FEATURES

8 | Emerging Pathogens of Concern

14 | Communicating About Emerging Contaminants

18 | Hexavalent Chromium Treatment with Strong Base Anion Exchange

22 | Localized Control of Disinfection By-Products by Spray Aeration

DEPARTMENTS

1 | Viewpoint
   The SDWA and the Water Research Foundation

2 | By the Numbers

4 | Q&A
   Q&A with John Huber: Safe Drinking Water Act: Utility Perspective
   Q&A with Peter Grevatt, PhD: Safe Drinking Water Act: Regulatory Perspective

25 | Completed Research of Note

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IN DECEMBER OF 1974, the 93rd United States Congress enacted an amendment to the Public Health Service Act to ensure that water providers continued to deliver safe drinking water to individuals and communities. The amendment, better known as the Safe Drinking Water Act (SDWA), created a national program to identify emerging challenges faced by the water community and to develop best practices to address these issues. By encouraging new treatment techniques for pathogen control, the identification of potential new contaminants, and more emphasis on source water protection, the water community and the U.S. government, together, made monumental advances in the quality of drinking water that have had a significant and lasting positive impact on public health throughout the country.

This issue of Advances in Water Research celebrates both the achievements of the SDWA and addresses some of the impending challenges utilities may face with pathogens and contaminants that aren’t currently covered by the SDWA.

As John Huber, retired President and CEO of the Louisville Water Company, so eloquently explains in a Q&A in this issue, the SDWA changed how the water community operated and inspired a new era of innovation. Water systems expanded their laboratories, focused on source water protection, emphasized interstate river compacts, and became far more proactive on water quality issues. Through implementation of the SDWA, the EPA, state agencies, water systems, and other constituencies all began working together in the regulatory process.

Mr. Huber also describes how the Water Research Foundation’s history is intertwined with that of the SDWA. When the SDWA was enacted in the 1970s, very little time and money had been spent on water research. After the advent of the SDWA, water utilities wanted to ensure that any new regulations were based on sound science. Some of these forward-thinking utilities, including Louisville Water, led an expansion of the Water Research Foundation to include a research subscription program with the mission to “advance the science of water.”

The primary way that the Water Research Foundation continues to support the SDWA and other federal or state regulations is to study potential contaminants in advance of regulation. For example, the Stage 1 Disinfectants and Disinfection Byproducts Rule was announced in December 1998 as part of the first set of rules under the 1996 SDWA Amendments. The Water Research Foundation’s first research project on DBPs (and one of the first research projects under the new subscription program), was completed in 1986. We studied why DBPs occur in water supplies, where they occur, how to detect them, and most importantly, how to cost-effectively remove them. The Water Research Foundation continues to study DBPs as the EPA continues to consider new regulations related to them. It’s one of the Water Research Foundation’s goals, and a goal of the greater water community, to always be ahead of regulation.

The first two feature articles in this issue of Advances in Water Research focus on emerging pathogens, such as mycobacteria and Legionella, and emerging contaminants, such as endocrine disruptors and pharmaceuticals. These pathogens and contaminants are “emerging” because they are currently under investigation by the EPA as part of the SDWA’s Contaminant Candidate List. If the EPA determines that any of these emerging issues are a threat to public health, Water Research Foundation research will help utilities respond appropriately, and will provide our subscribers the research solutions they need to manage them. “Advancing the science of water to improve the quality of life” is our mission, and the EPA, our subscribers, and others throughout the water community contribute to, and benefit from, that commitment.
This installment of “By the numbers” features selected tables and graphs that recognize the 40th anniversary of the Safe Drinking Water Act (SDWA). SDWA was originally passed by Congress in 1974 to protect public health by regulating the nation’s public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells.

### Number of SDWA regulated contaminants

![Graph showing the number of SDWA regulated contaminants from 1976 to 2000.](Image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Regulated Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>22</td>
</tr>
<tr>
<td>1979</td>
<td>23</td>
</tr>
<tr>
<td>1987</td>
<td>31</td>
</tr>
<tr>
<td>1989</td>
<td>35</td>
</tr>
<tr>
<td>1991</td>
<td>62</td>
</tr>
<tr>
<td>1992</td>
<td>84</td>
</tr>
<tr>
<td>1995</td>
<td>81</td>
</tr>
<tr>
<td>1996</td>
<td>90</td>
</tr>
<tr>
<td>2000</td>
<td>91</td>
</tr>
</tbody>
</table>

### Review and update on the Contaminant Candidate List

The Safe Drinking Water Act includes a process to identify and list unregulated contaminants that may require a national drinking water regulation in the future. EPA must periodically publish this list of contaminants (called the Contaminant Candidate List or CCL) and decide whether to regulate at least five or more contaminants on the list (called Regulatory Determinations).

<table>
<thead>
<tr>
<th>CCL</th>
<th>Year</th>
<th>Number of Regulated Contaminants</th>
<th>Microbial Contaminants</th>
<th>EPA decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1998</td>
<td>50</td>
<td>10</td>
<td>2003 Regulation deemed unnecessary for 9 of the contaminants</td>
</tr>
<tr>
<td>2</td>
<td>2005</td>
<td>42</td>
<td>9</td>
<td>2008 Regulation deemed unnecessary for 11 of the contaminants Regulation for one contaminant (perchlorate)</td>
</tr>
<tr>
<td>3</td>
<td>2009</td>
<td>104</td>
<td>12</td>
<td>2014 regulation deemed unnecessary for 4 contaminants Regulation for one contaminant (strontium)</td>
</tr>
</tbody>
</table>

Number of waterborne disease outbreaks associated with drinking water (n = 818),* by year and etiology—Waterborne Disease and Outbreak Surveillance System, United States, 1971–2008, data from CDC

The following graph shows how waterborne disease outbreaks in the United States have declined since the late 1970s and early 1980s. However, it also shows the increased threat of *Legionella* spp. in water, which is addressed in the feature article, Emerging Pathogens of Concern, in this issue of *Advances in Water Research*.

*Some outbreaks from prior reporting periods were added, reclassified, or excluded during an extensive review (Craun GF, Brunkard JM, Yoder JS, et al. Causes of outbreaks associated with drinking water in the United States from 1971 to 2006. *Clin Microbiol Rev* 2010;23:507–28); therefore, data are not comparable to figures in previous reports.

† Legionnaires’ disease (LD) was reported to the Waterborne Disease and Outbreak Surveillance System (WBDOSS) beginning in 2001. A review of publications and CDC-led investigations during 1971–2000 resulted in the addition of 17 historic LD drinking water outbreaks to WBDOSS.

§ Includes all bacteria except *Legionella*.
Q&A

Q&A with John Huber
President and CEO of the Louisville Water Company, retired

Safe Drinking Water Act: Utility Perspective

To mark the 40th anniversary of the Safe Drinking Water Act’s introduction, the Water Research Foundation sat down with John Huber, the now retired President and CEO of the Louisville Water Company, and Peter Grevatt, PhD, Director, EPA Office of Ground Water and Drinking Water (page 6), to provide historical perspective as well as present day context, opportunities, and challenges around the Safe Drinking Water Act.

Mr. Huber spent his entire working career in the water supply industry. He began his career in the Drinking Water Program at the Kentucky Department of Health in 1968. At the Louisville Water Company, Mr. Huber worked in various engineering, administrative, and leadership positions. He served as President and CEO of the Company from April 1991 to August 2007.

Water Research Foundation: How would you describe the drinking water regulatory landscape before the SDWA?

John Huber: Utilities and other groups involved in water safety were doing everything in their power to address water safety, but there were very few drinking water regulations and federal rule was very limited. The federal regulations were set by the U.S. Public Health Service, and they applied only at the point of delivery for interstate water carriers (such as airports, train stations, and bus stations). The states largely administered the public health service standards, but each state also had its own standards for water systems. Many of the states based their requirements on U.S. Public Health Service regulations, but this was not required.

What was the water community’s reaction to the initiation of SDWA?

When the SDWA first became law, the reaction was one of great concern and skepticism. It was the beginning of a new era and the EPA was a relatively new agency. The water community wanted to make sure regulations were set appropriately and based on sound science. We were also concerned about how the EPA would work with the water community and what type of role various advocacy groups could potentially play in the regulatory process.

Early on, these concerns led the water community to advocate that any new regulation be based on sound science. Compared to where we are today, the research effort back then was pretty small. It was probably less than $100,000 a year at the time, so we had to make sure more attention was paid to research. Additionally, there were no groups in the industry to advocate on behalf of the water community itself on the legislative and regulatory proposals. So, we had to create the business infrastructure to deal with this. We expanded the Water Research Foundation (formerly AWWA Research Foundation) to address the new research needs, and groups like the AWWA Water Utility Council and the Association of Metropolitan Water Agencies were founded to address regulatory and legislative issues.

What are the biggest changes in the way utilities operate pre-SDWA and post-SDWA?

I would say that the changes are significant. Pre-SDWA, most water systems effort was involved in creating the resources and infrastructure to support growth and to renew and replace treatment and pumping facilities. In many respects, water utilities were engineering companies that sold water. The SDWA triggered an influx of scientists and engineers with knowledge and capabilities that we simply didn’t have before. Really, it introduced a new era. Water systems expanded their laboratories and acquired what was then sophisticated laboratory equipment. They became more involved in water resource monitoring and pollution prevention, even advocating for limits on industrial waste streams. Source protection and pollution prevention became more important. Spill monitoring was intensified. Interstate river compacts became more focused and more active. Utilities became far more proactive on water quality issues. The EPA, state agencies, water systems, and other constituencies began working together in the
regulatory process. Water systems began paying more attention to customer satisfaction and expanded their customer information programs. All in all, the SDWA inspired the innovation and sparked the creativity that is so common today.

**How would you say the SDWA impacted public health?**

SDWA gave us a new perspective on health risk, risk management, and risk reduction. Before the SDWA, the focus was primarily on acute health risks. The SDWA opened the window to what the effect of lifetime exposure to low concentrations of substances in water might be. One of the things we really began to manage better was the lifetime risk and how we might better protect against chronic disease. It also allowed for better surveillance and better control in water systems. If there is a problem today, we’re going to know it much sooner and be able to react much quicker. We’re able to make sure the public is appropriately informed and knows what actions to take.

**In this issue of Advances in Water Research, we discuss unregulated pathogens and chemical contaminants. What contaminants or pathogens do you think may need to be addressed with future regulations?**

Well, I think one thing that has the public’s attention is the presence of pharmaceuticals and endocrine disruptors in the water column. We need to continue to increase our knowledge base in that arena and determine what risks, if any, exist. If such risks do exist, how do we better manage them? The other area we need to pay more attention to is water quality in the distribution system and on the customer’s premises. We can produce the greatest water in the world at the water treatment plants, but it’s what is delivered to the customer that really counts.

**What do you think the SDWA has done in terms of elevating the position and the importance of the water community?**

I believe it has raised the visibility and value of this industry to a national level. Utilities realized how important it was to have good information programs for customers. It was important that customers know what the issues are and how they were being addressed. It’s very hard to get the attention of customers. There’s a barrage of information coming from all over. But we have stepped up our capability for doing that, and the way we deliver information has improved.

**Where do you see the SDWA moving forward?**

The SDWA really started a new era in the drinking water community in particular. I would term it revolutionary. The revolution did not happen instantaneously, but it started a movement. That movement is what the SDWA will hopefully continue to encourage. We need to continue to track the trends in the environments we operate in, not only the physical environment, but also the business environment. What is happening in industry? What products and waste streams is industry creating? What are customer attitudes and perceptions, and how are they changing? In the end, regulation must first be built on sound science. Then, we can focus on how regulations can be developed to effectively respond to that sound science, so we truly advance the interests of consumers.
Q&A with Peter Grevatt, PhD
Director, EPA Office of Ground Water and Drinking Water

Safe Drinking Water Act: Regulatory Perspective

Dr. Grevatt is the Director of the U.S. EPA Office of Ground Water and Drinking Water (OGWDW). He is responsible for the development and implementation of national drinking water standards, oversight and funding of state drinking water programs, and the implementation of source water protection and underground injection control programs to protect public health nationwide. Prior to joining the OGWDW in October of 2012, Dr. Grevatt served as the Director of the Office of Children's Health Protection and as the Senior Advisor to EPA's Administrator for Children's Environmental Health.

Water Research Foundation: What were some of the concerns with the water supply before the Safe Drinking Water Act?

Peter Grevatt: President Ford signed the Safe Drinking Water Act on December 16, 1974, in the wake of newspaper headlines, television documentaries, and magazine features warning that our old assumptions about the quality of our drinking water may no longer be valid. Potential cancer-causing chemicals had been found in trace quantities in New Orleans’ and Pittsburgh's drinking water. In Boston, lead from water supply pipes had been found in water drawn from the tap. Viral or bacteriological contamination of drinking water resulted in communicable diseases, often in smaller communities where treatment works were outdated or the community could not afford to install. In other cities and towns, foul odors and tastes made the water unpalatable. Today, the EPA works closely with state co-regulators, water sector professionals, and academia to identify emerging challenges and develop practices to address these issues.

What are the biggest changes in the way the EPA helps to protect the water supply pre-SDWA and post-SDWA?

Before SDWA, the Agency lacked the authority, science, and funding to safely and effectively protect our nation’s drinking water. In 1962, there were approximately 28 regulated contaminants and approximately 40% of the water treatment plants in operation at the time delivered water that did not meet these standards. In addition, over 50% of the water treatment plants had major deficiencies, including disinfection, clarification, or maintaining adequate pressure in the distribution system.

Today, EPA regulates more than 90 contaminants. Every day, approximately 290M people depend on the water that is provided by 50,000 community water systems. SDWA improved public health protection from bacteria, arsenic, lead, disinfectants, and disinfection by-products. Since 1997, the Drinking Water State Revolving Fund has invested $25.8B in our nation’s drinking water infrastructure. These infrastructure projects ranged from planning, design, and construction of water treatment plants and storage facilities to laying pipes for transmission and distribution of water.

How would you sum up the effect of the SDWA on public health?

The Safe Drinking Water Act put into motion a new national program to reclaim and ensure the purity of the water we consume. Under the Act, each level of government, every public water system, and the individual consumer have well-defined roles and responsibilities. Drinking water that meets EPA’s health-based standards is generally considered safe to drink. The United States is among the relatively few countries in the world where tourists are not afraid to drink the water.

How would you sum up the effect of the SDWA on the water utility sector?

When Congress wrote SDWA in 1974, the law focused primarily on treatment systems as the key to protecting public health. The school of thought was—if we control certain contaminants at the treatment plant and coliforms in the distribution system, then the water will be safe at the tap. Over time, it was recognized that this approach was insufficient to deliver the results the American consumer expected.
The 1986 and 1996 SDWA Amendments enabled the SDWA to address the importance of treatment technique requirements for enhanced pathogen control, newly emerging contaminants, source water protection, certified operators, adequate training, funding for capital water system improvements (including the distribution system), and the importance of public knowledge regarding water quality. The water sector as a whole came to understand that quality drinking water requires protection from the source to the tap.

**What pathogens and/or contaminants do you see posing the biggest challenges to water utilities?**

Improvements in science and technology are revealing previously unknown contaminants in our water. Source water is often threatened by pollution or development. For example, two major drinking water systems have been shut down this year alone due to source water pollution emergencies. In addition, climate change is bringing warmer temperatures, rising sea levels, stronger storms, more droughts, and changes to water chemistry.

Given the progress we have made with controlling fecal pathogens originating from source water contamination, one of the next major challenges is enhancing control of pathogens associated with distribution system vulnerabilities. One major concern are the respiratory disease-causing pathogens, *Legionella* and Non-Tuberculosis Mycobacterium, which tend to manifest most significantly in building drinking water systems. While these organisms often manifest most significantly outside a drinking water utility’s immediate jurisdiction, the qualities of the delivered water may be important factors in influencing subsequent pathogen propagation in the building system environment. More research into this relationship will inform strategies to control such pathogens.

Given that all drinking water treatment plants that use chemical disinfectants are chemical reactors, the changing nature of source water conditions will influence the mixtures of disinfection by-products. Developing a better understanding of how these mixtures may be changing in chemical composition, their relative associated risks, and how to optimize prevention and/or remediation in the face of uncertainty will continue to pose challenges.

**Is there anything else you would like to add about the significance of the SDWA?**

Water sector professionals have made incredible progress in improving the safety of drinking water during the past 40 years. Safe and reliable drinking water is central to our lives. It is extremely important to recognize the essential work that water sector professionals perform every day to protect the health of the American people and the vitality of our local economies.
In the 1980s, water utilities were focused on water quality issues regarding coliform bacteria and the potential presence of *Giardia* cysts. In the 1990s, the list of waterborne pathogens grew exponentially, and the discovery of previously unknown microorganisms, which were responsible for waterborne outbreaks, raised concerns.

In 1996, the U.S. Environmental Protection Agency (EPA) amended the Safe Drinking Water Act (SDWA) to consider emerging waterborne contaminants for potential regulation in drinking water. The SDWA has included *Mycobacterium avium* in the Third Contaminant Candidate List (CCL3) for regulatory consideration. *Legionella pneumophila* and *Naegleria fowleri* were also included on the CCL3 in 2009. While these organisms have not resulted in SDWA regulations, drinking water utilities continue to be challenged by their presence.

In contrast to traditionally regulated pathogens in the SDWA, these emerging pathogens can be found in a wide range of natural and artificial environments (e.g., water, soil, building/home water systems). Also, the primary modes of exposure (e.g., inhalation, aspiration) for these pathogens differ from other drinking...
EMERGING PATHOGENS

EMERGING PATHOGENS

Table 1. Emerging Pathogens of Concern

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Disease(s)</th>
<th>Mode of Exposure</th>
<th>Reportable</th>
<th>Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Legionella pneumophila</em></td>
<td>Legionnaires’ disease or Pontiac fever</td>
<td>Inhalation or aspiration</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Mycobacterium avium</em></td>
<td>Pulmonary disease, cervical lymphadenitis (children)</td>
<td>Inhalation or aspiration</td>
<td>No</td>
<td>No, but listed on CCL3</td>
</tr>
<tr>
<td><em>Naegleria fowleri</em></td>
<td>Primary amoebic meningoencephalitis</td>
<td>Nasal aspiration</td>
<td>No</td>
<td>No, but listed on CCL3</td>
</tr>
</tbody>
</table>

Source: OSHA n.d.

Figure 1. *Legionella* Growth Temperature

In the distribution system, chemical disinfectants can be effective for controlling *Legionella*. In particular, chloramine appears to be more effective than chlorine (Moore et al. 2006). However, the mechanisms of chloramine and chlorine impacts on opportunistic pathogens are still not well understood (Health Canada 2013).

Water Research Foundation (WRF) project #4379, *State of the Science and Research Needs for Opportunistic Pathogens in Premise Plumbing*, states that *Legionella* is a normal part of the ecology of water distribution systems and is frequently present in high quality, regulatory-compliant drinking water distributed to customers. Also, it states that *Legionella* colonization of premise plumbing is not necessarily an indication of poor operating or maintenance practices by a community water system. Rather, it is a function of the conditions characteristic of premise plumbing that support proliferation. The CDC Morbidity and Mortality Weekly Report (2013) indicated that approximately 58% of *Legionella* outbreaks were identified in premise plumbing systems.

United Kingdom Water Industry Research (UKWIR) developed the “Database on Waterborne Microorganisms and Emerging Pathogens,” which includes information sheets on *Legionella* and other microorganisms that may be of concern to drinking water utilities. The database states that *Legionella* has been detected in both surface and ground water supplies by molecular methods but viable organisms are rarely recovered. Therefore, the risk of acquiring infection through a public drinking water supply is extremely low. The database can be accessed via the WRF website by searching for “Microbial Database.” www.waterrf.org/resources/Pages/MicrobialPass.aspx (subscriber login required).

Although several methodologies for detecting *Legionella* are available (e.g., culture, qPCR), the EPA and CDC have not recommended any routine surveillance testing for *Legionella* in building water systems other than hospitals and healthcare facilities. The reasons are: (1) *Legionella* are widely distributed in the environment; (2) there are no standardized sampling and monitoring protocols; and (3) it is difficult to establish meaningful quantitative data. For investigations of legionellosis outbreaks, the CDC provides...
Mycobacterial disease can be influenced by more factors than legionellosis. Swimming pools, spas, and hot tubs are frequently cited as sources of mycobacteria. Poor hygiene measures in the personal services industry (e.g., tattoos and piercings) have led to a number of mycobacteria infections. Whereas *Legionella* infections are almost exclusively pulmonary, NTM infections can occur anywhere. Skin and soft tissue can be a site of infection from wounds or surgery (Wentworth et al. 2013). Hospital acquired infection (HAI) can also be related to catheterization, dialysis, or surgery.

In general, NTM are highly resistant to disinfectants. Compared to *E. coli*, NTM are at least a hundredfold more resistant to disinfectants used in water treatment. NTM, however, include various species, with a range of susceptibility to disinfectants. The “Database on Waterborne Microorganisms and Emerging Pathogens” notes that UV is effective against MAC at doses used for inactivation of *Cryptosporidium*.

NTM are not uniformly present in distribution and household plumbing systems. Therefore, collecting several samples (at least ten) is recommended to ensure isolation or detection of NTM. Also, biofilm samples, instead of bulk water samples, should be collected to yield a higher frequency of NTM (Pruden et al. 2013, Falkinham 2011).

The most common detection methods are culture-based techniques. Recovery of NTM can be improved by the addition of chemicals and antibiotics to inhibit the growth of nontrade organisms. Because the majority of NTM are slow-growing bacteria, other microorganisms will overgrow the culture medium. There are also several other methods for detection of NTM, such as qPCR, acid-fast stain, and light microscopy. Although these methods are available, they lack the ability to discriminate between related species and provide only qualitative information. Again, there is no consensus on the best approach for detection methods.
PAM after playing all day on a slip-n-slide, and *N. fowleri* were detected in the residential plumbing system, hot water heater, and hoses supplying the slip-n-slide. At this time, the presence of *N. fowleri* was also confirmed in the public drinking water system.

During the 1970s and 1980s, a number of cases of PAM were reported in Australia and *N. fowleri* was detected in public water supplies (Dorsch et al. 1983). Since that time, several water systems in the states of Western Australia and South Australia continue to monitor regularly for *N. fowleri* colonization in drinking water distribution systems. Australian Drinking Water Guidelines indicate that adequate residual levels of chlorine and monochloramine concentrations (0.5 mg/L or higher) throughout the water supply system at all times can control *N. fowleri* (Australian Drinking Water Guidelines, 2011). Maintenance of cooler temperatures in the distribution system can also be one of several effective management strategies for *N. fowleri*. According to the "Amoeba Response Protocol" in Western Australia, the water should be monitored for amoebae if the water temperature within the distribution system exceeds 20°C (68°F).

In November 2013, the Louisiana Department of Health and Hospitals (LDHH) put in place an Emergency Rule addressing *N. fowleri*. This rule requires all water systems in Louisiana to increase monitoring of distribution systems by 25% of what is required by the Total Coliform Rule, the Surface Water Treatment Rule, and the Disinfectants/Disinfection By-Product Rule, and to increase disinfectant levels to 0.5 mg/l free or total chlorine. The requirements of this rule became effective on February 1, 2014 (Louisiana 2013b).

A monitoring program of Louisiana public water supplies that began in August 2014 has found *N. fowleri* in the distribution systems of two water supplies where disinfectant residuals were very low (Louisiana Center for Environmental Health n.d.).

There are several sampling methods. Simple grab sampling (~1 L) or large volume sampling methods (where hundreds of liters of sample are concentrated using ultrafiltration) have been used to detect *N. fowleri*. Swab sampling has also been used to detect amoebae in premise plumbing systems. Appropriate handling
of samples (e.g., not chilled, testing within 24–36 hours, headspace, not drying in air) is important to obtain accurate results. Detection methods for *N. fowleri* include: (1) culture-based methods, (2) molecular methods, (3) microscopy methods, (4) immunological assays, and (5) genotyping methods. Despite all these methods, sampling and monitoring of *N. fowleri* is still one of the research gaps identified in project #4379, *State of the Science and Research Needs for Opportunistic Pathogens in Premise Plumbing.*

**Summary**

LEGIONELLA, *N. FOWLERI*, and NTM are ubiquitous in our environment and premise plumbing systems can be a habitat for them. Although premise plumbing is not normally utilities’ responsibility, utilities should educate their customers on the potential risks of these pathogens and suggest methods to reduce the risk of pathogen buildup in premise plumbing. WRF continues to monitor and develop research for these contaminants along with other challenges facing utilities as they strive to produce safe water for their customers.

**References**


LOUISIANA CENTER FOR Environmental Health, Department of Health and Hospitals. N.d. State of Louisiana’s Response to Confirmation of Rare Ameba in St. Bernard and DeSoto

**ADDITIONAL RESOURCES**

**Legionella**


- Occupational Safety & Health Administration (OSHA). Legionnaires’ Disease: https://www.osha.gov/dts/osta/otm/legionnaires/


- CDC. Legionella (Legionnaires’ Disease and Pontiac Fever): http://www.cdc.gov/Legionella/index.html

**N. fowleri**


- CDC. Naegleria fowleri - Primary Amebic Meningoencephalitis (PAM): http://www.cdc.gov/parasites/naegleria/
EMERGING PATHOGENS

Communicating About Emerging Contaminants

Alice Fulmer, Water Research Foundation

This year marks the 40th anniversary of the Safe Drinking Water Act (SDWA), passed by Congress in 1974 to protect public health by regulating the nation’s public drinking water supply.

The law was amended in 1986 and again in 1996. The SDWA Amendments of 1996 sought to “provide greater protection and information to those served by public water systems” (EPA 2014). As described on the U.S. Environmental Protection Agency’s (EPA) website, the amendment’s changes fell into four themes:

1. New and stronger approaches to prevent contamination of drinking water
2. Better information for consumers, (including “right to know”)
3. Regulatory improvements, (including better science, prioritization of effort, and risk assessment)

The regulatory improvements included risk-based prioritization of contaminants for regulatory action, based on human health effects, occurrence in public water systems, and meaningful opportunity for health risk reduction. To support this regulatory framework, the 1996 amendments redesigned the Unregulated Contaminant Monitoring program to incorporate a tiered monitoring approach, which progressively became the Unregulated Contaminants Monitoring Rule (UCMR). The amendments also
gave consumers the “right to know” information about their water, including access to data collected, analyses done, and implementation strategies developed under new SDWA programs. As such, the amendments required water systems to prepare Consumer Confidence Reports (CCRs) and established the National Contaminant Occurrence Database (NCOD) for regulated and unregulated contaminants, the latter intended to both make data “available to the public in readily accessible form” and support EPA’s regulatory determination process (EPA 2004).

These improvements, while beneficial overall, have created communication challenges for water utilities, who need to communicate about the presence of unregulated substances in water for which human health effects may not be known. In recent years, public concern about the presence of these substances in drinking water, sometimes referred to as Contaminants of Emerging Concern (CECs), has increased. This concern has likely been influenced by the way contaminants are portrayed by the news media, and inconsistent messaging by public health groups, agencies, non-governmental organizations (NGOs), and water utilities.

To help utilities address this challenge, the Water Research Foundation (WRF) has funded many projects on CECs and communication, and currently has a Focus Area dedicated specifically to risk communication for CECs. One of the first projects funded by this Focus Area is project #4457, originally titled, “Core Messages for Priority Contaminants of Emerging Concern.” Conducted by Linda MacPherson of CH2M Hill, Shane Snyder from the University of Arizona, and a team of social scientists, this project builds on past research regarding consumer perceptions and attitudes, communication approaches, and the general challenges of risk communication.

A lesson learned from this research is that the term “contaminants of emerging concern” creates fear in consumers and thus should be avoided. The same holds true for the term “unregulated.” While further research is needed on terminology, the social scientists in this project recommend the use of the term “substances” instead of “contaminants of emerging concern.” This and other recommendations and insights were used to produce a narrated animated film and develop core messages on four priority substances: hexavalent chromium (Cr[VII]), NDMA, medicines and personal care products, and volatile organic compounds (VOCs). The team’s social scientists also recommended naming the four priority substances in the title for the sake of transparency, resulting in the new project title, “Context and Core Messages for Chromium, Medicines and Personal Care Products, NDMA, and VOCs.”

The animated film, Protecting Our Drinking Water (for which a final version is expected in early 2015), was designed to provide context about drinking water in general, the regulatory process, and substances in water. Animations are short and engaging, tell a story without complex terminology, and deliver messages in a simple way while still ensuring technical accuracy. They have proved very successful for science programming and social media. The visuals provided are important, because feelings are stimulated by images, and perceived risk (such as that for substances in water) is often informed by people’s feelings, as opposed to evidence or reasons.

Protecting Our Drinking Water was produced to build trust, which is critical. The animation emphasizes the sophisticated monitoring and control system that is highly protective of public health, as shown by the dramatic decline in waterborne disease over the past century. It
Emerging Contaminants also puts a new twist on the detection of substances in water. Instead of viewing detection in an alarming way, the animation presents detection as the first step in protection. Improvements in analytical detection capabilities have allowed us to see ever smaller concentrations of substances, and water professionals know that detection of a compound does not equal risk (it’s the dose that makes the poison), but this can be difficult to communicate. As shown in the animation, detection begets research, which can further protect public health.

In addition to the animation, the research team also developed Core Message Sheets (following best practices for risk communication), and Technical Information Sheets for each of the four substances. The Technical Information Sheets provide detailed information related to occurrence, toxicity, and treatment efficacy. The animation and Core Message Sheets were produced for direct distribution to and viewing by the general public, while the Technical Information Sheets were developed as a resource for water utilities to have more detailed information available, should a question or concern arise.

Focus groups were held to evaluate the effects of the animation and Core Message Sheets in Aurora, Colorado; Hillsboro, Oregon; Las Vegas, Nevada; and Louisville, Kentucky. At each location, a control group was shown newspaper articles about detection of substances in water before being asked a series of questions, and an experimental group was shown the animation and Core Message Sheets before the news articles. There were approximately 50 participants, with equal numbers of men and women, an average age of 49, and varying educational levels. Over 40% regularly drank tap water (unfiltered), 20% drank filtered tap water, 20% drank bottled water, and the remaining drank various combinations of these options. This relatively small sample size did not allow for statistical analysis of the results, but several conclusions were drawn based on the focus group discussions, as follows.

After viewing context animation and reading core message sheets, how well do you understand why and how substances are found in water, and what water utilities and governments do to protect public health?

First, local water organizations are often perceived as having primary responsibility for maintaining safe drinking water. The safety of the water depends on the level of resources and enforcement policies, mainly at the local level. The EPA is generally perceived as credible, but at the same time weak as a regulatory agency. Trust in the media appears to be low.

Second, information must be credible. People want to know the source of the information so they can evaluate any potential biases. Additionally, the information should be as complete as possible. Simple conclusions are not very helpful; context and explanation are needed. The data suggest that presenting levels of exposure and consequences of exposure would be an appropriate communication strategy. The information should be easy to understand, but not “dumbed down.”

The focus group questionnaires were analyzed to identify difference in responses based on the respondents’ sex, race, ethnicity, and presence of children in the household. Interestingly, no significant differences existed on any item based on these factors. These findings suggest that, in this context, modifying messages based on demographic differences may not be necessary. Though the focus group size was not large enough to be indicative of all possible audiences, the messages were constructed in a manner that worked well for the variety of people that participated in the focus groups.

In general, both the animation and Core Message Sheets were perceived as being informative, educational, well-constructed, and useful (Figure 2). Participants thought both would be effective in calming public reactions to contamination reports. The generally positive response suggests that the messages were designed effectively. While no message will be universally accepted, the messages produced should appeal to a broad range of audiences.

Additionally, the focus group responses indicate that trust is best maintained through open and honest communication. Lack of communication creates mistrust.
Messages that seem veiled or incomplete undermine trust. Utilities should avoid presenting overarching conclusions, but rather should provide data and context. Further, communications should explain what contaminant has been identified, what the level of the exposure is, and the potential consequences of exposure.

In addition to the above conclusions, the project produced the following recommendations:

- One of the most important issues that needs to be addressed is terminology. The water community needs to agree upon terms that clearly explain water issues in a manner that avoids confusion. Using terms such as contaminants, toxins, pollutants, and carcinogens without information on dose and concentration alarms the public. Easily understood words that simply and clearly explain water and wastewater quality and treatment should be used for lay audiences. Moreover, such terminology should be used consistently among the various forms of communication used by a utility or agency including websites, social media outlets like Facebook or Twitter, written communications, and spoken communications with citizens and elected officials. WRF’s new project #4551, “Terminology for Improved Communication Regarding CECs,” is addressing this need.

- It is important to better explain the pace of regulatory decision-making, including discussion of studies that have been undertaken, and when results will be presented. Explaining the safety factors used in regulatory decision-making is also important.

- It is clear that a better understanding of risk is needed. The public tends to think in terms of “safe” or “unsafe,” while scientists and engineers think in terms of relative risk. Providing information on potential health effects and exposure appears to be helpful in putting risk into perspective, but is rarely undertaken in media reports.

- Detection is the first step in protection. Suggesting or implying that detection of very small concentrations of substances in water necessitates a change in treatment approaches, however, is not necessarily reasonable.

- Trust is the critical determinant in risk communication. It is important for water professionals to address issues that are eroding public confidence and trust. This may mean providing more transparent information about why substances are present in water sources and how they are removed. News of mistakes tends to spread quickly and broadly, while successes receive little or no attention. Robust information provided in advance of these stories tends to put the risk into perspective. This research revealed just how important contextual understanding is to enable the public to develop balanced perspectives.

The findings of WRF project #4457 will be published in early 2015, at which time the animation, Technical Information Sheets, and Core Message Sheets will also be available.

This project was presented at a workshop sponsored by WRF and Toronto Water, entitled “Emerging Chemical Contaminants: Detection, Treatment & Public Communication,” in Mississauga, Canada, on October 7, 2014. At this workshop, local regulators and researchers, WRF staff, and Principal Investigators of relevant WRF projects made presentations related to monitoring, occurrence, treatment, and communication for emerging chemical contaminants. The workshop was educational and served as a forum for exchanging information and networking with peers. It was very well received and included over 100 representatives of water utilities, mostly from Canada, but also some from the United States. Workshops such as these are an important step in improving understanding and communication among utilities and water professionals with respect to this important topic.

References


On July 1, 2014, many California utilities faced a new reality as the Department of Drinking Water (DDW) of the California State Water Resources Control Board adopted the nation’s first hexavalent chromium (Cr[VI]) maximum contaminant level (MCL) for drinking water. California’s existing 50 µg/L total chromium MCL is to remain in effect unchanged.

With five critical groundwater sources having Cr(VI) concentrations between 7 and 40 µg/L that would potentially be impacted by the new MCL, the Soquel Creek Water District (District) proactively conducted a 2011 paper-based study considering technologies that might be best suited for Cr(VI) treatment at their wells.
HEXAVALENT CHROMIUM

The screening process identified strong base anion exchange (SBA-IX), potentially with spent brine minimization and handling. Two key factors that drove the process toward selecting SBA-IX were (1) the availability of non-hazardous regenerant brine discharge to the local sewer, and (2) the high alkalinity of the groundwater. The availability of the sewer offered the potential of lower cost disposal; however, high alkalinity could result in significant operational costs if a treatment technology requiring pH adjustment, such as weak base anion exchange, were selected.

Through the Water Research Foundation’s (WRF’s) Tailored Collaboration funding program, the District initiated WRF project #4488, Hexavalent Chromium Treatment with Strong Base Anion Exchange, to demonstrate the Cr(VI) removal performance of SBA-IX treatment through bench- and pilot-scale testing. In addition to characterizing Cr(VI) removal performance, the project also considered waste minimization strategies for SBA-IX brine residuals. The pilot testing protocol was developed to support full-scale treatment design and answer key operational questions that can impact capital and life-cycle costs.

Soquel Creek Research Approach

For the SBA-IX testing, the primary goals were to compare and validate commercially available SBA-IX resin performance for Cr(VI) exchange capacity, regeneration quality, and frequency requirements. As with any SBA-IX application, the ability to manage the regenerant brine was a critical operational parameter. Bench- and pilot-scale testing investigated innovative brine management techniques including brine reuse and treatment methods to render the spent regenerant brine waste non-hazardous. The techniques investigated included treatment of the spent brine to remove Cr(VI) and other co-contaminants using single-use weak base anion exchange (WBA-IX) resin, chemical reductive media (CRM), and reduction/coagulation/precipitation with ferrous sulfate to sequester the Cr(VI).

To achieve the District’s research objectives, SBA-IX testing was conducted at bench scale, followed by on-site pilot-scale testing at the District’s San Andreas well site. Objectives for each testing phase are shown in Table 1.

Table 1 Bench-Scale and pilot-scale objectives

<table>
<thead>
<tr>
<th>Bench-Scale Objectives</th>
<th>Pilot-Scale Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine optimal empty bed contact time (EBCT) to conduct subsequent experiments</td>
<td>Demonstrate bench-scale results could be replicated at pilot scale</td>
</tr>
<tr>
<td>Screen SBA-IX resins to identify the best performing resin</td>
<td>Determine the feasibility of reusing the sodium chloride regenerant brine</td>
</tr>
<tr>
<td>Demonstrate SBA-IX treatment performance through multiple loading and regeneration cycles</td>
<td>Generate sufficient brine to conduct treatment investigations at bench scale</td>
</tr>
</tbody>
</table>

Strong Base Anion Exchange (SBA-IX) Overview

Strong base anion exchange is a process that involves the exchange of ions from one phase to another. It has been implemented by drinking water utilities with nitrate, arsenic, and other groundwater contaminants, and, as such, has been researched extensively. During water treatment, negatively charged anions in the liquid or water phase are transferred to the solid phase of the resin by replacing anions, typically chloride, from the resin matrix. The SBA-IX process is shown schematically in Figure 1.

Raw water containing Cr(VI) is pre-treated as required. Pretreatment typically includes prefiltration to protect the resin bed from particulate fouling. Since the functional groups of SBA-IX resins remain ionized over a wide pH range, there is not typically a requirement for pH depression for operation (Clifford 1990). Once pre-treated, the water passes through pressure vessels containing SBA-IX resin where the Cr(VI) and other anions are exchanged for chloride. Following the ion exchange step, the treated water is typically disinfected, and if needed, pH adjustment and/or other stabilization may be performed prior to sending the water to the distribution system.

When the exchange sites are filled with contaminants, the resin is said to be exhausted and requires regeneration (Brandhuber et al. 2004). Regeneration is accomplished by using a 1.5% to 12% sodium chloride (NaCl) solution to impart...
a concentration gradient to replace the contaminant anions on the resin with chloride. Multiple bed volumes (BV) of the regenerant are typically used to restore the exchange capacity (Siegel and Clifford 1988).

**Brine Management**

**MANAGEMENT OF BRINE** often limits the applicability SBA-IX for drinking water treatment. Brine management options typically include the following:

- Discharge to a sewer or septic system
- Waste volume reduction using drying beds
- Trucking to an off-site approved disposal location
- Ocean discharge through a coastal pipeline
- Deep well injection
- Advanced treatment and disposal

Waste brine quantity and quality characteristics (e.g., salinity, metals, and radio-nuclides), and geographical location can affect the feasibility and costs of these disposal options. Proximity and access to offshore disposal options, such as a brine line to the ocean, can also be significant factors in determining the burden of brine disposal. Without the ability to dispose of the brine in municipal sewers or via a brine line, the regenerant brine requires off-site disposal. This can be complicated, as it is likely to be designated as hazardous waste due to elevated concentrations of hexavalent chromium and other co-occurring contaminants.

Alternatively, the regenerant brine can be treated to remove the Cr(VI) rendering it non-hazardous. Siegel and Clifford (1988) conducted bench-scale experiments with different reductants to evaluate their ability to reduce Cr(VI) to Cr(III) and determine the optimal conditions for precipitation of Cr(OH)$_3$ (s). The results showed that acidic sulfite, ferrous sulfate, and hydrazine are all capable of reducing Cr(VI) to Cr(III); however, ferrous sulfate was the only reductant that did not require pH adjustment for the reduction reaction to proceed and did not require additional chemical feed to achieve precipitation. In laboratory studies, Cr(VI) recovery with sodium chloride regenerations of SBA-IX was demonstrated to always be less than 100%, which was attributed to Cr(VI) reduction to trivalent chromium with subsequent precipitation of a greenish solid (chromium hydroxide) (Clifford 1990).

Regenerant brine optimization has also been investigated for Cr(VI) treatment during pilot-scale testing conducted in Glendale, CA (McGuire et al. 2006). In that case, a regenerant brine with a sodium chloride concentration of 6% was found to be insufficient to fully regenerate SBA-IX, and the BV to breakthrough during treatment declined from 1,900 BVs with fresh regenerant to less than 500 BVs after the first recycle pass. Further treatment capacity reduction after subsequent regeneration cycles was also noted. Increasing the sodium chloride concentration from 12% to 26% improved performance; however, the Cr(VI) exchange capacity continued to diminish after subsequent cycles. In this instance, the diminished capacity was attributed to sulfate accumulation in the brine.

**Soquel Creek Research Results**

RESEARCH CONDUCTED WITH the Soquel Creek Water District’s San Andreas well proved that SBA-IX can be effective for Cr(VI) treatment. At bench scale, commercially available SBA-IX resins were able to achieve 15,000 to 30,000 BV of treatment prior to an 8 µg/L treatment threshold. SBA-IX operating in this fashion is extremely efficient (greater than 99.97% water efficient), especially when compared to its use for nitrate removal where resins are typically regenerated after only 500 to 1,500 BVs. While some diminished capacity was observed, performance generally appeared to stabilize after the initial loading cycles. Regeneration of the resins at bench scale showed that the Cr(VI) could be recovered from the resin with mass balances showing 76% to 106% recovery of the Cr(VI), with the variability likely due to sampling and analytical limitations.

At pilot scale, the exceptional loading capacity of the initial loading cycle was replicated, but without the subsequent diminished capacity experienced at bench scale.
scale. This reduced capacity observed at bench scale may be the result of irreversible fouling of the resin that occurred when the feed water became contaminated with organic material. Regardless, there was no discernible performance decrease of the SBA-IX resin after five loading and regeneration cycles.

The feasibility of direct brine reuse was also proven at pilot scale. Regenerant brine was used 8 times consecutively at pilot scale with each of the reuses yielding loading cycles of at least 15,000 BV prior to 8 µg/L Cr(VI) breakthrough. A caveat to this is that there is extended leakage of total chromium which is illustrated in Figure 2 by the rise in the “floor” of the breakthrough curve. While not explicitly clear from the data, it is speculated that this rise results from an accumulation of co-contaminants in the brine. The pilot-scale testing also effectively generated sufficient volumes of brine for subsequent bench-scale brine treatment testing.

While SBA-IX is incredibly efficient for Cr(VI) removal when compared to other contaminants (e.g., nitrate and arsenic), the biggest challenge and operational cost of the process remains management and disposal of resulting regenerant waste brine. All of the brine generated at pilot scale would be designated a hazardous waste based on the total chromium concentration (> 5 mg/L). Traditional regeneration approaches typically use 3 to 5 bed volumes of an approximately 12% sodium chloride solution to regenerate the SBA-IX resin. Removing the chromium and other hazardous constituents from the brine increases disposal opportunities and lowers the associated cost of brine disposal. Three technologies were evaluated as means to treat the chromium-laden brine: reduction/coagulation/precipitation with ferrous sulfate, WBA-IX, and CRM. While each technology is capable of removing chromium below the hazardous threshold, reduction/coagulation/precipitation with ferrous sulfate appears to be most promising. If a utility does not want to manage the chemical feed systems required for reduction/coagulation/precipitation, a flow-through column-based approach with CRM may be feasible.

Conclusions
THE ABILITY TO effectively manage brine production and disposal is crucial for the long-term viability of SBA-IX treatment. The results from this project suggest that direct brine reuse is feasible and that Cr(VI) can effectively be removed from the brine solution by either reduction/coagulation/precipitation or CRM. While optimizing the regeneration process was not fully investigated in this project, simple strategies such as decreasing and optimizing the brine strength and volume could provide significant operational cost savings and should be further investigated. More complex strategies, such as segregated regeneration, where the highly concentrated portions of the regenerant are removed from the bulk solution prior to reuse, offer the possibility to significantly reduce the volume of brine requiring disposal.

The project findings confirmed SBA-IX as the best available treatment technology for the District, and the success of the regeneration studies prompted the District to construct the first SBA-IX system specifically for potable Cr(VI) treatment in California. This 1,000 gpm IonexSG system will be a temporary demonstration facility that will operate with a one-year lease, with an option for an additional one-year extension, and will serve as a stop gap to allow the District to design and construct permanent treatment facilities. The District’s treatment system will utilize a process that has the potential to reduce the overall volume of brine for disposal by nearly another order of magnitude. If successful, this process could further reduce the overall cost of SBA-IX Cr(VI) treatment.

References
Localized Control of Disinfection By-Products by Spray Aeration

Kenan Ozekin, Water Research Foundation

The need to disinfect and meet other water quality objectives must be balanced with the risk of forming regulated and unregulated DBPs, as well as other potential unintended consequences. Control strategies are often trade-offs since conditions used to minimize some DBPs may result in an increase in other species.

In the United States, Disinfection By-Products (DBPs) are regulated by the U.S. Environmental Protection Agency (EPA) through the Stage 1 and Stage 2 Disinfectants and Disinfection By-Products Rule (DBPR). In addition to setting maximum contaminant levels (MCLs) for the four trihalomethanes (THMs), five haloacetic acids (HAAs), chlorite, and bromate (Table 1), conventional water treatment plants treating surface water are required to remove DBP precursors through enhanced coagulation or enhanced softening.

DBP control strategies can be divided into the following three categories (Figure 1):

1. Removal of DBP precursors prior to formation

<table>
<thead>
<tr>
<th>Table 1 Disinfection by-products rule</th>
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<tbody>
<tr>
<td>Contaminant</td>
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<tr>
<td>------------</td>
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<tr>
<td>THMs</td>
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<tr>
<td>HAAs</td>
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<tr>
<td>Chlorite</td>
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<tr>
<td>Bromate</td>
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</tbody>
</table>
2. Modification and optimization of treatment and disinfection practices to minimize DBP formation

3. Removal of DBPs after formation

The best approach for controlling DBPs for any given utility will depend on source water quality and other site-specific considerations, and may vary seasonally. Strategies 1 and 2 listed above are based on treating 100% of system production at the water treatment plant, which can be quite costly. However, it can be much more cost-effective if localized treatment of DBPs targets specific problem areas of the distribution system. Post-treatment aeration inside water tanks has received attention recently because it has the potential to be the most cost-effective treatment option to comply with the Stage 2 DBPR. Therefore, the Water Research Foundation funded project #4413, “Localized Control of Disinfection By-Products by Spray Aeration in Storage Tanks,” to examine the effectiveness of the aeration approach. The objective of the project is to investigate in-tank spray stripping (ITSS) to provide guidance on the design, permitting, operation, and maintenance of ITSS for localized treatment of DBP.

**Bench Scale Experimental Results**

Using 800-gallon water tanks (see Figure 2 for the schematic of the experimental design), the project team tested three different nozzle types (full cone, hollow cone, and fan), three different nozzle sizes (3/4 inch, 1 inch and 1.5 inch), two different spraying angles (90° and 120°), two different nozzle pressures (10 and 30 psi), and three different drops (1 foot, 2 feet, and 3 feet; defined as the vertical distance from the nozzle to the sample collection point).

Table 2 summarizes the results for the 3-foot drop. As expected, stripping increased with the drop, spray angle, and nozzle pressure. Depending on the nozzle type and the experimental conditions, THM removal ranged from 20% to 71%. Chloroform was more easily stripped than the other THMs; that is chloroform percent stripped always exceeded the THM percent stripped. Stripping did not impact the chlorine residual; i.e., chlorine residual before and after the experiments was the same. The research team also tested the long-term performance of the nozzles under a variety of water quality conditions by installing them at ten different locations and continuously running them for one year. After the testing, the nozzles were evaluated for pitting, rounding, corrosion, deposition of hardness, and change in spray pattern. All nozzles tested showed no degradation of the spray inducing surface, little pitting, some limited rounding of nozzle edge, little corrosion, and almost no accretion of hardness.

<table>
<thead>
<tr>
<th>Table 2. Bench-scale experimental results</th>
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</thead>
<tbody>
<tr>
<td><strong>THM Removal (% at 3-foot drop)</strong></td>
</tr>
<tr>
<td><strong>Nozzle Type</strong></td>
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<tr>
<td><strong>10 psi Nozzle Pressure</strong></td>
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<tr>
<td><strong>Nozzle Size &amp; Spray Angle</strong></td>
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<td><strong>3/4”</strong></td>
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<td><strong>Fan</strong></td>
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<tr>
<td><strong>90°</strong></td>
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<tr>
<td><strong>120°</strong></td>
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<tr>
<td><strong>30 psi Nozzle Pressure</strong></td>
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<tr>
<td><strong>Full Cone</strong></td>
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<tr>
<td><strong>54%</strong></td>
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<tr>
<td><strong>71%</strong></td>
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<tr>
<td><strong>53%</strong></td>
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<tr>
<td><strong>57%</strong></td>
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<tr>
<td><strong>49%</strong></td>
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<tr>
<td><strong>Hollow Cone</strong></td>
</tr>
<tr>
<td><strong>56%</strong></td>
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<td><strong>60%</strong></td>
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<td><strong>40%</strong></td>
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</table>
Full-Scale Experimental Results
FULL SCALE SYSTEM testing began in May 2013. The data is still being analyzed but the results are clear. Based on historical data, the Stage 2 DBP site of maximum residence time downstream of this tank would have been out of compliance with the Stage 2 DBPR Locational Running Annual Average without the ITSS system. Also, the test plan was enhanced with two significant additions made to the project:
1. Two rounds of TOX testing are being performed to look at the fate of TOX from the plant, into the tank, leaving the tank, and at the Stage 2 DBPR maximum residence time location.
2. A pilot test is being conducted of the only two online THM analyzers on the market: the AMS THM100 from Aqua Metrology Systems and the MS2000 from Multisensor Systems. The “continuous” THM data from these instruments will be compared to weekly GCMS THM data. The report will include a brief discussion of the potential applications for each instrument.

Summary
POST-TREATMENT AERATION INSIDE water tanks has received attention recently because it has the potential to be the most cost-effective treatment option to comply with the Stage 2 DBPR. In the current research, chloroform was the most amenable to removal by aeration, but other THM species also showed significant removal. Stripping increased with drop, spray angle, and nozzle pressure. Full-scale results are being compiled and the full report will be published in 2015.

Figure 2. Bench-scale experimental design
Developing Robust Strategies for Climate Change and Other Risks: A Water Utility Framework (project #4262)

Utilities face planning challenges as they seek to identify and manage climate change risk. Decision processes responding to these challenges are evolving away from a deterministic prediction-based paradigm to one based on vulnerability identification and adaptation planning. This project highlights Robust Decision Making (RDM), a quantitative, iterative analytical framework that responds to the above challenges and needs of water utilities. This project offers practical guidance to the water industry on how to address climate change risk at a time when many agencies across the United States are updating their long-range plans. The type of approach presented in this study, to assess and identify climate change risk and then evaluate and prioritize risk management strategies, can directly influence the approach and scope of utility Capital Improvement Plans, Strategic Plans, or Integrated Resource Plans.
Effective Microbial Control Strategies for Main Breaks and Depressurization (project #4307)

THE PURPOSE OF the project was to improve utility responses to main breaks and depressurization events to better protect public health. A risk-based approach to main break responses was developed, resulting in four categories of main breaks with commensurate best practices for returning the main to service while reducing public health risks. In addition the final report, a Field Pocket Guide was published to help field crews remember and implement good practices during repair of water main breaks. The Field Pocket Guide may also be useful in utility training programs for crews involved in these activities.

Optimizing Engineered Biofiltration (project #4346)

BIOLOGICAL FILTERS CAN allow for the achievement of multiple goals in a single treatment step. However, these benefits can only be realized by managing potential filter hydraulic challenges caused by biological fouling. In this tailored collaboration project with Dallas Water Utilities (DWU) and Tampa Bay Water, the research confirmed and further optimized nutrient and peroxide biofilter enhancements. This work also showed that significant hydraulic benefits could be achieved with biofilter pH optimization. The project also evaluated the impacts of these enhancement strategies (peroxide and/or nutrient addition) on the holistic optimization of upstream treatment processes. Specifically, improved biofilter water treatment performance allowed a reduction in coagulant requirements at DWU, while providing the same level of treatment.
Effective Climate Change Communication for Water Utilities (project #4381)

WATER UTILITIES NEED to communicate the potential impacts of climate change on water supplies to many audiences; for example, internal staff, governing board members, customers, and the press. Based on a nationally representative survey, this project shares insights on the public’s attitudes, beliefs, and actions concerning the nexus of community water and climate change. The findings may surprise you. For example, 92% of Americans support their community water provider being a leader in preparing their community for climate change. In addition to the survey findings, the project developed pragmatic tools tested by the 13 water agencies who participated in the project. The tools include a message mapping strategy (with worksheets) and risk based communication templates for how to talk to people who indicate they do not believe in climate change.

National Economic & Labor Impacts of the Water Utility Sector (project #4566)

THIS PROJECT EXPLORED the significant impact the water utility sector has on the U.S. economy. Based on the planned operating and capital investments of 30 public water utilities, the research determined that these water, wastewater, and stormwater utilities will contribute approximately $524 billion to the U.S. economy over the next decade and will support roughly 289,000 permanent jobs. Study results show that investments by utilities generate similar job impacts as compared to investments in clean energy, transportation, and healthcare. In addition, these investments generate more jobs per $1 million than investments in military spending or personal income tax. Throughout the coming decade, the 30 participating utilities will undertake projects to replace aging infrastructure, improve local water quality, expand services to accommodate increased demand, and respond to a number of additional needs. These projects will sustain more than 131,000 jobs over the next ten years.

<table>
<thead>
<tr>
<th>City</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans</td>
<td>150,000</td>
</tr>
<tr>
<td>Miami</td>
<td>250,000</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>270,000</td>
</tr>
<tr>
<td>Sacramento</td>
<td>280,000</td>
</tr>
<tr>
<td>Denver</td>
<td>410,000</td>
</tr>
<tr>
<td>Washington DC</td>
<td>600,000</td>
</tr>
</tbody>
</table>

= 20,000 full-time employees

Total Employment Contribution of Utilities in this Study Compared to Total Employment of U.S. Cities
OCTOBER–DECEMBER 2014
ADVANCES IN WATER RESEARCH

COMPLETED RESEARCH OF NOTE

**Compendium of Sensors and Monitors and Their Use in the Global Water Industry (project #4428)**

ONLINE MONITORING IS made possible by various sensors installed at key points in a system that collect data on water quality. A key barrier to the use and acceptance of online sensors by water and wastewater industry is the lack of knowledge on the availability, reliability, serviceability, and placement of these sensors. The overall goal of the project was to identify and document information on types, costs (capital and operating), and real-world experiences with the use of sensors in the global water and wastewater industry focusing on commercially available online monitoring technologies for the measurement of water quality and quantity. The main deliverable of this project is an online compendium that includes general information on the workings of these technologies; advantages and disadvantages of the various technologies; and best practice information concerning installation, operation, maintenance, and calibration of instruments. Twenty-two case studies conducted by drinking water and wastewater utilities in United States, United Kingdom, Australia, the Netherlands, South Africa, Singapore, and Namibia are also included.

**Acoustic Signal Processing for Pipe Condition Assessment (project #4360)**

UNIQUE TO PRESTRESSED concrete cylinder pipe (PCCP), individual wire breaks create an excitation in the pipe wall that may vary in response to the remaining compression of the pipe core. In non-PCCP, the structural excitation would require an external source acoustic pulse, causing a response indicative of relative pipe wall stiffness. This project was designed to improve acoustic signal processing for pipe condition assessment in an experimental environment, which includes burial, pressurization, and subsequent intentional damage to the pre-stressing wires in three specimens of PCCP.
ON MAY 29–30, 2014, with support from WRF and WERF, the San Francisco Public Utilities Commission hosted a group of water agencies, public health departments, and research institutions from across North America to discuss onsite water treatment systems at a meeting, titled “Innovation in Urban Water Systems.” The purpose of this meeting was to share knowledge and lessons learned in order to overcome institutional barriers to onsite water treatment. Based on the discussions at the meeting, the group developed this Blueprint to assist communities with developing a local program to manage and oversee onsite water systems that protect public health. A local program can build on existing plumbing, public health, and building standards and codes while addressing water, stormwater, and wastewater management programs in a coordinated and streamlined manner.
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