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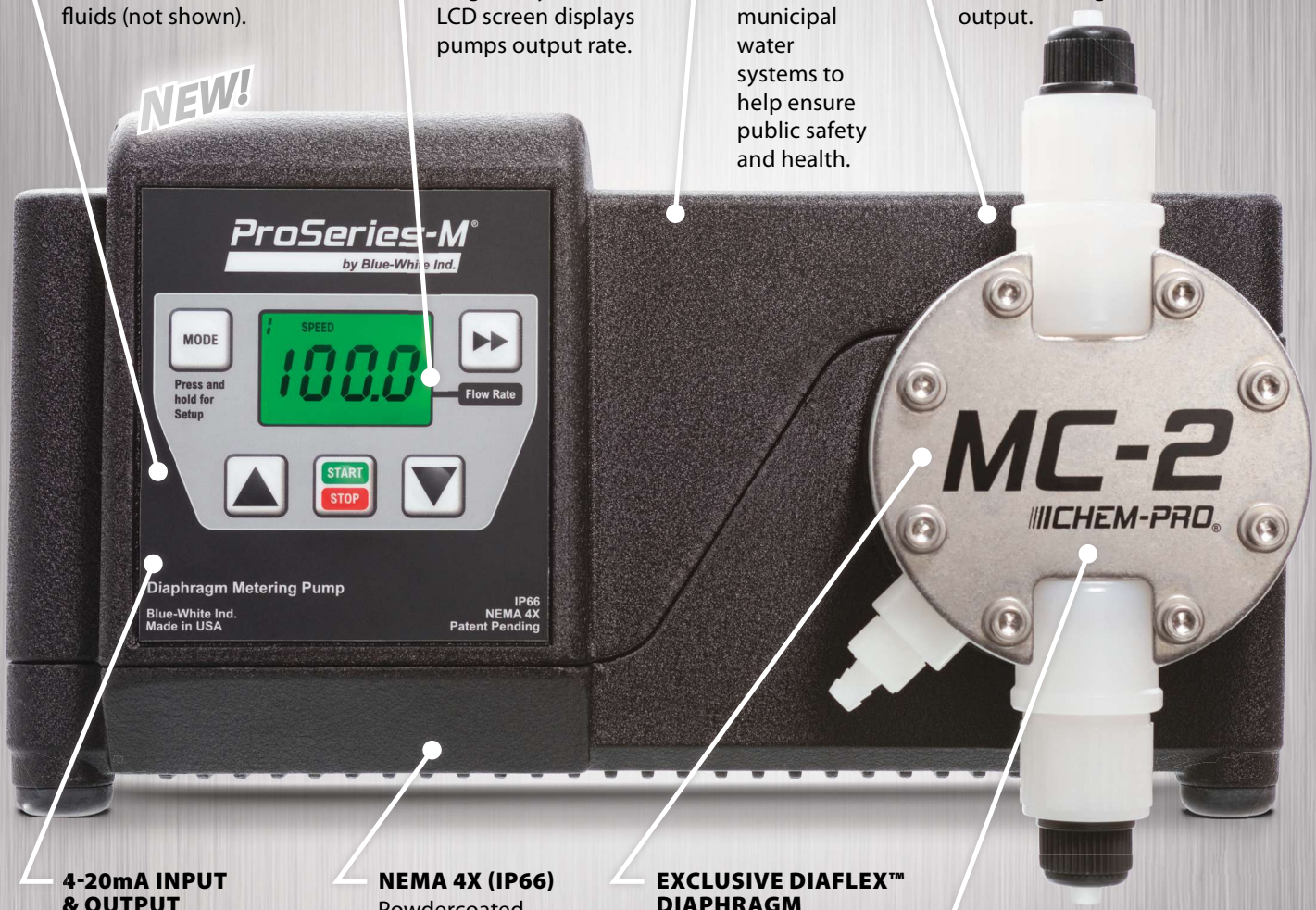

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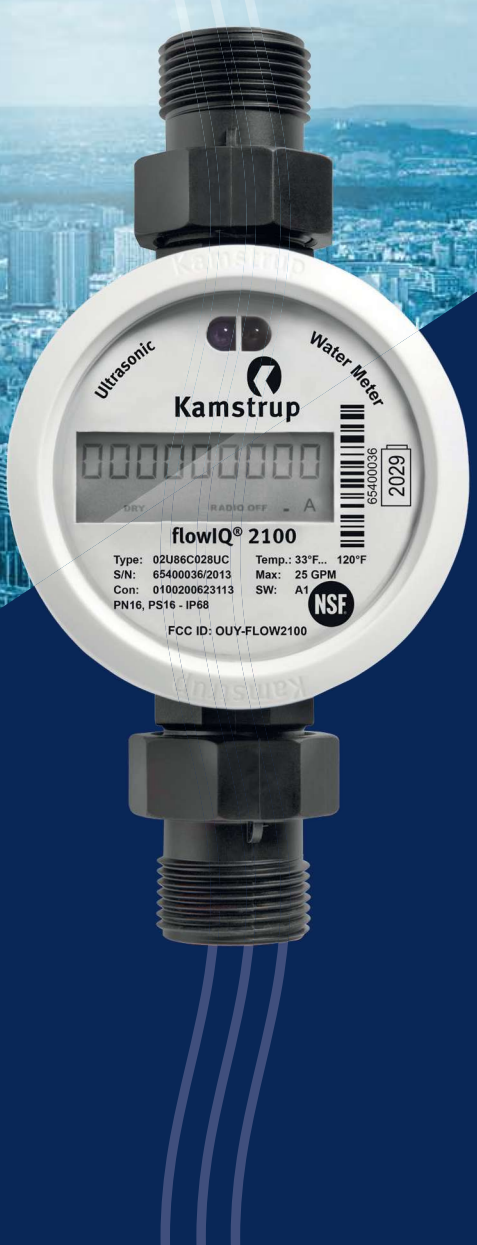

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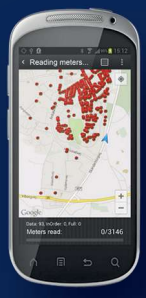

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Membrane Masters: Learning From The Best

Put Dr. Jim Birkett and professor David Furukawa together in the same room and you have nearly a century of experience in membranes and desalination. The industry icons have been around since the early days of reverse osmosis (RO), yet they remain thoroughly engaged (and engaging). I recently had occasion to absorb the pair's wisdom — equal parts history lesson and predictive analysis — at the AWWA/AMTA 2014 Membrane Technology Conference. It was a rare opportunity, and one that should be paid forward by sharing some of their insight.

Birkett, a 40-year industry veteran and the first-ever president of the International Desalination Association (IDA), grabbed attention by refuting a common belief, stating that "RO for seawater is not as energy-intensive as everyone claims."

Birkett explained that after 35 years of progress we have nearly reached the point of minimum energy for seawater reverse osmosis (SWRO), thanks in large part to energy recovery devices (ERDs). The specific energy required for SWRO — dictated by chemical-free energy differences between feed water and permeate — has been very nearly mastered. To reduce energy much further, he said, we have to look at reducing peripheral energy requirements for pumping, pretreatment, posttreatment, and instrumentation and controls.

The "real problem," Birkett noted, is the expectation of cheap or free water — an antiquated notion in today's world. "We are loathe to accept that these days are over, but they are over."

To bolster our potable water supply, reuse and desalination will both need to be adopted, and both processes rely heavily on membranes. While thermal desalination persists, RO is trending as the preferred option, currently accounting for 65 percent of new installed capacity. Wastewater reuse is equally important, and is often more economical than desalination. In addition to RO, membrane bioreactors (MBRs) and ultrafiltration (UF) membranes are increasingly popular options for turning wastewater into "new water."

Indeed, membranes are the central technology in the quest for renewed supply. As professor Furukawa observed, "Membrane treatment today is a multibillion-dollar worldwide industry" … and growing.

Membranes Moving Forward

Furukawa, chief scientific officer for the National Centre of Excellence in Desalination (NCED) in Australia, has worked in the field for more than 50 years. Through a five-year NCED project, he has helped secure six major desalination plants in five Australian cities. "Australia will never have to worry about a drought again," he asserted.

Furukawa, who has spent most of his career in R&D, focused much of his discussion on innovation and the bright future for membranes. He sees expanding use not just for desalination and water reuse, but also for point-of-use systems. This prediction speaks to one of the technology's greatest strengths — scalability.

Membrane capacitive deionization (MCDI) and forward osmosis (FO) are new desalination technologies that can be sized and situated virtually anywhere. MCDI utilizes ion-exchange membranes, porous carbon electrodes, and electrical potential difference to remove salt ions, while FO uses an osmotic pressure gradient to transport water across a semipermeable membrane, with no energy required to drive the flux.

Both MCDI and FO are finding application mainly in oil and gas (O&G) and mining operations, and both are exemplary of Furukawa's Rule No. 1 for R&D practitioners: "The primary target may not be profitable, so look for secondary uses." While the vision for these technologies was initially seawater desalination, the market led them to O&G — an opportunity and industry that should only expand as water-intensive hydraulic fracturing flourishes amid the shale gas boom.

After more than 50 years, it seems membrane technology is ready for liftoff. It's hard to overstate the significance of membranes for the future, or that of the "membrane masters" who charted the course.

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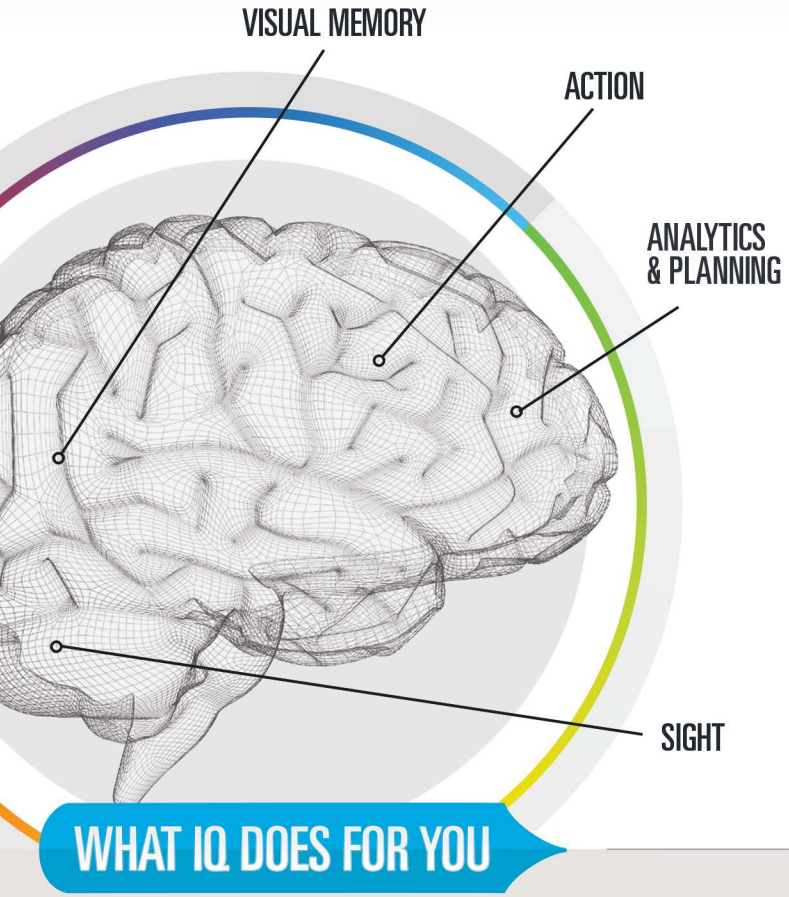

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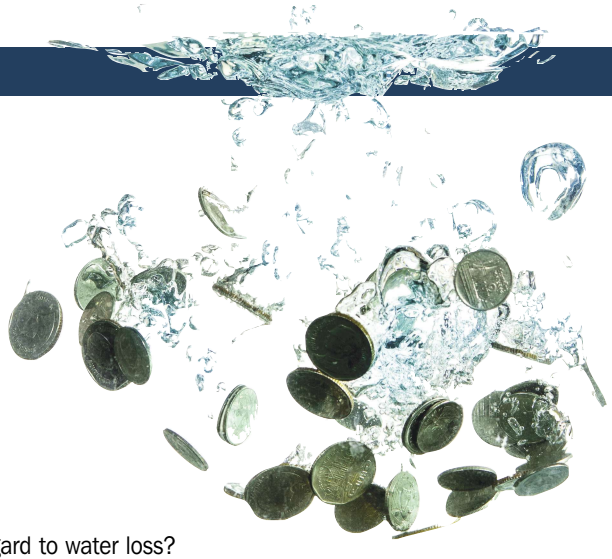


State Of The States: Emerging Water Loss Regulations In The U.S.

Where does your state stand — both statistically and strategically — with regard to water loss?

By Will Jernigan

Water system regulations in the U.S. have been around for 100 years. Forty years ago, Congress passed the State Drinking Water Act that brought sweeping changes for America's drinking water systems. For nearly all of that time, those regulations have been solely focused on water *quality*. Only in recent years has the issue of water *quantity* found its place in the regulatory arena.

It is important to recognize that resources — both environmental and financial — will become more restricted with time, not less. Management of water loss is "supply-side" conservation — that is, reducing wasteful losses that occur on the utility's side of the customer meter. Historically, conservation has been a more common practice in the western U.S., where arid climates and severely restricted supply set the stage. Recent water loss legislation in the eastern U.S. has begun to bring conservation and supply-side efficiency to the center stage, particularly in the Southeast. The EPA put out a report[1] in 2013 articulating the importance of water auditing and water loss control, recognizing the emerging adoption of best practices to address an already prevalent issue.

Drivers Can Be Different

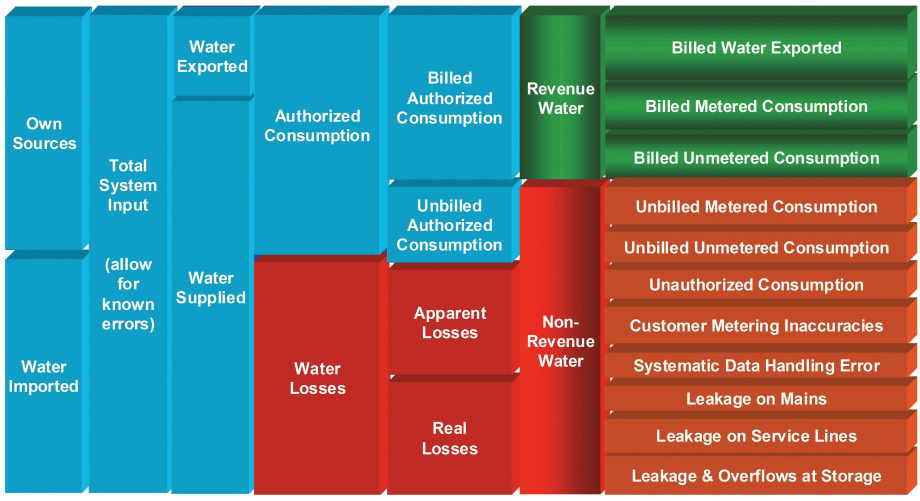
So why do we care about water loss? Just in the U.S., the drivers that make water loss important can vary widely from state to state, even utility to utility. For some, there are extreme drought conditions or arid environments with constrained water supplies that make water loss management a necessary source of new supply and resource stewardship. For some, it's a plain bottom line. There are strained budgets, with expenses outpacing revenues and they see water loss management as fiscal shoring. They understand the inherent business case for system efficiency, including the complex but proven dependency between water and energy. For some, the driver is political — where pending rate increases fuel customer distrust and outrage ("You're asking me to pay more for your inefficiencies?"), where water loss management provides defensibility and action and an offset to the severity of the required rate increases. For others, as is the case in Georgia and Tennessee, a primary driver is regulation. While there tends to be a primary driver, in most utilities all of these drivers exist to some degree. For this reason, the cost of doing nothing far exceeds the cost of water loss management in both the short and long term.

Water Loss, Exposed

We must understand the nature of any problem to stand a chance of solving it. The tricky part about water loss is that it's not a singular problem. Water loss has multiple components, each having multiple subcomponents, and there is not a single tool or technique for universally addressing all components. Thus, a collective strategy must be developed and designed to appropriately target each subcomponent.

So what is water loss made of? Chances are by now you have seen or heard much of this, but it bears repeating. The Water Audit Method developed by the International Water Association and the American Water Works Association (AWWA)[2] defines water loss on the basis of the Water Balance (see Figure 1). Water loss is derived as "real losses" plus "apparent losses." Real losses are physical losses from

Figure 1: AWWA Water Balance



the distribution network, via leakage from mains, services, and storage tanks. Apparent losses are economic, nonphysical losses that result from underregistering customer meters, underbilling of customers, and theft. Imbedded into the Water Audit Method is the Data Validity score — a measure of confidence and reliability in the Water Audit outputs.

Data Validity must be your first consideration in using the Water Audit to guide water loss management activities. Systems with low Data Validity scores must focus next steps on improving data. Those with high Data Validity should focus next steps on reductions in water loss. Those with medium Data Validity scores must examine closely to determine the appropriate balance of next steps for data improvement and water loss reduction.

All systems have water loss, and all systems have some of each component — real losses and apparent losses. The big question is how much of each, and what are the cost impacts of each? This is central to any effective strategy. Consider the importance of applying the right strategy to the right problem. How effective will implementing a comprehensive customer meter testing and replacement program be for solving a leakage problem? How about an active leak-detection-and-repair program for solving systemic billing system issues? And consider the cost effectiveness of any strategy, even if it's the right tool for the job. Are we spending a $1,000,000 on a $500,000 problem? An effective strategy — for both results and cost — must match the problem in both scale and nature.

State Of The States

In 2002, an analysis[3] of state agency water loss reporting practices was conducted by Beecher Policy Research, Inc. Two primary conclusions came from this survey — the first was the widespread use of the performance term "unaccounted-for water percentage" and the second was a clear inconsistency in what was considered "acceptable loss" (see Figure 2 on page 10). AWWA has long since denounced use of the imprecise term "unaccounted-for water" (UFW), as well as percentage-based metrics, as they have been deemed inconsistent and unreliable as performance measures. UFW has been abandoned as an "old technology," joining the likes of the 8-track and rotary phone. In its place the IWA/AWWA Water Auditing Methodology, as defined in the *M36, Manual of Practice for Water Audits & Loss Control*[4] (M36 method), is recognized world-wide as best practice in the industry for the accounting and control of losses in drinking water systems. Central to the M36 method is the rational segregation of real (physical) and apparent (economic) losses and analysis of the components of each type of loss, which informs an effective control strategy.

An analysis[5] in 2005 on water loss policy and regulation

Figure 2: 2002 states survey of "unaccounted-for water" standards

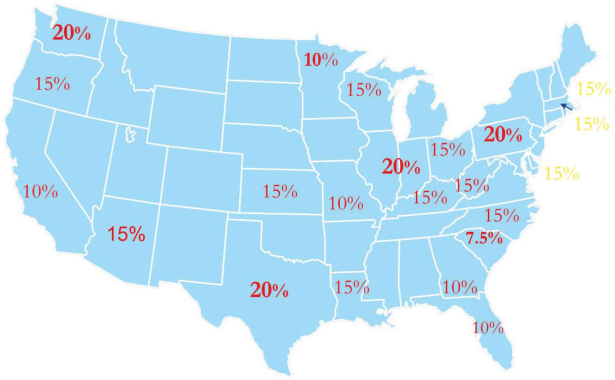
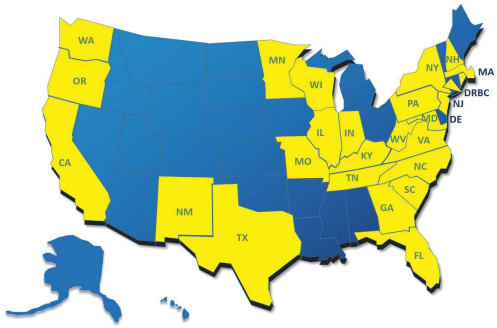


Figure 4: States with water loss regulatory or policy framework (2013 statistics)



further describes a highly fragmented and complex water supply and regulatory structure. The complexities stem from the sheer volume of regulated community water systems in this country (more than 54,000), as well as the intricate framework of regulatory agencies — often multiple agencies in a given state with varying regulatory jurisdiction, and sometimes agencies that regulate water systems across multiple state borders. Further research[6] was conducted by the Alliance for Water Efficiency in 2011-12, revealing that through the network of regulatory agencies, an indication of regulatory momentum is beginning to emerge in the water loss arena.

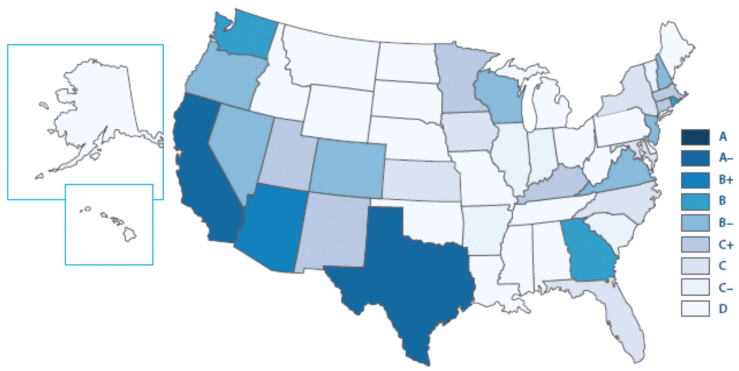
Clearly, there have been significant evolutions in water loss policy and regulation in just the last 10 years. The scope of the research presented in this article is focused on identifying where a framework for water loss auditing and reporting exists today, where there are performance targets, and which states or agencies align their requirements with the best practices of the M36 methodology. The research methodology consisted of compilation and review of regulatory texts (existing and proposed), statewide planning documents, sanitary surveys, state funding applications, and policy memorandums as available from states across the U.S.

Figure 4 above presents the landscape of states where at least some type of framework exists for water loss auditing, reporting, and performance targets. The format of this framework varies widely from state to state. In some cases, water loss auditing, reporting, and/or performance targets are *required* by mandate, with varying degrees of penalty for enforcement. In other cases, water loss auditing, reporting, and/or performance targets are not required, but are otherwise incentivized through priority on state funding applications, consideration for new withdrawal permits, or other means.

Figure 5 on page 11 presents those states where that regulatory framework exists, and it directly aligns with or references the best practices of the M36 method for water auditing and loss control.

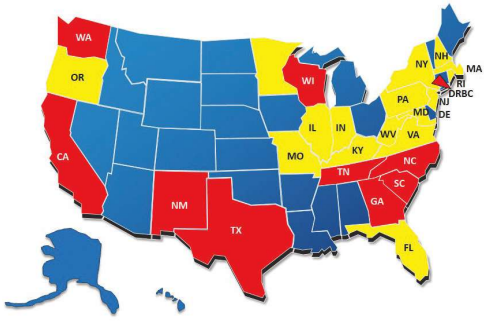
California and Texas were the first states to adopt M36 as the required methodology. Most recently, Georgia, Tennessee, and Wisconsin have joined them in adopting the M36 requirement. Similarly in California, the requirement only applies to those utilities that are part of the California Urban Water Conservation Council (CUWCC). The Delaware River Basin Commission (DRBC), while not a state, instituted a requirement in 2013 for all M36 auditing by most water systems under its regulatory purview — about 300 utilities including Philadelphia, Aqua Pennsylvania, and New Jersey American Water. M36 auditing is incentivized in New Mexico via consideration for new permit applications, in North Carolina via priority points for SRF applications, and in South Carolina via incorporation into annual surveys conducted by state inspectors. Among others requiring M36 auditing, only California, Tennessee, Georgia, and the DRBC use the AWWA Free Water Audit Software as the required format for submittal. This software was developed and released by AWWA to provide the industry with a standard format for the water audit, along with a free compiler tool to allow ease of collection and analysis for large numbers of water audits. The current version of the Free Water Audit Software (v4.2) was released in 2010, and the next version (v5.0) is due out in mid-2014.

Figure 3: 2011 states scorecard for water efficiency policy



A trend that has been reported by most of the M36 early adopter states is an inherent challenge in the reliability of many of the audits submitted, citing examples of errors and anomalies such as water loss greater than 100 percent or less than 0 percent. These challenges are largely attributed[4] to the lack of understanding for the auditing process (as many utilities are conducting these audits for the first time), quality control on the audit data inputs, and the "top-down" nature of the initial audit. The DRBC reported[6] that approximately 100 of the 300 audits initially submitted in 2013 were not suitable for analysis, requiring extensive cleanup of errors and anomalies. In California, the CUWCC reported[7] that among audit

Figure 5: States with water loss regulatory or policy framework per AWWA M36 method (in red), as of 2013



submittals from 2010, 36 percent were unsuitable for analysis due to errors. The Texas Water Development Board and Tennessee Comptroller's Office have reported similar challenges since they began collecting water audits in 2005 and 2007, respectively. In Georgia, a statewide training and data validation initiative was conducted for the 200+ water systems subject to the water auditing and reporting requirement beginning in 2012. The training and validation initiative was ordered because the presence of unvetted audits and their performance indicators undermined the credibility of the entire dataset, and the auditing process as a whole[8].

A survey of the regulatory landscape today reveals growing regulatory momentum for water loss in the industry and a foundational need for education, training, and validation per the AWWA M36 auditing and loss control methodology. A look back at prior research efforts[3,5,9] on this topic reveals that much has changed in a short amount of time. A look ahead at leading indicators[10,11,12] — such as draft M36 legislation in New Hampshire, or M36 policy objectives established in statewide water conservation planning documents in Oklahoma and Hawaii — suggests that we may see an increasing rate of change in the future. ■

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Will Jernigan, *P.E., is the director of Water Efficiency with Cavanaugh, and is an industry expert in water efficiency with a focus on water loss control and revenue recovery.*

Next-Generation Arsenic Removal

A novel process gives spent adsorptive media – and utilities' budgets – new life.

By Kevin Westerling, editor, Water Online

The U.S. Environmental Protection Agency feels your pain.

That's what the EPA seems to be saying through its Arsenic Removal Technology Demonstration Program. Initiated in 2002 — the same year federal limits were dropped from 50 micrograms per liter (µg/L) to 10 µg/L — the program seeks out and verifies low-cost solutions for utilities struggling with arsenic removal.

The latest breakthrough shows tremendous promise: The first (and only) full-scale deployment is saving the participating utility $20,000 to $30,000 per year. The savings are gained by backwashing and regenerating, rather than repurchasing, iron-based adsorptive media — a major development considering many utilities' tight budgets and the rising cost of replacement media.

The EPA partnered with Battelle, an applied science and technology development company, to demonstrate the ability of a caustic solution (sodium hydroxide) to strip the arsenic from spent media in a lab setting. In 2009 the project went full-scale at Twentynine Palms Water District in California, where it has since been adopted as regular operating procedure, post-EPA demonstration program, and continues to thrive.

Startup requirements for media regeneration are relatively modest — chemicals, feed pumps, and tanks — but there are certain mitigating factors, discussed below, that should be evaluated before adopting the process. The right candidates, however, could be on the cusp of significant savings.

The Arsenic Problem ... And Solution

Arsenic is an odorless and tasteless semi-metal that is naturally present in aquifers throughout the country, and thus also shows up in well water. At concentrations above the EPA's maximum contaminant level (MCL) of 10 µg/L, arsenic can cause skin damage, circulatory problems, and an increased risk of cancer. It is a common issue for many small communities — and an expensive one.

"A lot of people are out of compliance because they just can't afford the cost of arsenic treatment," said Ray Kolisz, operations manager for Twentynine Palms, who often travels to water-quality conferences to speak on adsorptive media regeneration. For traditional treatment, the biggest expense is purchasing new media.

According to EPA research engineer Tom Sorg, 80 percent of utilities that treat arsenic do so with adsorptive media, and 80 percent of the operating cost is for media replacement. Sorg, who was responsible for taking regeneration from the lab to Twentynine Palms, also noted that iron-based media, particularly Bayoxide® E33, is the industry standard for arsenic removal. Other types of adsorptive media include activated alumina (AA) and titanium- and zirconium-based media, but full-scale regeneration, at this stage, is exclusive to iron-based media.

The typical process consists of media inside the

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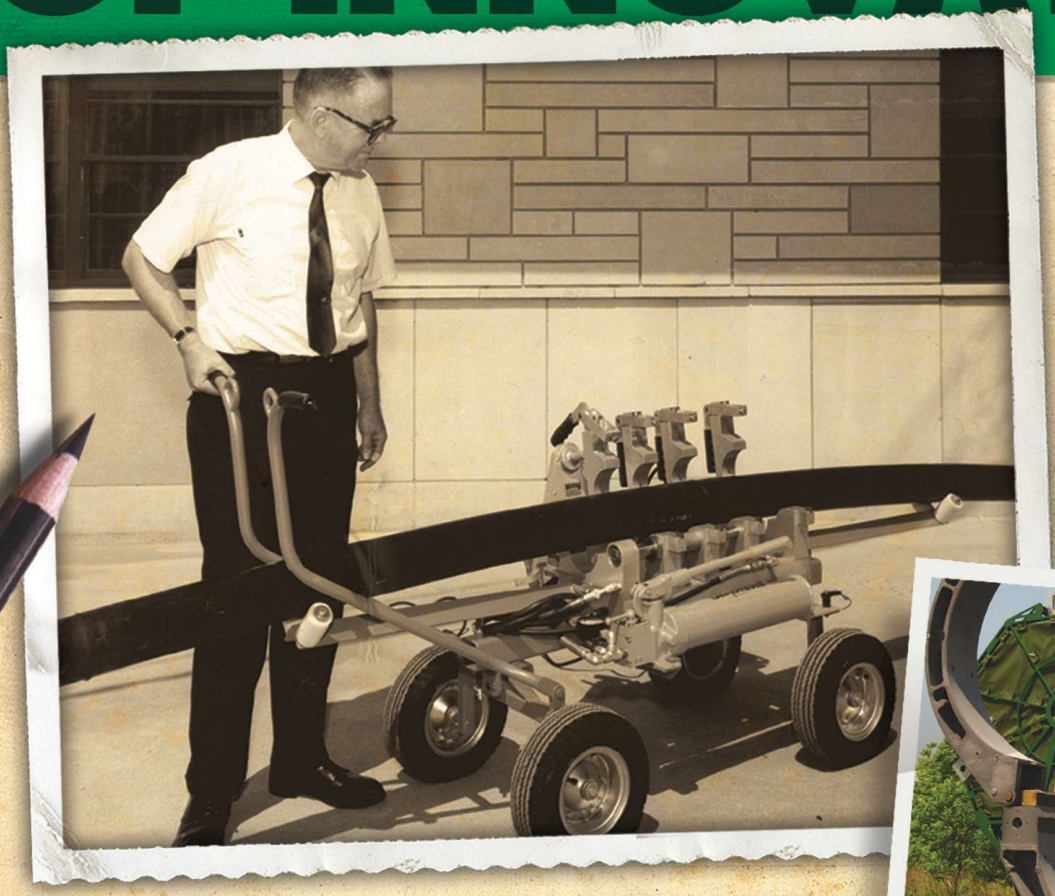

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The cost savings came through as expected, but the performance of the regenerated media was eye-opening.

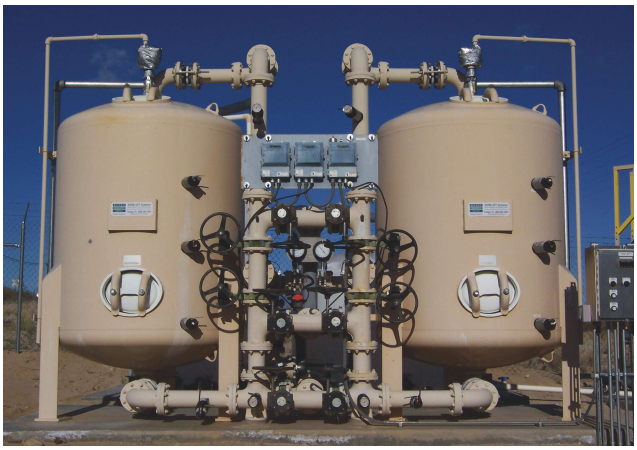
pressure vessel(s), where the arsenic adsorbs onto the media. As it starts to lose its adsorption capability, the media is replaced with new, virgin media.

The new process features upflow regeneration utilizing 4 percent caustic solution (pH of 13) to strip the arsenic off the media. A second step, neutralization, injects 93 percent sulfuric acid into the flow stream to lower the pH of the treated water. The resulting hazardous-waste effluent must be handled appropriately, whether sent into the public sewer system (if available), treated on-site, and/or hauled offsite. Equipment requirements for Twentynine Palms were two HDPE tanks (3,200 gal) to collect wastewater, a tank (1,000 gal) and pump for the caustic solution, an acid-dosing pump, and a pH meter.

Twentynine Palms also underwent minor pipe modifications to the existing treatment system, including plumbing for upflow and downflow application of the reagent, before regeneration could begin.

The Twentynine Palms Experience

Located in the Mojave Desert in Southern California, San Bernardino County, the Twentynine Palms Water District covers roughly 86 square miles and serves a population of approximately 17,800. When the updated MCL came out, the water district had three wells that were above the allowable limit. Two were shut down because of their age — "It wasn't worthwhile treating those wells," said Kolisz — and one was treated with Bayoxide E33 adsorptive media as part of a conventional use-and-replace treatment program. Raw water at the site in question, Well 11, averages 16 µg/L of arsenic.



Pressure vessels at Twentynine Palms

Though Twentynine Palms stayed in compliance by reducing arsenic below 10 µg/L, it was a consistently expensive endeavor. Kolisz, the operations manager both then and now, recalled the issue:

"We put the system online, and the media wasn't performing as expected. We weren't getting the bed volumes that we thought we would. It prompted us to replace the media more often, which was a significant cost."

The EPA and Battelle, having proved media regeneration in a lab environment, sought out Twentynine Palms to pilot-test the process in the field at full scale. The treatment system consisted of two vessels, each with 69 ft^3 of media. One vessel was set up to regenerate the spent media, while the other vessel's media was replaced with virgin media.

To say the test results were positive is an understatement. The cost savings came through as expected, but the performance of the regenerated media was eye-opening.

Despite the somewhat harsh process of removing the arsenic from the media, the regenerated media showed zero signs of degradation after use; in fact, it performed better on its second run, outshining even the virgin media. Kolisz explained that this was likely related to oil residue originating from the oil-lubed vertical turbine shaft pump that interfered with, or "blinded," the media. The caustic used to strip the arsenic off the media for regeneration essentially cleaned it of everything, thus improving performance.

Today, Twentynine Palms continues to regenerate media at the 400-GPM Well 11 site — now served by two parallel vessels — removing 90 percent of accumulated arsenic with each regeneration (and still no indication of media breakdown). The efficient arsenic-removal rate allows some raw water to be bypassed and blended with the treated water, while still staying far below the regulated limit.

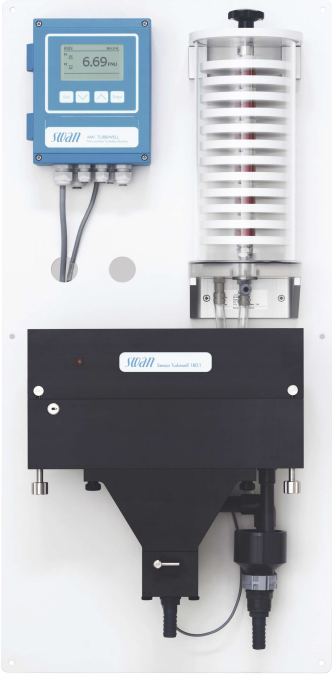
Mitigating Factors To Consider

There are two major responsibilities to recognize before taking on media regeneration: operator training and wastewater disposal.

A main reason Twentynine Palms was chosen for the EPA's demonstration program was the utility's familiarity and training with adsorptive media regeneration — not for arsenic removal, but for fluoride removal. Twentynine Palms regenerates activated alumina to remove naturally occurring fluoride, so it had comparable equipment and training in place.

swan

ANALYTICAL INSTRUMENTS



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For traditional treatment, the biggest expense is purchasing new media.

Most utilities will be starting from scratch, however, from a learning standpoint.

"There's quite a bit of training and chemical handling," noted Kolisz. "A process like this is a lot more challenging than just replacing the media. When you start getting into pH control and those chemicals, there's a certain level of operator that you would want to have working on the system."

Safety training is equally important. Operators need to exercise caution when working with sodium hydroxide and sulfuric acid. They need to be trained in safe use and handling, and always wear proper personal protective equipment (PPE).

The effluent produced from the regeneration process is also dangerous, at least from an environmental perspective. Twentynine Palms, which is not connected to a centralized sewer system, was initially forced to haul the effluent for offsite industrial treatment, which cut into its savings considerably. Much of the savings was recouped once the utility began treating the wastewater onsite — using ferric chloride to precipitate arsenic from the effluent — after which only a small amount of residual needed to be disposed.

Though Kolisz called disposal "a major cost," it's worthy of mention that when Twentynine Palms was paying for wastewater removal, the entire media regeneration process was still 60 percent less expensive than repurchasing.

Communities and water agencies that are piped into the sewer system are in better shape, as sewers are deemed an appropriate and acceptable discharge point.

A third factor to consider before adopting regeneration is attaining proper permission. "Any time you change a process, you have to get state approval," the EPA's Tom Sorg reminded.

The approval and success at Twentynine Palms should bode well for others, however. Referencing the California Department of Health's strict reputation, Sorg commented, "If you can get California to approve something, then you can get almost any other state to do it."

A final point of consideration, submitted by both Sorg and Battelle research scientist Vivek Lal, is the acknowledgment of a "break point" where operations would be too small to realize the value of media regeneration — where replacement is the less expensive option. "I suspect that the break point would be between 25 and 50 ft^3" of media volume," estimates Sorg.

The Bottom Line

The cost-saving opportunity from regeneration is variable depending on the amount of media typically used and frequency of replacement, but Twentynine Palms Water District serves as a good gauge of potential.

With each regeneration performed in lieu of repurchase, Twentynine Palms saves nearly $15,000. The utility reports the cost of media replacement to be $20,500 per tank for Well 11, compared to chemical expenses of just $1,000 per tank and current disposal costs of around $5,000. Even with the initial, one-time investment for minor pipe modifications and design work (less than $5,000) coupled with the former disposal cost of $10,000 (prior to instituting on-site treatment), Twentynine Palms saved $5,000 on its very first media regeneration.

"It saves us quite a bit of money," said Kolisz.

That is perhaps more understatement, considering that Kolisz's colleagues — the EPA's Sorg and Battelle's Lal — attested to the rising costs for adsorptive media. As the price continues to climb, utilities will save even more.

And, again (amazingly), Twentynine Palms is still seeing no degradation in the regenerated media. Could it be that they will never purchase media again?

While the true potential for this new process has yet to be determined, the opportunity to take advantage of its proven benefits is readily available to water agencies right now.

"We're trying to get the word out that this can be done, and it can save you a whole heck of a lot of money," said Kolisz. "It's up to the agencies to use the data and resources they have to make that decision." ■

Sodium hydroxide is prepared for regeneration.

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Water Online

How To Raise Consumer Confidence In Your Water

Utilities already have the resources to deliver the key ingredient: education.

By Julia Adamiak

Despite stringent regulation of public water supplies, many consumers are still concerned about the quality of their tap water. Topics of concern include health effects of treatment chemicals, natural and synthetic contaminants, as well as temporary changes in water quality due to repairs and routine maintenance of the distribution system. Recent widespread publications of chemical spills and bacterial contamination of public water supplies have caused consumers to be more wary of tap water. Bottled water, through mass million-dollar marketing campaigns, is perceived as an increasingly appealing alternative. On top of that, there is a lack of communication and information on the part of utilities and an overload of negative information or misinformation regarding tap water. The good news is that the majority of utilities already have the resources and tools needed to reach out and educate consumers about the water that they produce. With the right approach, utilities hold the power to positively change their consumers' perception of tap water.

The Waukegan (IL) Water Treatment Plant has tapped into consumer outreach.

It is a widely known fact that water utilities are facing challenging times in terms of budget constraints and manpower reduction. They are also simultaneously managing pressing problems such as aging infrastructure, increased compliance monitoring, and expanding regulations. As a result, the importance and quality of the services provided and the finished product delivered to the consumer have unintentionally taken a backseat. It is important to remember that the consumer pays for the services and the product. This is where revenue comes from. Not paying enough attention to consumers' needs and concerns will potentially push more of them away from using tap water and cut revenues even further. Most water professionals are not only confident in the tap water that they help produce, but also agree that tap water is in many respects safer to drink than bottled water. Why is it then that many consumers do not share this perception? Why are studies still showing a lack of confidence in municipal water on the part of the consumer? Consumer confidence in tap water is lacking because most information reaching consumers about tap water is coming from sources other than the water utility. Usually the information comes from traditional media outlets and is focused on dramatic or shocking topics like "water contamination" or "dangers of fluoridation." Unbiased and factual information from authoritative and verifiable sources, although widely available, is not reaching enough consumers.

Provide Authoritative Information

So, what can water utilities do to better educate their consumers about tap water and increase confidence in the process? Many consumers are unaware of what exactly it is that water utilities do. To fix this, water utilities must be completely transparent and make an effort to provide authoritative information

on a regular basis. The easiest way to do this is for the water utility to increase its presence online. This is also the most cost-effective way, as many cities already have established websites for their various departments. Under a water department Web page, water utilities should create informative and educational content with relevant sources and links.

At its minimum every water utility website should have general information about the various departments that fall under the water utility, including the water treatment plant, meter department, main department, and billing. Each department should be described and photos should be included if possible. It is also important to describe the water treatment process that the utility uses, the chemicals that are used, and why they are used. Include some of the laboratory testing that is conducted throughout the treatment process. Using photographs, showcase the best parts of the facility, key process and control components, and equipment. Do the same for the other water departments. Often maintenance, repairs, and the constant monitoring of the distribution system handled by water main field crew goes unappreciated. Describe some of the work that is done to maintain water distribution system integrity and post pictures of the water main crew working on the system, especially during extreme weather temperatures. This will imbue consumer respect and appreciation for staff as well as an understanding when service needs to be interrupted for maintenance or repair.

Consumer confidence in tap water is lacking because most information reaching consumers about tap water is coming from sources other than the water utility.

Update Mailings And CCRs

According to the Water Research Foundation (WRF), information sent through mail or written on mailed water bills has the highest likelihood of being read by customers. The Consumer Confidence Report (CCR) is still the best way to reach out to the highest number of people. For many utilities, however, the CCR content is very much the same from year to year. More effort needs to be put into compiling a CCR that contains refined and tactical information that will raise consumer confidence, supplemented with the rigorous testing results for all monitored contaminants. Those contaminants that are hotly debated, receive a lot of publicity, or are of concern to consumers need to be explained in more detail. For those utilities forced to stick to the four-page format due to budget constraints, a separate detailed document can be compiled and posted online together with the official CCR. In the mailed CCR and on water bills include the direct website link to this comprehensive "secondary" report.

The CCR should also be posted under a general water quality section on the website. This section should also house FAQs and articles written by the utility addressing topics of concern as well as links to respectable websites and authoritative research or study reports. The most common issues consumers are concerned about are "dirty" water, cloudy water, and particulates in water. These water quality issues are common to most utilities and can usually be traced to hydrant flushing, main break repairs, and other maintenance done on the water system. Prepare FAQs to address these issues and offer solutions.

Don't Just Warn, Explain

For utilities located in northern climates, recent extreme cold temperatures have placed more pressure on the already aging and fragile infrastructure, resulting in more water main breaks and other repairs. When water shutoffs are necessary to make these repairs, water utilities are required to issue boil-order notices to affected customers. Recent news of water contamination and the increasing frequency of main breaks have customers on edge. Often customers given boil-order notices due to repairs assume the water is contaminated. Utilities must review their boil-order procedure and explain that process to the consumer so that they understand that not all boil orders are a result of contamination. In fact, most boil orders are precautionary in nature and due to ongoing system maintenance.

Debunk Myths

There are two more items that every utility should make an effort to compile

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Let's Solve Water

Many consumers are unaware of what exactly it is that water utilities do. To fix this, water utilities must be completely transparent and make an effort to provide authoritative information on a regular basis.

and post online: information on tap versus bottled water, and fluoridation. To do this, more effort and time may be required to research these topics and then summarize and compile a document in a way that will be easy for consumers to understand. It may be useful to also post links to any articles or research findings for those informed consumers who would further like to research those topics on their own.

Endocrine disrupters and chromium-6 have been making headlines as well in recent years. Most state Environmental Protection Agency websites contain a wealth of information accompanied by assessments and testing results, which can be posted directly on the utility's website. Consumers should also be provided with links to the Environmental Protection Agency, Centers for Disease Control and Prevention, Public Health Department, World Health Organization, and other scientifically based media sources and encouraged to visit them for more information.

Get The Word Out

Once relevant content is gathered and made available online, it is time to come up with ways to get this information to the consumer. Many cities have their own public relations department. This can be a great resource to get a message out there. For water utilities that are fortunate to have a PR department, arrange for a meeting and collaborate on possible PR methods to educate and increase awareness and benefits of drinking municipal water in the community. Consider creating educational flyers, which can be posted in public places, distributed across various departments within the city for employees, or included in water bills.

Meet with operators and lab personnel to let them know of the available online content. Provide them with a website address to the water department page where concerned customers can be directed.

For those utilities that already have a "Pay Your Water Bill Online" link, think of ways to place this link strategically so that consumers paying a bill online will see the available content. For example, once a consumer clicks on "Pay Online," a catchy phrase with a link such as, "Find out more about your tap water," could entice them to click. Be creative. Include the website on water bills with a summary of what can be found online. Do the same with CCRs mailed to consumers.

Many city websites also have notification systems where messages can be sent out automatically to a majority of residents as both phone and text messages. These are used for both emergency alerts and outreach purposes. Many water utilities already use these notification tools to inform residents of impending repairs, water shutoffs, and boil orders. Using this tool, as well as RSS feeds and social media, to disseminate the information mentioned in this article should be considered.

In conclusion, water utilities must increase transparency about the vital role that they play in their communities. Having a website is the most cost-effective way to accomplish this. Consumers who view this content should gain a greater appreciation for the work that the water utility does. Once consumers have an understanding of the hard work involved in running a water utility, they will become more confident in the staff that runs the utility and place a greater value on water.

Publication of testing results complemented by the emphasis of the rigorous compliance monitoring and regulation that tap water is subjected to should serve to ease consumers' concerns. Articles with links to further information on topics such as tap versus bottled water and water fluoridation will show consumers that the water utility is knowledgeable and competent in addressing more complex concerns. Educating consumers also serves as an indirect way to facilitate approval for rate increases in the future and procurement of necessary funding that needs both public and stakeholder approval. ■

Julia Adamiak *has been the laboratory supervisor for the City of Waukegan Water Treatment Plant since 2008. Adamiak holds a B.S. degree in biological sciences from the University of Illinois at Chicago.*

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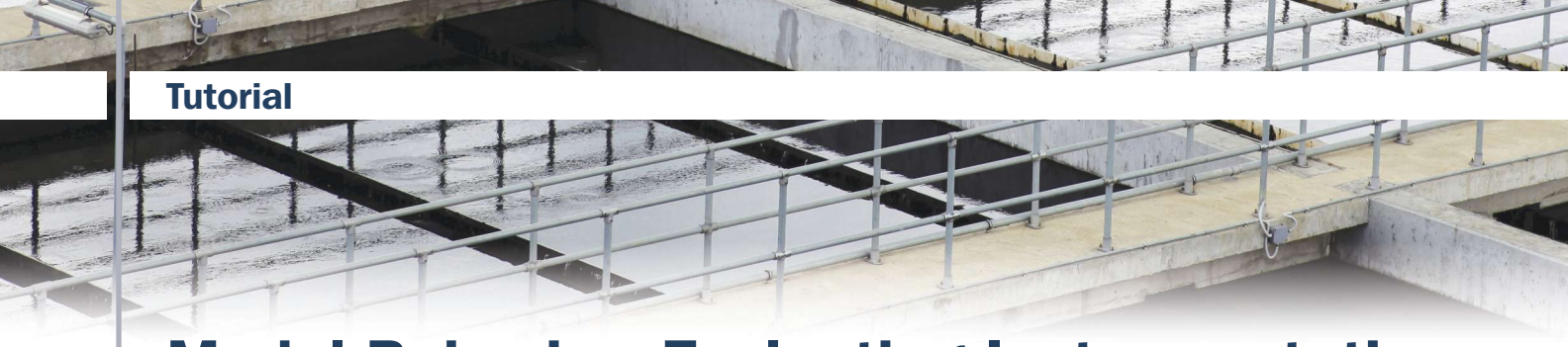


Model Behavior: Evaluating Instrumentation And Control In The Coagulation Process

An electrical engineer does the math on coagulation process control, using computational modeling to determine best practices.

By Selma Parreira Capanema

Developed from a water treatment plant (WTP) in Brazil, a new study aimed to evaluate the use of analytical instrumentation in coagulation process control and to develop models that, once associated with control technique, could be applied to carry out the coagulant dosage automatic control.

Once the more suitable instruments for this WTP's water quality were defined, a database was built. Applying non-parametric methods through cross correlation, it was possible to evaluate the relationship among the process variables and identify the most relevant variables for the development of the models. Once the variables were defined, a variety of models were developed using an artificial neural network (ANN) and a neuro-fuzzy network (NFN) of distinct topology. The goal was to come up with a representative model of the operator's behavior when controlling the coagulant dosage, and a model to predict the settled water turbidity. These models were implemented in a program in C++ language. The program was connected to a SCADA system by applying the plant's automation resources, which are what made it possible to acquire the values of the input variables and to record the output of each model online.

Analytical Instrumentation For Water Features Measurement

The analytical instruments supply data in real time for a great variety of needs in WTPs. Before any modeling technique or process control system could be implemented, we first had to identify the instruments we needed to assess its response, choose the measurement technique best suited to installation conditions, define the needs for processing the output signal, and decide on data validation rules.

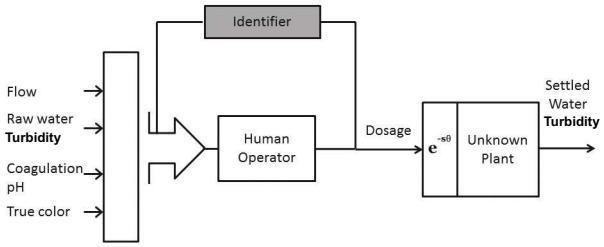
Considering the errors from the measurement system, we determined that using the raw data without any kind of processing could damage the efficiency and the reliability of the model and the control system.

Methodology Used For The Development Of The Work

The development of systems that could identify the operator's behavior and predict the turbidity of the settled water involved creating models from a database collected throughout one year. For the construction of these models we used a technique of parametric modeling based on fuzzy logic and an artificial neural networks approach.

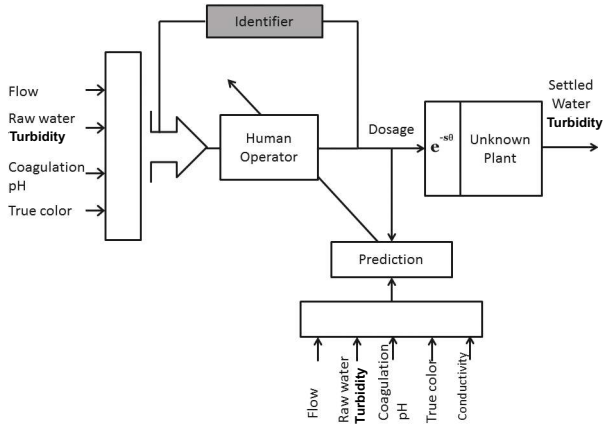
In the WTP studied, the operator performs the analysis of turbidity of the settled water to evaluate the efficiency of dosage adjustment. The operator's behavior while controlling the coagulation system is similar to an open-loop control because the control action is defined only by the input parameters of the system. In this case this behavior could be represented as shown in Figure 1:

Figure 1: Identification of the operator's behavior



In order to close the loop, it is necessary to obtain a prediction of the system output because there is a dead time between the control action and the effective reaction of the system.

Figure 2: Prediction of settled water turbidity



The alternatives for the identification of the systems involved in the coagulation process (coagulant dosage

control based on operator's knowledge and prediction of the settled water turbidity from the entries of the plant) are the construction of linear or nonlinear models.

Adopting a linear modeling technique would demand a multivariable and high complexity model. In addition, the representation of these systems from the impulse response is not possible due to the natural coupling of input variables and also due to the fact that these impulses interfere in the operation of the water treatment station that cannot have its productive process disturbed or interrupted.

Therefore, we opted for an identification approach based on the techniques of artificial intelligence. In this way we create a tool to aid the operator. As the operator changes the dosage, information of the estimated turbidity of settled water is obtained, which will allow the operator to perform interventions in the process in order to improve the quality of the settled water. Once the behavior of the operator controlling the coagulant dosage is identified, it is possible to provide references for dosage adjustment for the different conditions of the process. Such models can also be used in a strategy to perform the automatic control of the coagulant dosage.

Correlation Of Variables For Determining The Parameters

Analyzing the correlations of the variables of the coagulation process, one can identify in an appropriate way which of them may compose the inputs of the neural networks that will identify the operator's behavior and predict the turbidity of the settled water.

We used the MATLAB routine called crosscorr.m to generate graphs of cross-correlation. Using the graphs of cross-correlation, we made an analysis to check whether there is a relationship between the variables, the direct or inverse way that they relate, and the dead time of the process.

Table 1: History of attempts to obtain the model for prediction of the settled water turbidity

IMPLEMENTED MODEL	*STRUCTURE*	*INPUTS*
Preliminary model based on a MLP (multilayer perceptron).	1 ANN with 10 inputs, 15 nodes in the hidden layer.	Turbidity of the raw water, conductivity, flow, pH, dosage, and their respective values 30 min before and the type of coagulant used.
Remodeling of the previous attempt.	1 ANN with 10 inputs, 25 nodes in the hidden layer.	
Set of models with simple selector.	2 ANN with 10 inputs, 25 nodes in the hidden layer using the turbidity of the raw water as parameter of model selection.	
Set of models with selector based on LVQ algorithm.	2 ANN with 5 inputs, 25 nodes in the hidden layer using the LVQ algorithm with the raw water turbidity and the true color as parameters for the model selection.	
Neuro-fuzzy structure with online training.	Yamakawa Network considering 2 membership functions.	Turbidity of the raw water, conductivity, flow, pH, dosage, settled water turbidity, and their respective values 1.5 h before.

Modeling

Prediction Of The Settled Water Turbidity

Several models were developed performing variations in parameters and in the topology of the ANN. See Table 1.

Identification Of The Operator's Behavior

In order to model the system to identify the operator's behavior, when performing the coagulant dosage control activity, we used the same database used for predicting the settled water turbidity and cross-correlation of the graphics obtained.

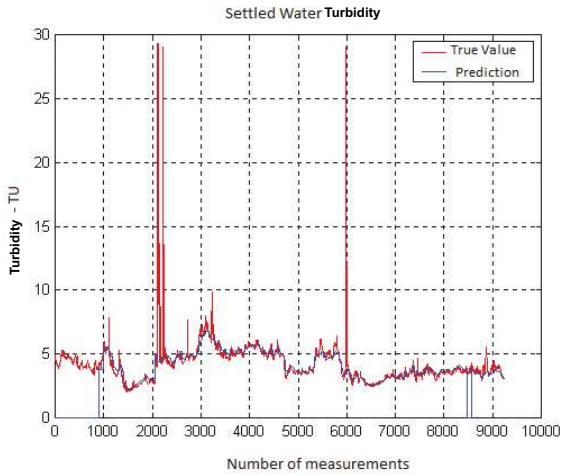
The prediction of the settled water turbidity was not initially inserted as neuro-fuzzy model input because the operator does not currently use this information to control the dosage. The prediction will be inserted as information for the operator to improve the performance of the coagulation process and consequently generate a new database useful in remodeling the identification of the operator's behavior system. The prediction is also a feature of great value when there is a failure in any instrument, working as an estimator of the settled water turbidity.

ANFIS network was used to model the operator's behavior. Gaussian membership functions were used to perform the training. The type of equation used in defuzzification was a linear equation in the parameters ΣPij. Three membership functions were used.

Presentation Of Results

In order to obtain results in the field, automation resources available in the WTP were used. The existing

Figure 3: Settled Water Turbidity



SCADA allows access to the database through programs developed in C++. This SCADA's feature allowed the programs developed for implementing the models to perform the reading and writing in tags configured for the model's input and output variables.

Prediction Of The Settled Water Turbidity

Figure 3 on page 25 shows the signs of turbidity and prediction in different real-time base, i.e., to each measurement the real current turbidity value is shown in the red curve and in accordance to the modeling; the blue curve shows the turbidity for the next 1.5 hours.

Identification Of The Operator's Behavior

The program developed to identify the operator's behavior uses resources already developed for the program in predicting settled water turbidity.

The amendment made was basically in the class that implements the model being tested, in which we used the following matrices obtained from training for the calculation of the output, i.e., the value of dosage:

Matrix P — matrix 3 x (4 +1) that represents the linear models;
Array S — matrix 3 x 4 with the standard deviations for the Gaussian for each entry;
Matrix Xm — matrix 3 x 4 with the average values for the Gaussian for each entry.

This program reads the configuration file of the following data:

- *Tags of input variables* — turbidity, color, flow, pH;
- *Tags of program output* — color and dosage generated by the model;
- *Neuro-fuzzy model* — averages and standard deviations of the membership functions, in addition to the linear models used for defuzzification, expressed by the matrix mentioned above.

When the program is connected to the SCADA, it performs the following functions:

- Reads variables that were collected manually, which are color and type of coagulant;
- Reads and stores the input variables to each second, understanding that before storing the variable it undergoes a process of filtering;
- Computes the dosage based on current parameters and model neuro-fuzzy;
- Writes the dosage calculated and the color in the SCADA;
- Shows onscreen all current process variables and makes a comparison of the program between the dosage of the model and the actual dosage performed by the operator.

The results obtained in the field are presented in Figure 4. The graph shows the daily record history for the dosage values effectively practiced by the operator and those calculated by the model.

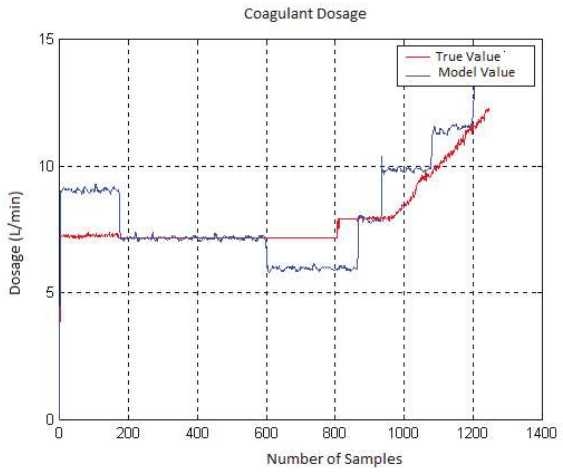
Although we tried to use different topologies of ANN, the results of the field were not satisfactorily observing that variations in input variables had little significant weight in output variable. The model output was primarily influenced by its own delayed output. These facts raise several hypotheses, such as:

- We may not have considered all the variables of entry necessary for the proper representation of the process.
- The operator's action may have been the cause of low correlations obtained, making it difficult to obtain a representative model of the dynamics of the plant, based on the data collected.

For future work we suggest the construction of a new database considering the system in open-loop control and segregating the operator action from the dynamics of the process.

The modeling of the operator's behavior presented results considered satisfactory. This implemented model already has practical application and may be used to replace most of manual interventions. However, because it is a model in open-loop control, it still requires a feedback signal, in this case represented by the prediction of the settled water turbidity. ■

Figure 4: Identification of the operator's behavior



Selma Parreira Capanema *is an electrical engineer who develops studies in the field of computational intelligence with application to real-world problems in water supply systems. She currently works for Copasa, located in Brazil.*

Meeting The Workforce Reliability Challenge

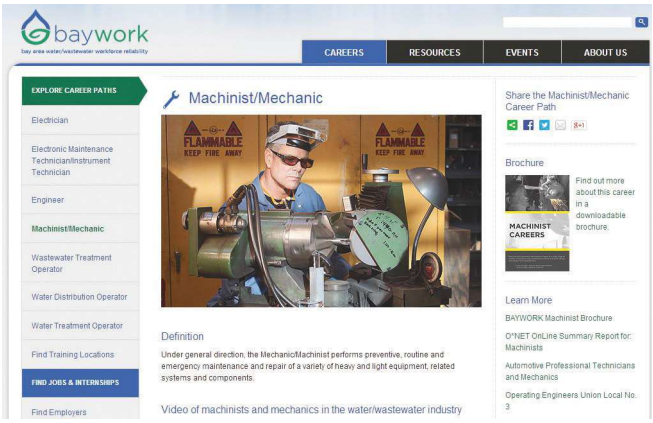
A forward-looking utility responds to workforce retirement with a jobs program worth replicating.

By Cheryl Davis

Within the water and wastewater industry, asset management efforts have focused on infrastructure and equipment, even though experienced managers, engineers, and operators know that reliable operation depends on a different asset — the knowledge of prepared staff. In fact, as the industry turns to increasingly automated processes for the sake of efficiency, the level of expertise required by individual engineers and skilled-trade workers has increased. As Baby Boomers retire, insufficient numbers of qualified candidates are prepared for mission-critical trades and engineering work. Facilities, technology, equipment, and regulations also change without sufficient training for staff, and the operational reliability of water and wastewater utilities is put at risk.

In the San Francisco Bay Area, water and wastewater utilities have recognized that operational reliability depends on workforce reliability. BAYWORK, a consortium of 24 signatories (21 water and wastewater utilities, the Bay Area Community College Consortium, and Cal/Nevada American Water Works Association) works from a road map that includes four strategies:

- Develop qualified candidates for mission-critical jobs (engineers and skilled trades).
- Provide staff with the information they need to do quality work.
- Maximize the cost-effectiveness of investments through collaboration.
- Modify work processes to optimize use of staffing available.



Not just a job listing: The BAYWORK careers section offers brochures, videos, and more.

Although some BAYWORK programs and activities are available only to water and wastewater utilities in the Bay Area, BAYWORK's website at http://baywork.org provides information, products, and services that can be used by any component of the water and wastewater industry in any location. It also serves as a model for other utilities to construct job portals of their own, following the four basic strategies and examples described below.

Develop Qualified Candidates

In the area of candidate development, the careers component of the BAYWORK website provides background information (e.g., required credentials and skills) on mission-critical jobs as well as brochures, posters, and video interviews with engineers and skilled-trades workers. These materials can be used with youth, college students, veterans, and unemployed workers to make them aware of career opportunities available in the water and wastewater field. The jobs and internship posting component of the website can be used by any water or wastewater utility to post job openings; posting is free. BAYWORK has also created a career road map brochure (available from the website) that advises students on the steps they should take during their middle school and high school years to prepare themselves for skilled-trades positions such as electrician, electronic maintenance technician, machinist, water treatment operator, and water distribution operator.

The resources page of the BAYWORK website provides access to how-to guides and information on workshops that relate to candidate development. It contains,

for example, a guide from the City of Waco on how to create a high school water training program. The events section provides PowerPoints and videos from a how-to workshop on successful internships. BAYWORK supports Bay Area vocational training opportunities (e.g., high school and community college programs) and also builds bridges between training institutions and utilities by expanding internship and apprenticeship programs.

Provide Staff With Information

BAYWORK is also addressing the issue of staff preparedness. Historically, the water industry has had the benefit of experienced employees and low staff turnover. The downside of this benefit is that many utilities have become lax in relation to documentation (e.g., standard operating procedures), technical training, staff development, and knowledge management. As Baby Boomers leave and work requirements change, few water industry employers have programs and practices in place to bring new employees up to speed on the facility and utility-specific knowledge needed. Given the spottiness of many utilities' documentation, technical training, and knowledge management programs, even experienced workers may not know everything they need to know to use or maintain new facilities, processes, and equipment.

Interagency staff training lets plant operators see and learn from other facilities.

BAYWORK members are learning how to do better. For example, a 2012 workshop called *Using Technology to Teach* covered interactive e-learning, creation of video standard operating procedures, videoconferencing, and podcasts. The events component of the website includes not only information on all BAYWORK workshops, but also highlights the outstanding programs of star utilities such as Metro Vancouver and Colorado Springs Utilities.

Maximize Investments Through Collaboration

One way BAYWORK implements its commitment to cost-effective investments through collaboration is through resource-sharing in the area of staff training. BAYWORK has sponsored training shared by multiple agencies in multiple locations via videoconferencing, and multi-agency training involving shared use of a single agency's training infrastructure (e.g., structures built to provide training on how to work safely in confined spaces). Additionally, the site includes a bulletin board that allows utilities to post training opportunities that they are willing to share with others.

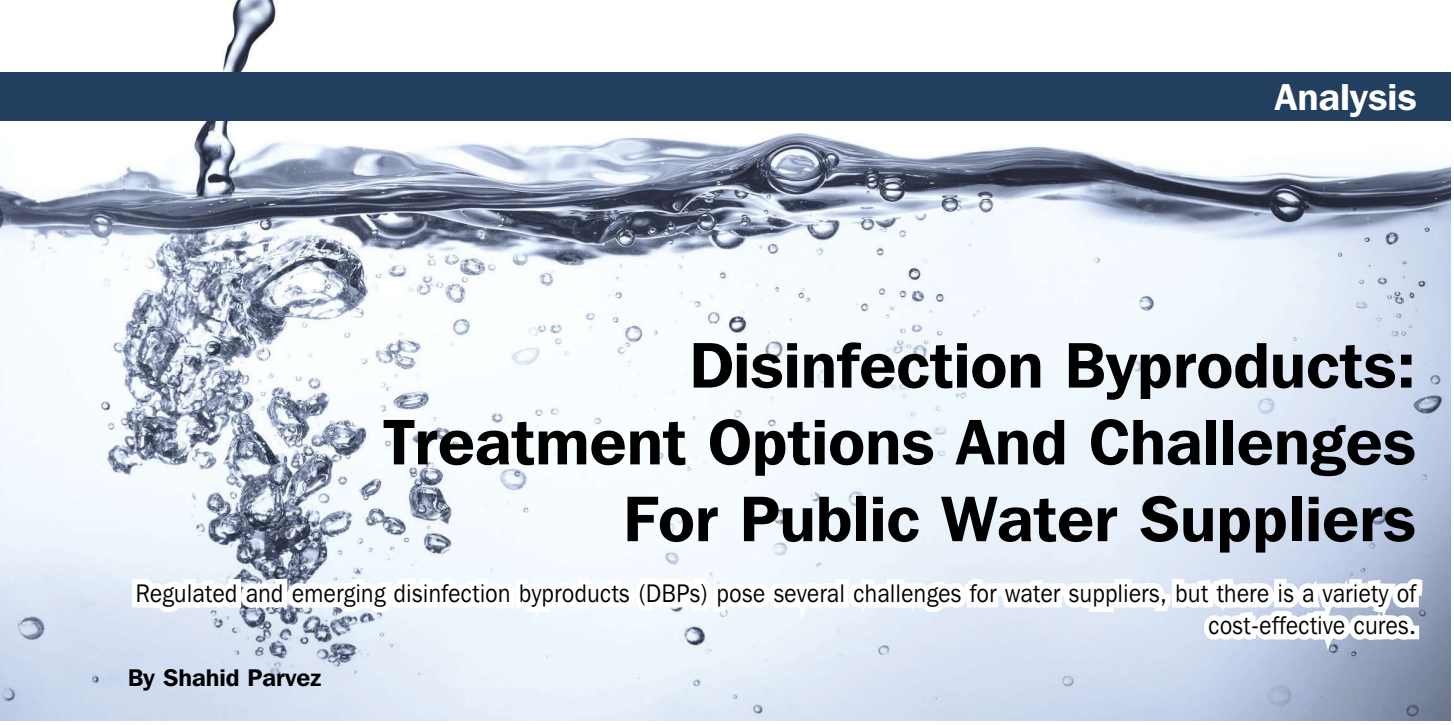
BAYWORK is currently sponsoring a series of *Workshops on Wheels,* a new approach to technical training that involves preworkshop research and allows water and wastewater staff to tour multiple sites to learn about innovations in water and wastewater treatment. For example, the North Bay workshop included site visits to plants that were treating wastewater for innovative nonpotable uses, dechlorinating wastewater effluent using engineered wetland, using new water treatment processes, and converting food waste to energy. The events section provides access to a page on each of these workshops, so that water and wastewater staff from utilities in any part of the country can view PowerPoints, videos, and surveys associated with the tour. How-to guides are another resource available to everyone; several how-to's, for instance, relate to the use of video technology to develop standard operating procedures and staff training materials.

Modify Work Processes

In the wringing of hands about the loss of Baby Boomers, a point sometimes overlooked is that staff turnover provides an opportunity for change. Knowledge and skills are clearly being lost. On the other hand, new workers may be more open to learning to do old jobs in new ways and have a comfort level with use of computers that will help them adopt IT-related solutions. At BAYWORK we support this type of innovation. In 2010 we did research on innovations in the workplace that were helping utilities optimize their use of staffing available. These innovations included combining wastewater and water treatment classifications, use of mobile devices to create work orders on equipment maintenance, and interagency MOUs (memorandums of understanding) relating to facility maintenance. These ideas were presented in a workshop on innovations; the PowerPoints and video associated with this workshop are available in the BAYWORK events section of the resources page. Findings from the research and the workshop were combined into a white paper entitled *Workforce Innovations: Doing More With Less*, posted as a how-to guide.

Programs similar to BAYWORK could be successfully implemented in any region where utilities are willing to organize and collaborate. In the U.S., water and wastewater treatment services are extremely decentralized, with the result that few agencies, if any, have the resources to successfully take on these challenges alone. ■

Cheryl Davis *has been a manager at the San Francisco Public Utilities Commission for more than 25 years. Davis currently serves as the chair of BAYWORK and manager of the Workforce Development Initiative of SFPUC's Water Enterprise.*



Disinfection Byproducts: Treatment Options And Challenges For Public Water Suppliers

Regulated and emerging disinfection byproducts (DBPs) pose several challenges for water suppliers, but there is a variety of cost-effective cures.

By Shahid Parvez

Most public water suppliers are interested in findings ways to comply with existing regulation on disinfection byproducts (DBPs) at minimal treatment cost. The Stage-2 DBP Rule is pushing water suppliers to find alternatives for maintaining the level of trihalomethanes (THMs) and haloacetic acids (HAAs) below regulatory standards. Several water suppliers preferred to switch to chloramine for secondary disinfection. Although chloramine is a less powerful disinfectant than chlorine, it is adequate to inhibit microbial growth in finished drinking water. Water suppliers love the chloramine approach because it helps them keep the level of THMs and HAAs below regulatory limits and creates low temporal-spatial variability in the distribution system (Parvez et al., 2011). This makes more economical sense to water suppliers than treating water with high levels of THMs and HAAs.

However, chloramine is blamed for producing toxic nitrosamines and extracting lead from old distribution pipes. This is particularly true for water systems with higher pH and lower redox potentials. Some of these problems can be controlled by frequent flushing of the system, minimizing the use of free chlorine, and reducing the water retention time, but they cannot be eradicated. Also, chloramine does not prevent DBP formation in the preceding disinfection stage (primary disinfection) where chlorine reacts with organics (natural organic matters) to form high concentrations of THMs and HAAs.

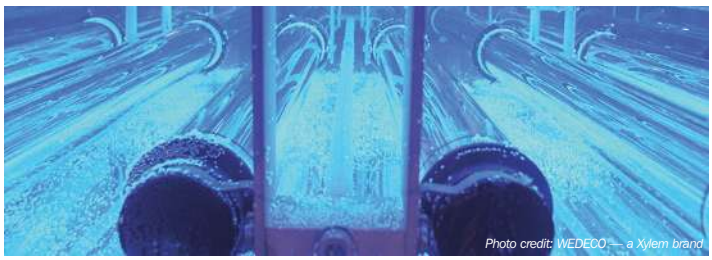
To eliminate or minimize DBP formation, water engineers need to focus on two fundamental things: First, find ways to incorporate technology for the removal of organics; and second, identify a good alternative disinfectant for chlorine. Fortunately, there are technology and alternative disinfectants available to address both issues. However, it is important to note that no single, stand-alone technology or disinfectant can prevent DBP formation. The important key is to use them in the best possible combination to meet the individual water supplier's treatment needs. Let me discuss some of the important treatment options and disinfectants that can be useful to minimize DBP formation.

Options For Organics Removal

The removal of precursor organics before disinfection prevents DBP formation. Enhanced coagulation (EC), powdered activated carbon (PAC), and granulated activated carbon (GAC) are effective for removing organic precursors. EC is quite affordable and commonly used by water suppliers. However, this has low organic removal efficiency (45 to 50 percent) and works best when removing negatively-charged, large-molecular-weight organics. Therefore, most water suppliers prefer PAC to boost removal in wet seasons when high organic load is expected in raw water. PAC in general has better removal efficiency than EC, but it works best for low-molecular-weight and uncharged organics. A combined EC and PAC approach works best for maximizing removal efficiency (75 to 80 percent) for both high- and low-molecular-weight organics (Kristiana et al., 2011).

To achieve superior organic removal efficiency, GAC filters work best and are preferred by water suppliers with high organic load in raw water. Iodine and molasses numbers are typically used to characterize GAC filters. These numbers describe the quantity of small- and large-pore volumes in a sample of GAC. For GAC filters, a minimum iodine number of 500 is recommended by the American Water Works Association (AWWA). The granular volume of the filter allows higher flow rates and provides good molecular adsorption for a range of contaminants. It also improves the taste and odor of drinking water by removing chlorine.

However, high installation, operation, and maintenance costs make GAC unaffordable to many water suppliers. It is also susceptible to biological growth, which helps to degrade organics and other biodegradable compounds, but reduces the performance of the filter. To control biological growth, frequent backwashing (once a week) is required. Disinfection is recommended after GAC adsorption of organics to prevent biological growth in the distribution system. In addition to the technologies discussed above, other treatment technologies include ion exchange and nanofiltration. However, engineers



As the problem of DBPs has risen, so has the popularity of UV.

and researchers need to do further work to make these technologies more efficient and affordable for commercial use.

Alternative Primary Disinfectants

DBP formation is primarily influenced by disinfectant type, dose, reaction time, temperature, and pH. Chlorine is the most commonly used oxidizing agent for primary disinfection. But its use has been criticized because it produces high amounts of THMs and HAAs. For this reason, many suppliers want to switch to alternative means, such as ozone and ultraviolet (UV) disinfection, which are superior choices for primary disinfection and produce little to no THMs and HAAs. Although the raw drinking water quality, the nature of organic precursors, and the amount of bacterial contamination will rule the decision on disinfectant choice, ozone and UV are gaining popularity among water suppliers.

Ozone has been a popular choice for bottled water suppliers, but most water suppliers hesitate to try this technology for a variety of reasons. The technology is widely accepted in the UK and Netherlands, but the U.S. has some catching up to do. Ozone is a powerful disinfectant and produces very low concentrations of DBPs. However, the issue with ozone is that it does not remove organics from water, which triggers DBP formation after secondary disinfection. Also, it is not a good disinfectant to treat water with high pesticide and bromate contents because it oxidizes them into more toxic epoxides and bromates. It also produces unknown byproducts that trigger microbial growth in GAC. It is recommended to use GAC filters before ozone treatment to minimize byproducts formation and subsequent regrowth of microorganisms in finished water. Consequently, ozone-based disinfection requires periodic replacement of GAC filters, thus raising the overall cost of water treatment.

UV is another attractive alternative for primary disinfection because it produces no byproducts. It is more effective than chlorine in killing cryptosporidium and other pathogens. New York City recently opened the world's largest UV drinking water treatment facility. This $1.5 billion facility serves 9 million residents and provides treatment specifically for cryptosporidium and giardia. UV works best when combined with high-grade GAC filters to minimize DBP formation. Although the high cost of UV-bulbs has been a discouraging factor for several water suppliers, low maintenance and operational expenses can lower the overall treatment cost. The business of UV-based treatment technology has tripled in the U.S. in last six years and is rapidly gaining acceptance in the water industry. Also, several countries in Europe, the Middle East, and Asia are offering subsidies to promote UV technology in the water treatment industry.

Paradigm Shift

The DBP paradigm is shifting from the nine regulated THMs and HAAs to emerging DBPs such as nitrosamines, halonitriles, haloamides, halonitromethanes, and iodinated aldehydes. With the growing evidence of nitrosamines' toxicity in humans, they are anticipated to be included in the national drinking water regulations as they are at the state level in California and Massachusetts. Recent studies have found that nitrosamines are more genotoxic, cytotoxic, and carcinogenic than the regulated THMs and HAAs (Richardson et al., 2007). The toxicological review of such studies takes years and will not impact water suppliers in the near future. However, it is possible that some of the emerging DBPs will eventually end up being on the list of regulated DBPs. The treatment difficulties due to the variability in raw water quality, the complex nature of DBPs, and growing health evidence will continue to pose challenges for water suppliers to comply with the regulations. They need to remain in dynamic mode and continue to upgrade their technology to keep up with ever-changing regulations on DBPs in order to protect community health. ■

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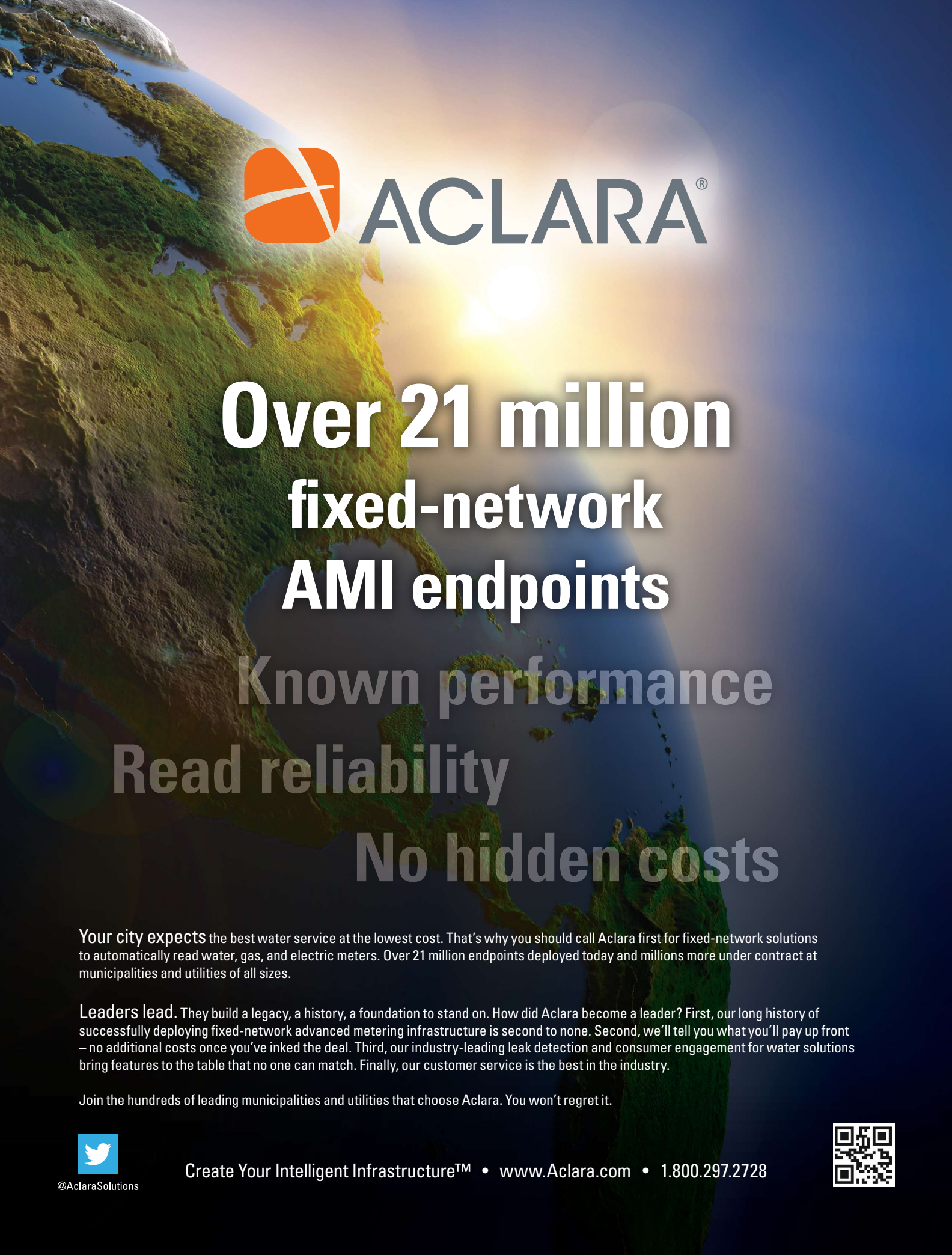
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