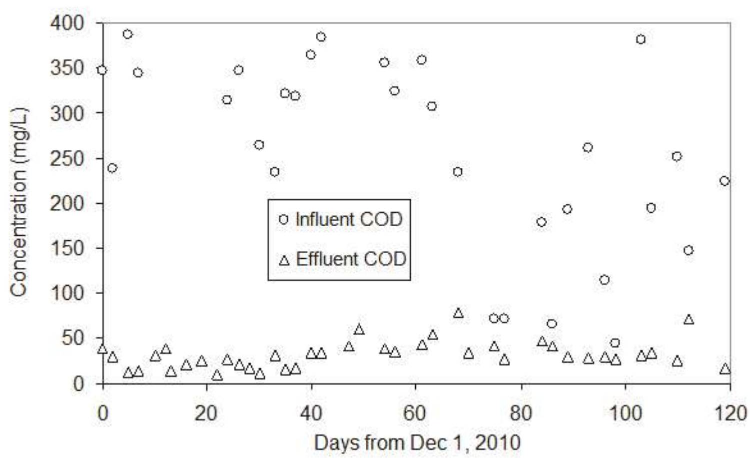


Figure 3. 20' BBR COD performance data

Another feature of the BBR is sleeping mode operation. Where there is no influent, or when the influent load is low, the equipment automatically switches to a sleeping mode, which uses only 200 watts of energy to maintain the activity of the activated sludge. This feature also allows the BBR to handle large flow and quality variations of the influent. A recent test also indicated that the BBR can be recovered very quickly after loss of power for 4 hours without compromising the effluent quality. Moreover, the BBR can handle the shock load very well. Doubling the influent load for a day will not impact the effluent quality. All these features make the BBR technology unique for small-flow wastewater treatment, especially for applications in remote communities and military bases where power supply is often interrupted.

Testing Data

One 20' BBR was continuously operated for over a year, from May 2010 to May 2011, using the raw influent from the Rolla Southeast Wastewater Treatment Plant as the feed. The operation and performance data from the four coldest months, from December 2010 to March 2011, which represent the least favorable conditions, are presented here.

Figure 2 shows temperature, dissolved oxygen (DO), and mixed liquor suspended solids (MLSS) profiles. The average reactor temperature during these four months was 11.5°C, with the lowest temperature of 8.5°C. The average DO was 4.5 mg/L, typical for winter operations. The average MLSS was

The effluent BOD_5, TSS, and ammonia-nitrogen is consistently better than EPA's future permit standards.

6,000 mg/L during this period, which is significantly greater than that of conventional activated sludge plants. This high MLSS resulted in more stable operation of the treatment system, even with a significant fluctuation in the operating DO and temperature. Figure 3 shows the influent and effluent chemical oxygen demand (COD) concentration. The average influent and effluent COD concentrations were 321 mg/L and 32 mg/L, respectively, giving the BBR 90 percent COD removal. Effluent COD is generally three to five times that of biological oxygen demand (BOD_5); therefore, the estimated effluent BOD_5 was less than 10 mg/L.

Figure 4 shows the influent and effluent total suspended solids (TSS) data. The average influent and effluent TSS concentrations were 196 mg/L and 9 mg/L, respectively, achieving 95 percent removal efficiency. Figure 5 shows the influent and effluent total nitrogen (TN) concentrations, as well as effluent ammonia-nitrogen. They were 24 mg/L, 15 mg/L, and 0.5 mg/L, respectively.

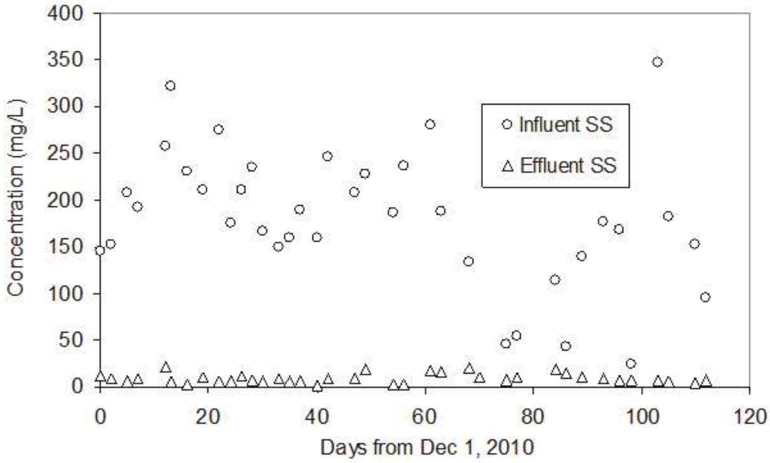


Figure 4. 20' BBR TSS performance data

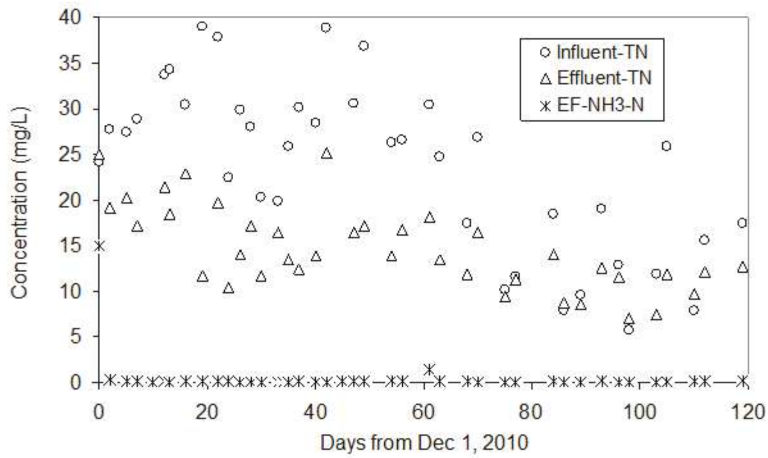


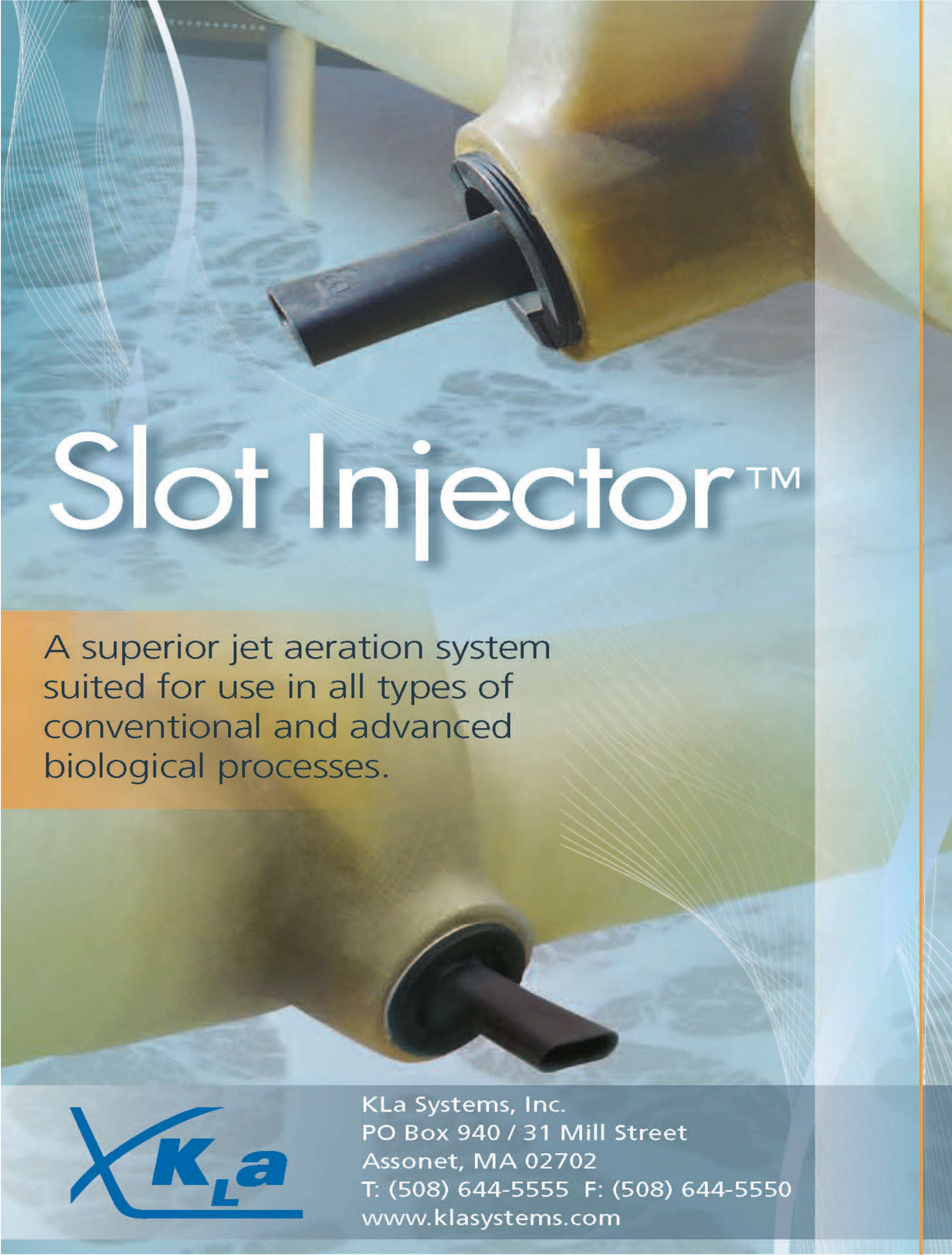
Figure 5. 20' BBR nitrogen performance data

As indicated in Figures 2 through 5, at a flow rate of 15,000 GPD, both the average effluent BOD_5 and TSS were less than 10 mg/L, and the average effluent ammonia-nitrogen was 0.5 mg/L, meeting future U.S. EPA regulatory needs. The effluent TN is 15 mg/L without any external carbon addition. These data results show that the 20' BBR performed consistently well, regardless of influent strength variations, and even under very low winter temperatures. The effluent BOD_5, TSS, and ammonia-nitrogen is consistently better than EPA's future permit standards. In addition, very little attention was given to maintaining the reactor during the entire experimental process, further demonstrating the robustness of BBR technology. Basically, as soon as the BBR was set up, there was essentially only minimal additional work to do with the BBR. It will operate itself.

Note that since 2011 the BBR has been optimized with improved design. The new version performs better than the aforementioned testing version based on testing data — especially the TN removal. However, because this new version has not been continually operated for an entire year, the data were not presented here.

Cost Comparison

The overall construction cost to install a community version 20' BBR, including a fully functional BBR, delivery, installation, site work, engineering, permit application, and other minor costs, is expected to be $200,000 to $220,000, which is approximately $15/GPD of capacity. Figure 6 shows the construction cost comparison for the BBR versus other technologies used by small communities. Using a BBR can save up to 60 percent of the overall construction cost. The major cost savings is from the fabrication of the BBR unit, which uses very minimal equipment and controls, and the ease of installation. It is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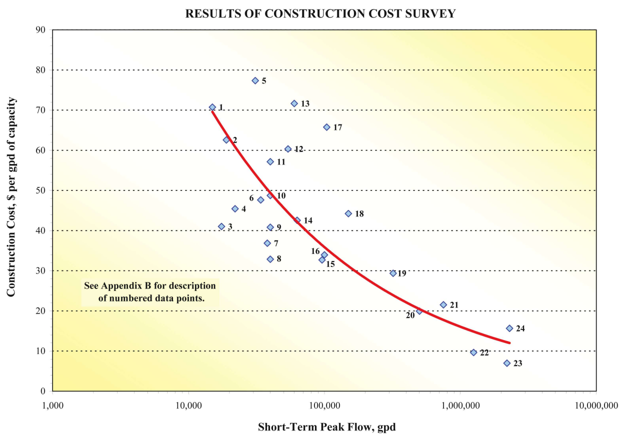


Figure 6. Construction cost comparison

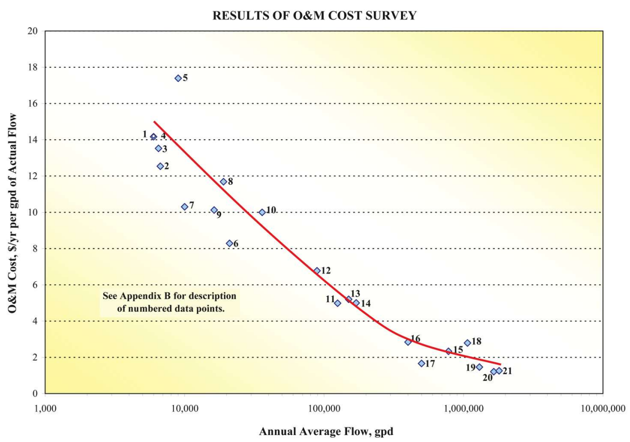


Figure 7. Operational cost comparison

**The survey data is taken from "Comparison of Costs for Wastewater Management Systems Applicable to Cape Cod," prepared by Barnstable County Wastewater Cost Task Force, April 2010.*

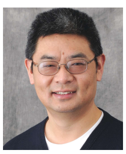
basically a plug-and-play system, as long as the site is leveled and there is power and a wet well nearby.

The operational cost is mainly composed of equipment depreciation, power consumption, and maintenance. Based on current testing, the total power and labor cost is expected to be $2/1,000 gals. If the equipment depreciation and sludge hauling is included (assuming 15 years), the total treatment cost is $5/1,000 gals, which is within the range that city residents pay for their wastewater bills where centralized treatment plants are available. This overall treatment cost is equivalent to an annual cost of $1.6/GPD capacity. Figure 7 shows the O&M cost comparison between the BBR and other technologies used by small communities. Using a BBR can save more than 85 percent of the O&M cost. The cost savings is mostly from its high operational reliability, low maintenance needs, low power use, and no chemical additions.

Conclusions

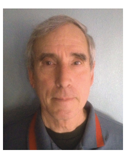
Extensive data from pilot and full-scale experiments have demonstrated that the BBR technology has a very low construction cost and minimal operational costs and can provide advanced treatment quality including complete nitrification and significant total nitrogen removal. It is also very easy to set up, simple and reliable to operate, energy-efficient, and resistant to low-temperature shock-loading effects. Therefore, the BBR technology is a practical solution for small community wastewater treatment and reclamation. ■

About The Authors



Dr. Jianmin Wang, PhD, PE, is an associate professor of environmental engineering at Missouri University of Science and Technology and cofounder of Frontier Environmental Technology, LLC. His research interests include sustainable technologies for advanced wastewater treatment, synergistic toxic effect of nanoparticles and heavy metals, and the fate and transport of heavy metals in natural and engineered systems. Email: wangjia@mst.edu

Dr. Guoqiang Liu, PhD, is an associate professor at Jinan University since August 2015. He was a senior research engineer for Frontier Environmental Technology from January 2013 to May 2015, working on wastewater treatment and reuse. Before that, he was a graduate research and teaching assistant at Missouri University of Science and Technology from September 2008 to December 2012.



Dr. Robert Tucker, PhD, is an adjunct professor of civil, architectural, and environmental engineering at Missouri University of Science and Technology. He is a three-time presenter for the Army Science Conference and was Chief of Environmental Programs for Afghanistan Theater in 2010 and Chief of Environmental Branch for the Balkans in 2003-04. He also serves as the Senior Applications Engineer for Frontier Environmental Technology since March 2015. Email: support@FrontierET.com

Can The Internet Of Things Lower AMI Solution Cost?

Low-power wide-area networks are critical to the Internet of Things but may also work to bring advanced metering infrastructure to the masses.

By Hardy Schmidbauer

Many municipalities across the U.S. do not use advanced metering infrastructure (AMI), especially small and midsize communities. Some communities like Madera, CA, in the middle of California's drought-stricken Central Valley, have many households with no meters. Municipalities that still use drive-by automated meter reading (AMR) systems often state that the number-one reason they have not moved to AMI is cost. The Internet of Things (IoT) networks, such as low-power wide-area networks (LPWANs), offer low-cost connectivity that will permit new, lower-cost AMI solutions. LPWANs allow long-range connectivity and use lower-cost infrastructure to connect sensors in many applications, including metering, agriculture, parks, golf courses, and smart city, which can provide more value and savings than systems dedicated exclusively to metering.

The Internet Of Things Networks

IoT networks have been a popular technology trend over the last few years. Gartner, Inc., the world's leading information technology research and advisory company, forecasts there will be up to 20.8 billion connected devices by 2020[1]. Cellular companies have been pushing machine-to-machine (M2M) connectivity for more than five years, but only 10 to 15 percent of IoT-connected devices will use cellular M2M due to its cost and limited battery lifetime. Other widely adopted connectivity options, such as Wi-Fi and Bluetooth® technology, serve their targeted applications well, but they also have limited battery lifetime and do not offer the long-range connectivity needed in many applications, such as water metering. Over the last few years, LPWANs specifically catering to IoT have emerged to help solve the issues of battery life, cost, and range. These LPWANs, comprising low-cost infrastructure systems that offer long battery lifetime and wide-range connectivity, are predicted to connect the bulk of IoT devices.

Telecom companies, mobile network operators, and utility companies have been among the early adopters of LPWAN technology because of their access to elevated deployment sites, which are required for optimal network coverage. Major telecom companies, such as Orange S.A. in France and Tata Communications Limited in India, as well many startups, such as Senet, Inc. in North America, have announced LPWAN deployments based on LoRa™ technology, creating a worldwide ecosystem that can support LPWAN-based AMI.

AMR, Traditional AMI, And LPWAN-Based AMI

Traditional AMI systems offered by many metering companies require a significant amount of infrastructure because they do not have the same range (link budget) capability as the LPWAN alternatives. In a LPWAN, multiple applications can connect to the network and a single LPWAN gateway in a rural environment can collect data from applications in a 15- to 30-mile radius. In contrast, a traditional AMI system would require at least 10 gateways or 10 repeaters speaking to a master gateway to cover the same area. Using a 10,000-household city over 10 square miles as an example, a comparative analysis shows that using a LPWAN system is commensurate in cost to a walk-by AMR system, whereas a fixed infrastructure system using traditional AMI is significantly more expensive. Finding locations for the gateways is also a challenge in traditional AMI systems. Because the network operator incurs the cost of network deployment and the gateway, the cost for a LPWAN remains relatively low.

LPWAN solutions use a simple, asynchronous protocol to optimize battery lifetime, whereas most existing AMI systems are synchronous systems and typically use a high-power front-

	AMR	AMI	LPWAN
Number of meters	10,000	10,000	10,000
Required gateways (infrastructure)	1	10	1
CapEx for Infrastructure	$5,000	$25,000	$0
Reoccuring for tower and maintenance	$0	$56,000	$0
Labor cost for AMR	$30,000	$0	$0
Connectivity cost to LPWAN operator	$0	$0	$30,000
Total Infrastructure Cost	**$35,000**	**$81,000**	**$30,000**

Estimated costs of network infrastructure *(Source: Semtech Corporation)* end module to increase range, which significantly increases required battery capacity and, in turn, increases the end-node cost. A smaller battery and removals of the front-end module in a meter designed for LPWAN can reduce the end meter costs by up to 30 percent, as these are often the most-expensive smart meter components.

More important than the infrastructure cost savings from LPWAN are the cost savings and benefits that other applications using the network can provide. For example, the same LPWAN deployed for water metering can also be used for leak detection devices in businesses and residences, sensors that detect soil moisture in agricultural areas to reduce wasteful watering, or building temperature monitoring systems that can send alerts when a pipe freezes — all beneficial applications to reducing overall water consumption in a municipality.

Building An IoT Ecosystem

A key growth driver of the adoption of new technology, in this case LPWAN, is standardization among a robust ecosystem of companies. The LoRa Alliance and similar groups are working to standardize and scale their respective LPWAN technologies to ensure deployments can make an attractive return on investment. Many LPWAN operators have announced partnerships with water metering companies and other related utility providers so there will be increased LPWAN-based AMI rollout in 2016. LPWANs will eliminate the cost of infrastructure and network deployment complexity for application users, creating an environment in which municipalities of all sizes can implement more-effective water management systems.

Beyond water metering, LPWANs are optimal for other IoT and smart city applications, including smart waste management, smart parking and traffic systems, intelligent building monitoring, automated supply chain management, intelligent lighting systems, and more. With more and more announcements of smart metering adoption and the proliferation of sensors and LPWANs throughout the world, it will be increasingly easy for municipalities to adopt LPWAN AMI solutions and begin reaping the benefits of lower infrastructure costs, minimal maintenance, and real-time data. ■

[1]*Gartner Says 6.4 Billion Connected "Things" Will Be in Use in 2016, Up 30 Percent From 2015, Gartner, Inc. Press release, November 10, 2015.*

About The Author

Hardy Schmidbauer is the director of wireless products at Semtech Corporation, a leader in wireless solutions and IoT connectivity. Schmidbauer has more than 15 years' experience in wireless design, product definition, and strategic marketing through director, marketing, and design positions for wireless solutions targeted at low-power connectivity, M2M, and IoT applications. He holds an MBA degree from Santa Clara University, as well as MSEE and BSEE degrees from Oregon State University.

How To Communicate The Value Of Water – And Rate Hikes – To Customers

A champion of water investment shares four strategies for winning over customers to support both short-term and lasting utility initiatives.

By Radhika Fox

Water is a constant. It's a thread that weaves through our lives on a daily basis. But water utilities are evolving rapidly, and tomorrow's water utility is going to look very different from previous generations.

Historically, water and wastewater utilities were happy to be out of sight and out of mind. The incredible systems, which bring water to homes and businesses and then take it away and treat it, were built generations ago. They have served their communities well — and in most parts of the country, customers are intrinsically used to clean, safe, reliable water service. As a result, most Americans take our most precious resource for granted. And utilities were largely content with that arrangement. They could quietly go about their business, proud to do the work that keeps communities going.

However, external and internal factors are changing that arrangement — and utilities are changing with it. We have seen steadily declining federal investment in water infrastructure; now, 98 percent of water and wastewater projects are financed locally through revenue generated by water bills. Utilities are becoming creative in a number of ways: how they are financing projects, how they engage with their customers about the state of water systems, the need to invest, and how precious dollars are being spent.

The US Water Alliance convenes the Value of Water Coalition, which is focused on building public and political will for investment in sustainable water infrastructure and water resources. Through education and advocacy campaigns, strategic communications and media activities, high-impact events, and publications, we are helping the nation understand that water is essential, invaluable, and in need of investment. We are sharing some of the best practices from the members of the Value of Water Coalition for communicating the value of our water infrastructure and the need for smart and responsible rate proposals.

It may be tempting to revert to "out of sight, out of mind," but it is better to be loud and proud about a rate proposal than lurking in the shadows.

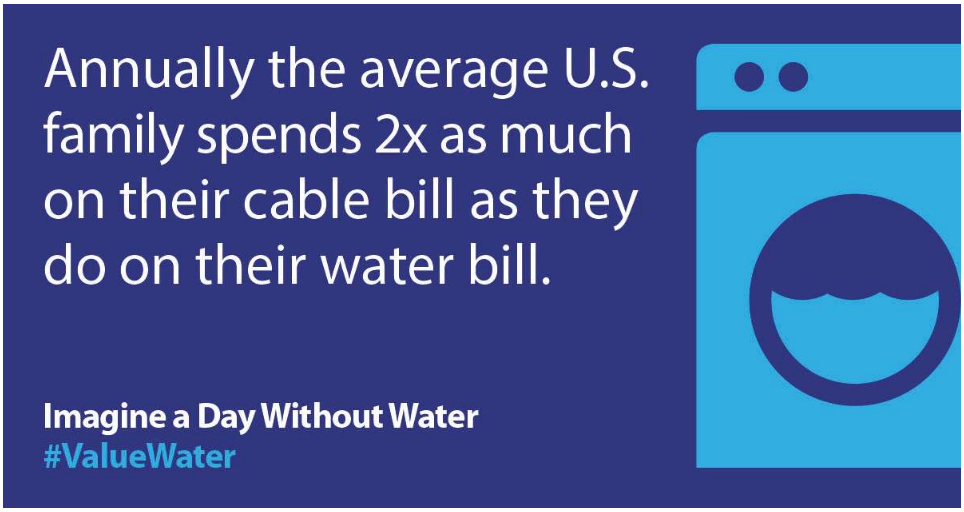
Educate And Engage Customers About Their Water Systems

Utilities should constantly remind and educate customers about their systems, not just when a new rate proposal is on the table. When customers understand the incredible and complicated systems that bring water to and from homes and businesses, they understand why investments need to be made. They feel pride in their water systems.

DC Water, for example, offers wildly popular public tours of its magnificent Blue Plains Advanced Wastewater Treatment Plant. In 2015, more than 2,000 people toured the plant, and by January 2016, the tour wait list was already six months long. Bringing everyone from school students to members of Congress through the plant is an opportunity to pull back the curtain and show — not just tell — people where the revenue generated from water bills goes. In Cleveland, the Northeast Ohio Regional Sewer District took stakeholders and local press on a "Follow the Flow" tour during Infrastructure Week 2015 to showcase all the incredible steps water goes through from treatment to safe return to receiving waters.

Seek Open, Honest Feedback On Rate Proposals

It may be tempting to revert to "out of sight, out of mind,"



One of many infographics shared on social media during the Value of Water Coalition's "Imagine a Day Without Water" campaign

but it is better to be loud and proud about a rate proposal than lurking in the shadows. Utilities are actively and consistently engaging with community leaders, elected officials, and commissions to shape and advance the rate proposals needed to operate and invest in water infrastructure. Explaining that these systems are aging, the potential hazards of not investing, and the fact that utilities are prudent stewards of ratepayer dollars is essential. When the San Francisco Public Utilities Commission recently adopted its four-year rate proposal for water and wastewater rates, it was preceded by hundreds of meetings with stakeholder groups from the Bay to the ocean. From neighborhood councils to the Rotary Club, the San Francisco utility went out of its way to engage stakeholders and transparently acknowledge that the system had been really affordable, but the community needs to actively invest in it for future generations.

Activate The Business Community As Champions

When Atlanta's Department of Watershed Management wanted to communicate about the importance of creating a more secure water supply for the city, it was an economic argument that sealed the deal. Currently, the city only has a three-day emergency supply of water. If there were a water crisis upstream that shut down the flow of water into Atlanta, the city could lose $100 million a day in economic activity. Atlanta has the busiest airport in the world and is home to major global corporations. Losing water would mean closing restaurants, hotels, and the airport. It would be a public safety and public health crisis, and it would be an economic catastrophe. But investing in a new reservoir that will hold a 30-day emergency supply of water will create a more secure water future and create more jobs.

That is why the business community stood with Atlanta in support of the reservoir project. The Value of Water Coalition went to the reservoir site for "Imagine a Day Without Water" — a national education campaign to promote investment in water — and standing side-by-side with the Department of Watershed Management and Mayor Reed were business leaders who are building the Atlanta Falcons' new football stadium. Athletes and fans alike need water! Elected officials listened closely to business leaders. The message was clear in Atlanta: The reservoir was a worthwhile investment.

Make It A Dialogue With Your Customers

Communications is about having a conversation with customers that goes beyond simply informing them about the utility's needs. As customers are increasingly turning to online platforms and social media as primary channels of communication, water providers need to diversify their communication tools as well. For American Water, that has meant a significant increase in maintaining consistent, responsive, and robust social media presence. "The key is to tailor how you connect with your customers, understanding what kind of information they want from you and the context in which they want it," says Maureen Duffy, vice president of corporate communications and external affairs for American Water. "We want our customers to know we are working for them, helping to improve the systems, and striving to earn and keep their trust as their water services provider."

Value of Water Coalition members are leaning in to the challenges facing modern water utilities. By increasing efforts to educate and engage their communities, utilities are entering a new era that is no longer out of sight, out of mind. Tomorrow's water utilities should be at the center of the conversation for how to build strong, equitable, and sustainable communities. ■

About The Author

Radhika Fox is the CEO of the US Water Alliance, a national nonprofit organization dedicated to uniting people and policy for one water sustainability. Radhika also serves as director of the Value of Water Coalition, a collaboration of water agencies, business leaders, and national organizations dedicated to educating and inspiring people about how water is essential and invaluable and needs investment.