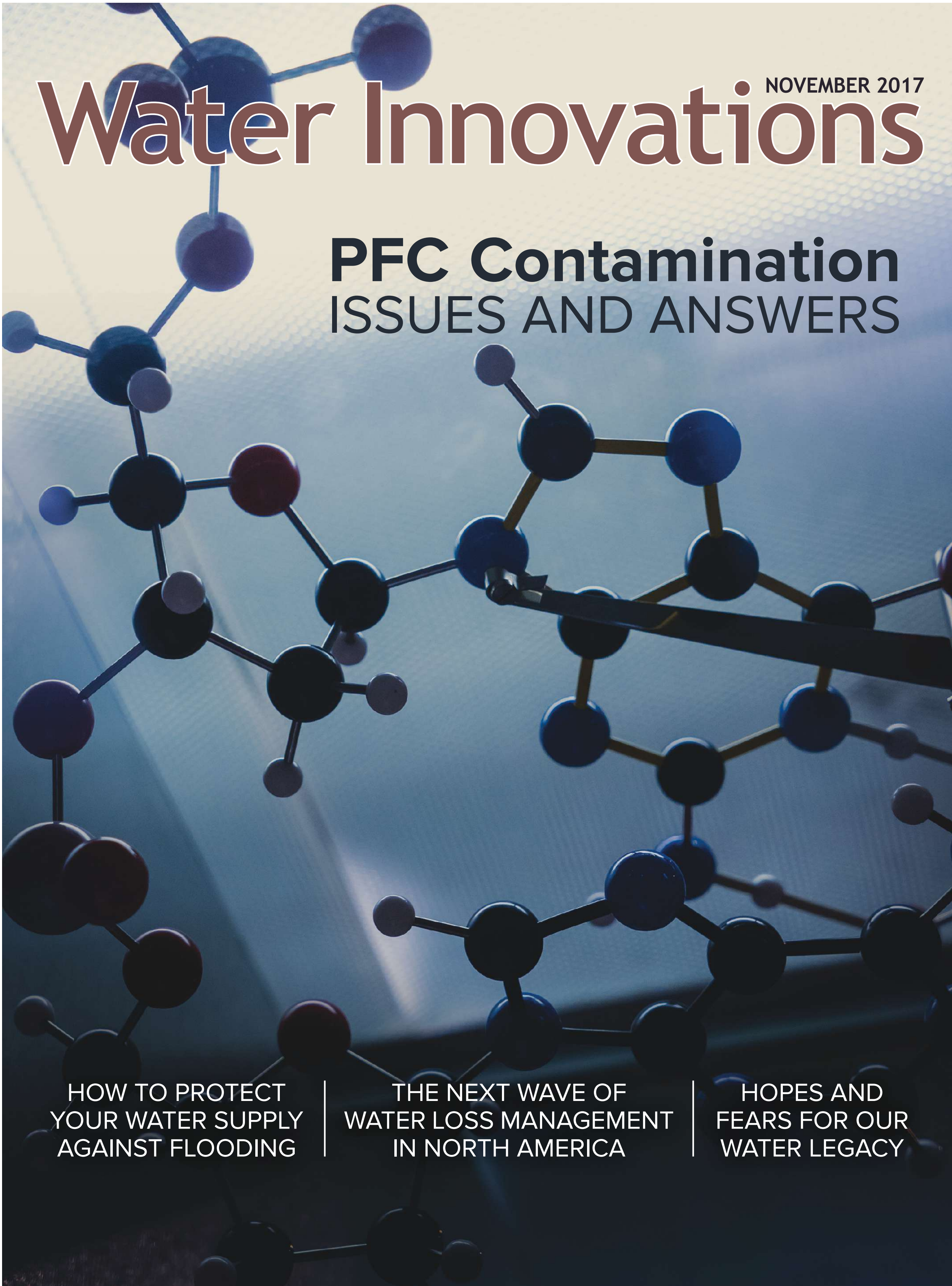
NOVEMBER 2017

Water Innovations



PFC Contamination
ISSUES AND ANSWERS

HOW TO PROTECT YOUR WATER SUPPLY AGAINST FLOODING

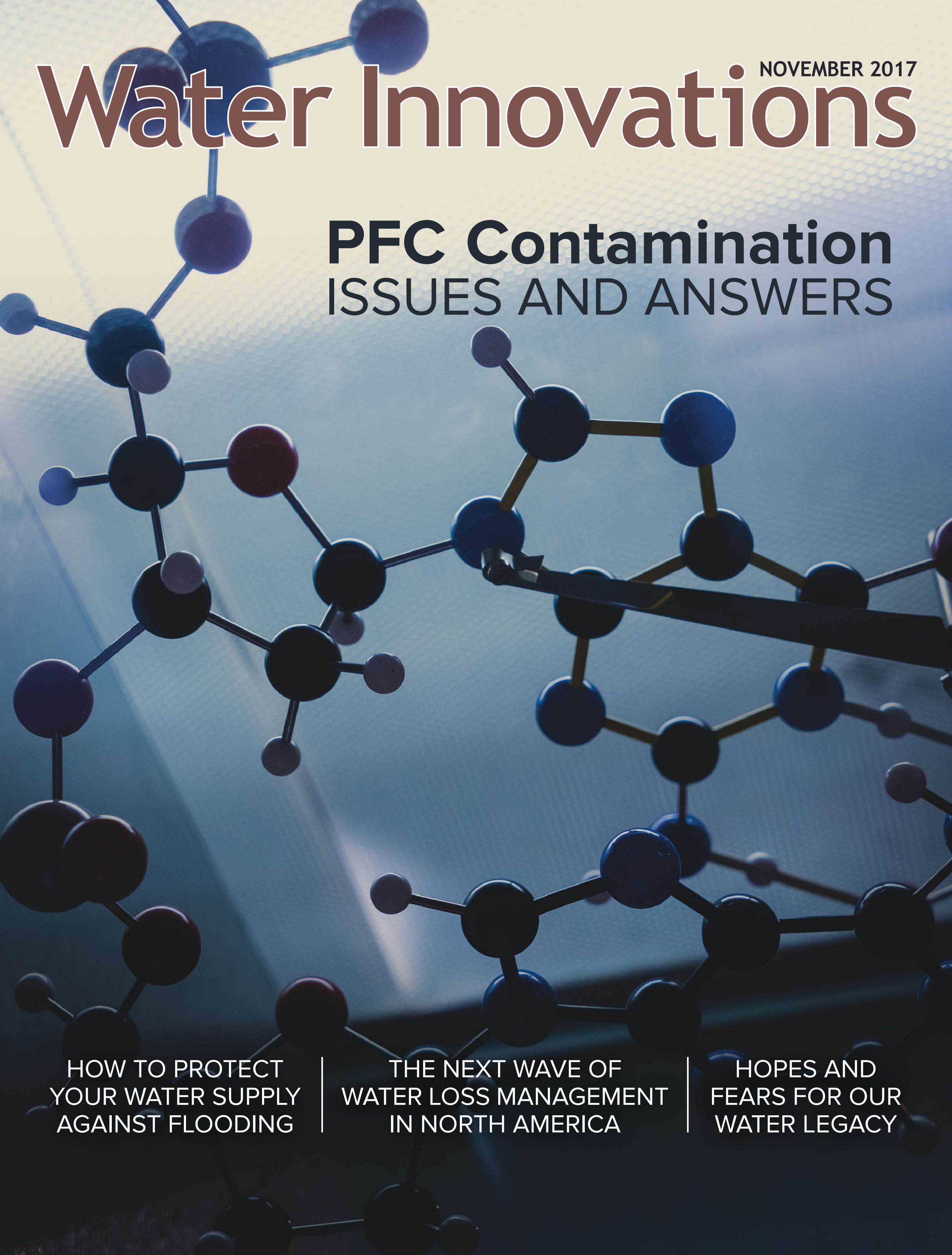
THE NEXT WAVE OF WATER LOSS MANAGEMENT IN NORTH AMERICA

HOPES AND FEARS FOR OUR WATER LEGACY

FEATURED ADVERTISERS

NOVEMBER 2017

Water Innovations



PFC Contamination
ISSUES AND ANSWERS

HOW TO PROTECT YOUR WATER SUPPLY AGAINST FLOODING

THE NEXT WAVE OF WATER LOSS MANAGEMENT IN NORTH AMERICA

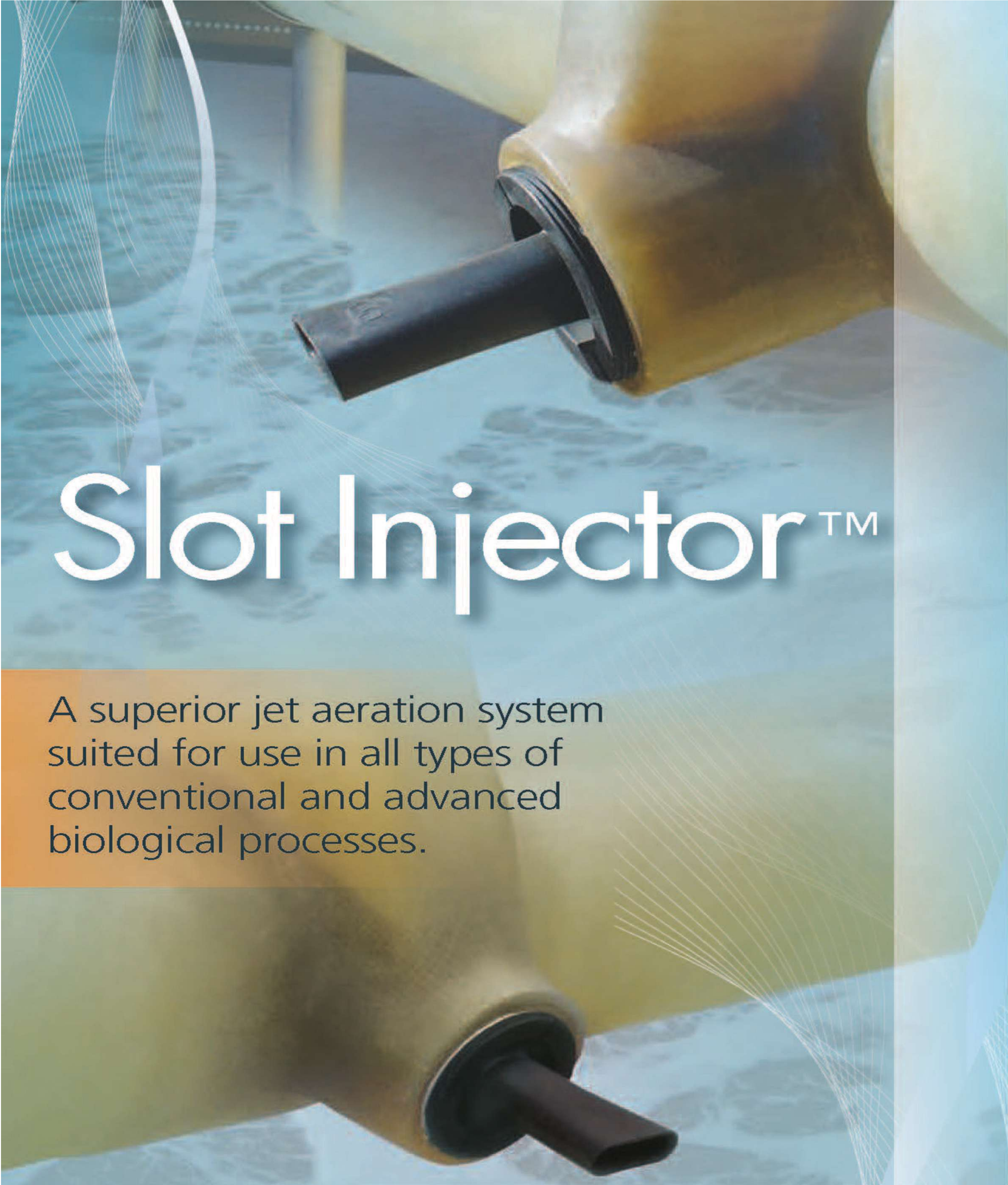
HOPES AND FEARS FOR OUR WATER LEGACY

TABLE OF CONTENTS

November 2017

@WaterOnline

Advertiser Index



Slot Injector™

A superior jet aeration system suited for use in all types of conventional and advanced biological processes.

KLa Systems, Inc.
PO Box 940 / 31 Mill Street
Assonet, MA 02702
T: (508) 644-5555 F: (508) 644-5550
www.klasystems.com

EDITOR'S LETTER

By Kevin Westerling
Chief Editor, editor@wateronline.com

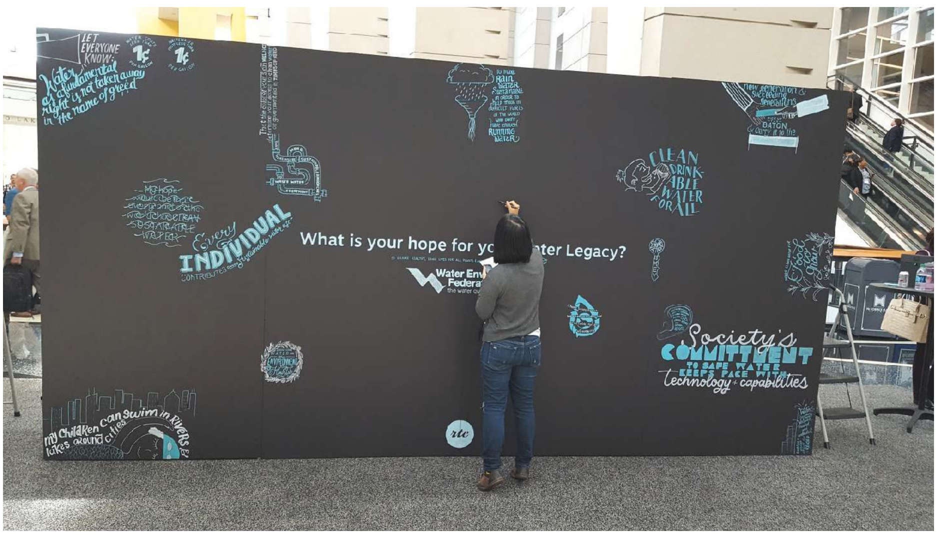
Hopes And Fears For Our Water Legacy

The world's largest annual water quality event provides the setting for a public display of water affection – and anxiety.

In early October, I covered the annual Water Environment Federation Technical Exhibition and Conference (WEFTEC) for *Water Online*, as I have for the past nine years. That makes me a mere rookie relative to most of the attendees, and yet I'm an industry veteran to many others. This age disparity is a major talking point in the water industry, and it took center stage at WEFTEC17.

The concern is that the workforce, particularly water/wastewater treatment plant operators, skews older and is set to retire at a higher rate over the next decade than the national average compared to other industries. Some have termed it "brain drain," referring to the institutional knowledge that goes out the door as retirees hang up their hard hats. So how does that knowledge get transferred to the next generation of operators? How do we attract young people to the cause and vocation of water stewardship at a time when water issues are more critical than ever? And are they ready for the challenge?

The hopes and fears of water professionals of all ages were on display — literally — at WEFTEC17, in the midst of Chicago's McCormick Place concourse. Attendees were asked "What is your hope for your Water Legacy?" as well as "What is your greatest fear around your Water Legacy?" These simple questions summoned responses that reflect all that is good and worrisome about our industry and must have been an especially emotional exercise for those just embarking on a career or leaving one behind. The ballot-box responses were artistically rendered onto a giant chalkboard, creating an enlightening collage that developed as the show progressed.

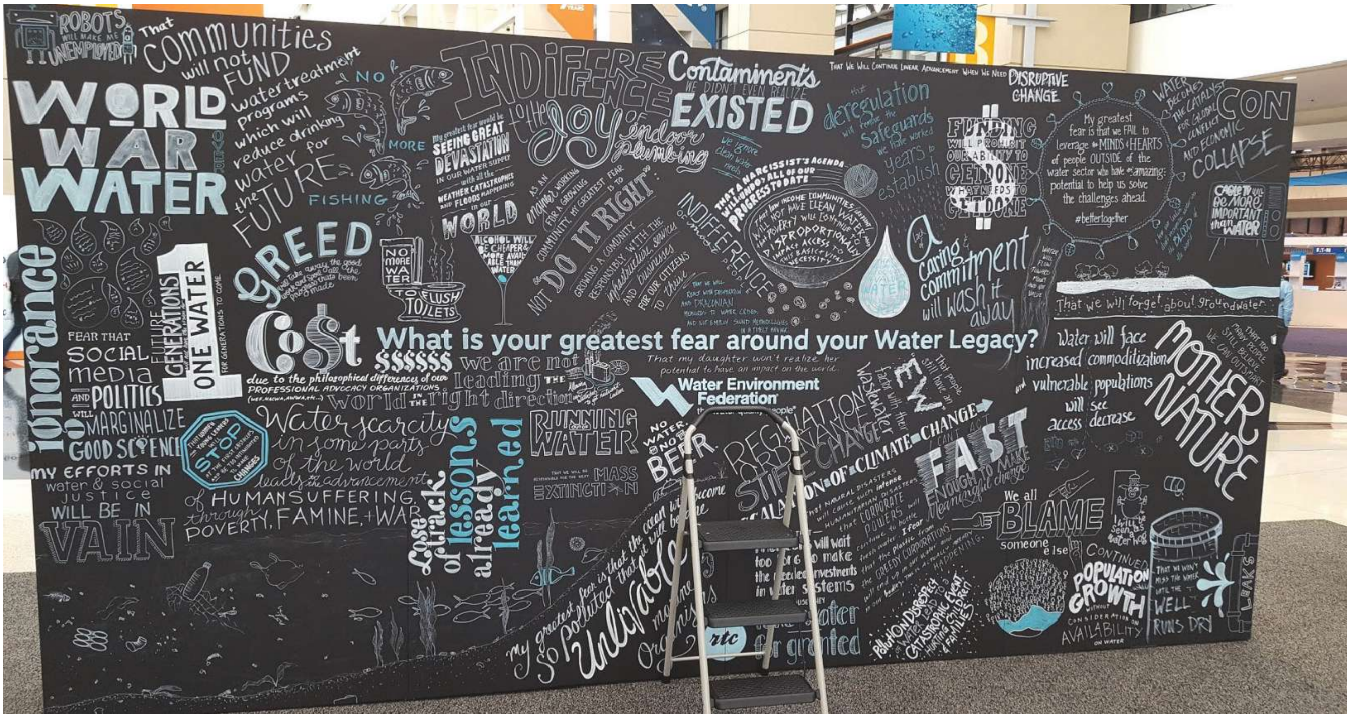


Water Innovations

101 Gibraltar Road, Suite 100
Horsham, PA 19044
PH: (215) 675-1800
FX: (814) 899-5587
Email: info@wateronline.com
Website: www.wateronline.com

Reprints, Eprints, and NXTprints
The YGS Group (800) 290-5460
VertMarketsReprints@theYGSgroup.com
www.theYGSgroup.com

ADDRESS CORRECTIONS
Send to Water Online at above address, or email circ@vertmarkets.com.
Please give old and new address, and enclose or reference your latest mailing label.



How do we attract young people to the cause and vocation of water stewardship at a time when water issues are more critical than ever? And are they ready for the challenge?

Hopes:

If you're part of the retiring set and can't quite see the above (just kidding), here are some highlights.

> *"I hope to see direct water reuse technology accessible for all humanity."*
>
> *"That society's commitment to safe water keeps pace with technology and capabilities."*
>
> *"Change the status quo to make environmental consciousness the norm."*
>
> *"Protect and enhance our waterfronts as the center of our communities."*
>
> *"That more people value water and are proud of being a water professional."*
>
> *"That the new generation and succeeding generations pick up the baton and carry it to the finish line."*

...And Fears:

> *"My greatest fear is that we fail to leverage the minds and hearts of people outside of the water sector who have the amazing potential to help us solve the challenges ahead."*
>
> *"Fear that social media and politics will marginalize good science."*
>
> *"Water will face increased commoditization and vulnerable populations will see access decrease."*
>
> *"As an engineer working for a growing community, my greatest fear is to not do it right."*
>
> *"That we will continue linear advancement when we need disruptive change."*
>
> *"That we won't miss the water until the well runs dry."*

There were some very practical responses on both sides of the equation — or chalkboard, as it were — with hopes including solutions for "flushable" wipes and proper funding, and fears such as job-stealing robots and regulatory uncertainty. But more than anything, I'm struck by the sense of service and compassion conveyed. This is an industry that cares about taking care of others, and if that's the Water Legacy passed down from one generation to the next, the future is in excellent hands.

PFC Contamination: Issues And Answers

PFCs are turning up in source waters and news cycles, drawing both public and regulatory concern. How pervasive is this group of emerging contaminants – namely PFOS and PFOA – and how might the saga unfold for utilities?

By Greta White

The perfluorinated chemicals (PFCs) contamination crisis in Hoosick Falls, NY stirred the nation. This group of human-made compounds is considered "emerging contaminants" by the U.S. EPA. This means they are chemicals or materials that are characterized by a perceived, potential, or real threat to human health or the environment, a lack of published health standards, the discovery of a new source or pathway to humans, or the development of a new detection method or treatment technology.

PFCs are synthetic chemicals predominately utilized in manufacturing, particularly for their lipid- and water-repellent characteristics. They are used in a wide variety of products such as textiles, packaging, and cleaning products and are also additives in coating and plating processes. However, one of their most significant uses has been in firefighting as a compound in aqueous film-forming foam (AFFF).

Large quantities of these chemicals have been released over the years and can be found in the air, groundwater, surface water, soil, and sediments. They are chemically and biologically stable in the environment and resist degradation, have low volatility, and are water-soluble; all of these characteristics have led to widespread bioaccumulation, bioconcentration, and long-range transport of PFC compounds.

PFCs were brought into the limelight in 1999 when 3M submitted to the EPA information on their potential risks. Over the following years, several environmental hazard/risk assessments were undertaken, leading the EPA to revise and finalize the health advisory levels for perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) from 200 and 400 parts per trillion (ppt), respectively, down to 70 ppt, both individually or in combination, just this year. PFOS and PFOA are two of the most widely used compounds of the hundreds of PFCs and are particularly persistent in the environment and resistant to degradation.

PFOS and PFOA are two of the most widely used compounds of the hundreds of PFCs and are particularly persistent in the environment and resistant to degradation.

In order to develop new health-based regulations, the EPA takes into account a chemical's toxicology, including sources and pathways to receptors, sampling and analysis methods, fate and transport of the compounds, and remediation techniques. While it would appear that regulators have an understanding of these factors, as they have been creating new regulations, significant knowledge gaps remain in the overall understanding of the impacts associated with PFOS and PFOA.

What Do We Know?

PFOS and PFOA, in particular, have been detected nationwide in blood samples from both humans and wildlife, and the levels reported are significantly higher in areas near PFC production facilities. Exposure pathways include ingestion through food (particularly in fish) and water, product use, and inhalation of PFC-containing particulate matter. These chemicals are being found to accumulate primarily in the serum, liver, and kidneys. Studies on rodents have raised further concerns about developmental, reproductive, and other systemic effects as

Before PFCs were extinguished from the formula, firefighting foam was a leading source of PFOS/PFOA pollution — and the contamination persists.

well. While PFOA is known to be carcinogenic to animals, its relevance to human health is yet unknown and is something the EPA is still evaluating. For the time being, the EPA describes PFOA as “likely to be carcinogenic to humans.” Clearly, the recent updates to the regulatory limits were in order.

How Do We Sample For Them?

The trace background levels of PFCs, combined with the low-level reporting and regulatory limits, require a careful sampling protocol utilizing measures to prevent cross contamination, which is of utmost importance in obtaining valid results. Trace background levels may be present both in the field and at the laboratory, like that from rain or some drinking water systems; thus, cross contamination effects can be difficult to quantify. Therefore, sampling for these compounds is not your typical routine sampling event and analysis program. Initial sampling protocols were extremely stringent, with field staff needing to be careful of what they wore, the equipment they used, and even what they ate. As we have progressed in our knowledge and testing of PFOS and PFOA, protocols have already been modified and items taken off the “do not use” lists. As always, quality control samples are a must, and water for equipment decontamination must be tested to be PFC-free. Laboratories can incidentally cross-contaminate samples during either extraction or analysis. On top of that, analytical methods and capabilities are still being developed for this group of compounds.

Not only are sampling and analysis for PFCs difficult, but also the fate and transport of these compounds are still largely unknown.

Not only are sampling and analysis for PFCs difficult, but also the fate and transport of these compounds are still largely unknown. As previously mentioned, PFCs are chemically and biologically stable in the environment and resist degradation, have low volatility, and are generally water-soluble, thus highly mobile. However, most precursor compounds to PFOA and PFOS can neither be characterized nor quantified, and biotransformation and oxidation rates in the environment are unknown. There is much to be learned about PFC plumes through upcoming site characterizations and collaboration among the professionals evaluating the results.

The more we know about PFCs, the better we can address the problem and alleviate their impacts on human health and the environment. Many types of both in-situ and ex-situ treatment techniques have been utilized in the search for the best, most cost-effective treatment of PFCs. While currently available techniques, such as activated carbon adsorption (the “best” option identified to date), excavation and disposal, biological treatment, thermal treatment, and chemical oxidation have been assessed, researchers continue to toil as they look for the ultimate remedy.

Where Do We Go From Here?

There are many PFC compounds with varying characteristics and formulations/compositions that impact the development of appropriate regulatory limits. In addition, the background level and cross contamination issues, lack of experienced field and laboratory staff, and the existence of large, potentially comingled plumes will certainly impact the ultimate handling of PFC contamination and remediation costs.

In New York, we have already seen the Department of Environmental Conservation (DEC) require analysis of these compounds at sites contaminated by other compounds of concern, leading to delayed spill closures and opening new spill numbers. With public interest in PFOS and PFOA heightened by recent news reports, will the DEC soon request to re-open “Closed” spill sites, such as crash sites where AFFF was used? And what about known heavy-use locations, such as fire training centers?

With the ubiquitous use of products containing PFC chemicals, along with the chemicals’ low volatility and fast mobility, will we be able to discern between background levels and appropriate regulatory limits? Should regulatory limits be increased or decreased? And what about indoor air quality? Only time will tell.

In the future, we can expect that as more contaminated sites are identified, studied, and analyzed, we will gain a better understanding of the compounds’ fate and transport and health effects, leading to new regulations, modified sampling and analytical methods, and effective remediation techniques. ■

About The Author

Greta White is a geologist with 11 years of experience in the environmental consulting industry. She is skilled in site investigations and remedial activities for government, commercial, industrial, and residential sites in NY, NJ, PA, VT, and MA that have been impacted with PCBs, chlorinated solvents, petroleum, PFCs including PFOA/PFOS, and other constituents of concern. She has participated in all phases of project execution from the pursuit phase through project closeout. Greta can be reached at gwhite@walden-associates.com.

How To Protect Your Water Supply Against Flooding

A small, coastal Massachusetts town plagued by floods and imperiled drinking water supplies teamed with the EPA to bolster its defenses, resulting in a framework for other at-risk communities to follow.

By Peter Chawaga

It may seem counterintuitive, but too much influent is one of the greatest threats that any water system faces.

The dangers of flooding should be top of mind for any water utility, because of its potential to disrupt operations, damage equipment, and even endanger lives. And it's a threat that is likely to become only more acute as climate change raises sea levels and brings storm surges more regularly.

To reduce vulnerability, the EPA has undertaken efforts to educate the country's water utilities about how best to prepare for and respond to flooding events.

"Flooding is one of the most common hazards in the United States, causing more damage than any other severe, weather-related event," an EPA spokesperson said. "It can occur from tropical storms, hurricanes, swollen rivers, heavy rains, tidal surges, spring snowmelt, levee or dam failure, local drainage issues, and water distribution main breaks. Impacts to drinking water and wastewater utilities can include loss of power, damage to assets, and dangerous conditions for personnel. As storms become more frequent and intense and as sea levels rise, flooding will be an ongoing challenge for drinking water and wastewater utilities."

To reduce vulnerability, the EPA has undertaken efforts to educate the country's water utilities about how best to prepare for and respond to flooding events.

A Small, Coastal Town

The agency's education efforts have ranged from online tools to funding opportunities, but perhaps nothing is quite as powerful as hearing from a peer. So the EPA developed a list of best practices based on how it helped the small town of Mattapoisett, MA deal with floods.

"Mattapoisett's drinking water system is extremely vulnerable due to its location," said the spokesperson. "Its drinking water wells run along the Mattapoisett River Valley located in the 100-year flood plain and hurricane inundation zone."

Located across the water from Cape Cod on the Nantucket Sound, the town's roughly 6,000 residents have decades of experience with severe weather. They are fully aware of the dangers that storms and flooding present to water operations.

"Mattapoisett has suffered from a number of extreme weather events, flooding from storm surge, hurricanes, and severe winter storms," said the spokesperson. "Two of the most significant storms we focused on were the unnamed storm in 1938 and Hurricane Bob in 1991. Other severe weather that impacted Mattapoisett include Hurricane Gloria in 1985 and Hurricane Carol in 1954."

Hurricane Bob, for instance, overtopped drinking water supply wells, allowing saltwater to enter the local aquifer. These wells still haven't recovered and have been out of commission ever since.

Given its history, Mattapoisett's leadership, town manager, and water superintendent expressed interest in learning more about the impacts of extreme weather, sea level rise, and how to protect their town's drinking water supplies. The EPA's Region 1 and Office of Research and Development worked with the town and made some of the lessons learned available to other communities that might share the same concerns.

Mattapoisett, MA

Lessons Learned

With firsthand experience of how flooding can be detrimental to water supplies and confidence that the threat only stands to get stronger, Mattapoisett has taken some direct action to better prepare itself in the future.

"The town has been actively working to make sure its drinking water and community are resilient," the EPA spokesperson said. "It has procedures prior to storms to stop drinking water production wells from pumping to reduce the likelihood of salt water intrusion into the aquifer. In addition, certain parts of the community's drinking water distribution system are shut off two to four hours before a storm."

Town managers are also aware that hazardous materials can be leaked into groundwater due to extreme weather events. There are concerns about how fuel and gas tanks that aren't properly secured might pollute drinking water supplies.

Mattapoisett's best practices for mitigating these threats have been documented in an informational video (available online) to better serve other communities that can benefit.

"One of the outcomes from this project is a video about preparedness," the spokesperson said. "This informational video, created by the town's cable station, features town officials explaining how to prepare for extreme weather."

4 Best Practices

The decades of climate stress and extensive collaborative work with the EPA have been boiled down to a list of best practices that, if applied appropriately, can make a world of difference for water systems that might not be as prepared as Mattapoisett's.

1. Work smarter, not harder: When you begin a flooding preparedness project, conduct an assessment to identify local priorities and champions.
2. Solicit buy-in: It's critical to have town leaders' support. They can bring in the right people and make projects happen.

The decades of climate stress and extensive collaborative work with the EPA have been boiled down to a list of best practices that, if applied appropriately, can make a world of difference for water systems.

3. Utilize your community's strengths: Piggyback on community resources like the cable television station, the library, schools, and city council.
4. Share success: Communicate results in various ways to get the word out to the community.

By developing these best practices, collaboration between the EPA and Mattapoisett has created benefit beyond what was reaped by either entity. While Mattapoisett bolstered its resiliency and the EPA helped mitigate fallout from the coastal community's next great storm, communities all over the country and world now have a project to point to for confidence that flooding can be protected against, as well as actionable steps to take for themselves.

Altogether, it makes a small town seem much bigger. ■

About The Author

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

The Next Wave Of Water Loss Management In North America

Though the field of water loss management is ever-growing and refining, a validated water audit to disaggregate volumes and values of all loss components remains the essential first step to reduce water loss in a way that is economically sustainable, both for your utility and your ratepayers. With extreme weather events, conservation rate structures, and regional population shifts changing the face of business as usual, it's time to get with the program.

By Will Jernigan

It's an exciting time to be in water loss management. In its basic sense, water loss is a resource opportunity waiting to happen. The culmination of the last 25 years has taken water loss from an afterthought to a driving force for policy and management in water utilities across North America. We sit today on the cusp of widespread adoption of standard annual water auditing, validation, and economically driven water loss programs. The AWWA Free Water Audit Software (now in its fifth generation) recently turned 10 years old, and the current version, at over 8,000 downloads, has far eclipsed its predecessor (2,000 downloads). AWWA's M36 Water Audits and Loss Control Programs manual recently came out in its fourth edition; interestingly, the first edition (1991) of this anchor reference manual was entitled *Water Audits and Leak Detection* — a testament to how far the industry has come. In fact, AWWA's water loss brain trust, the Water Loss Control Committee (WLCC), bore this same name as its original moniker. George Kunkel is an integral member of the WLCC and former longtime manager of Philadelphia's water loss program (the longest-running in the U.S.). George was an inaugural member of the committee in 1991, rumored to have showed up and asked so many questions that they made him the committee chair. A lot has happened in subsequent years, and the WLCC has largely been the driving force.

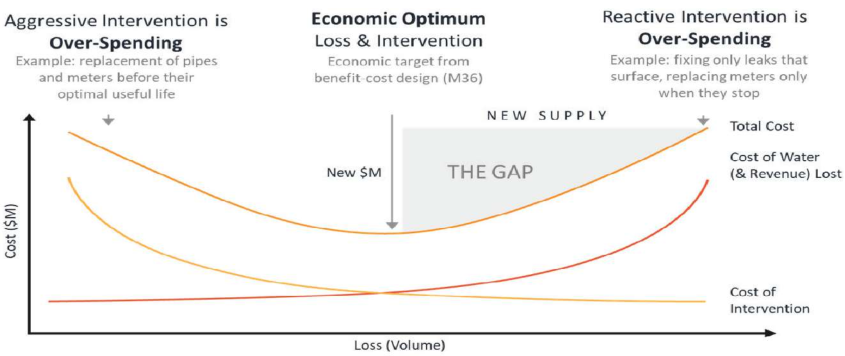


Figure 1. AWWA M36 concept of economic optimum

Then And Now

Fast-forward to 2017. Multiple states around the U.S. are adopting the AWWA M36 standard. Presently, regulations in 11 areas (California, the Delaware River Basin, Georgia, Hawaii, Indiana, New Hampshire, Pennsylvania, Tennessee, Texas, Washington, and Wisconsin) require utilities to report water loss with AWWA M36 terminology. Water Research Foundation (WRF) projects have proven out widespread challenges with audit data reliability and have established formal guidelines for water audit validation. Those widespread challenges, by the way, have very little to do with direct human error. While there will inevitably be a miscalculation here and there and an ever-improving understanding of the basic audit process, the WRF studies suggest that "getting the math wrong" is not what we are

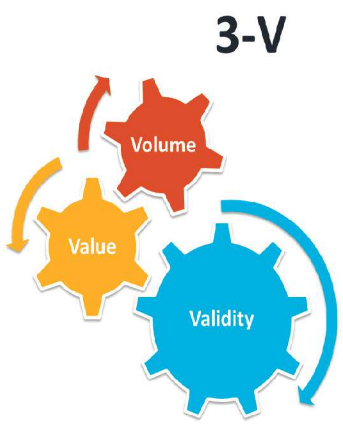
What we are up against is systematic gremlins that endeavor to introduce error into the underlying data we rely upon to develop the water balance and conduct the annual water audit.

up against. The water industry is staffed with highly competent professionals with whom we entrust our public health. What we are up against is systematic gremlins that endeavor to introduce error into the underlying data we rely upon to develop the water balance and conduct the annual water audit. These gremlins live in the supply measurement systems — through meter wear, poor meter siting/installation, and conversion/transfer/archival error. They can live in our consumption measurement systems — through data transfer, archival, and coding error. Largely, these issues stem from the original system design rather than system operation, which means the root cause traces back years and even decades to when the systems were installed. Like many problems that are long in the making, they don't get solved right away. But the industry's level of awareness and the toolkit to address these gremlins continue to gain steam through the work of AWWA and its expert volunteers, the increased focus on water loss research from WRF, and the ever-changing water loss regulatory landscape.

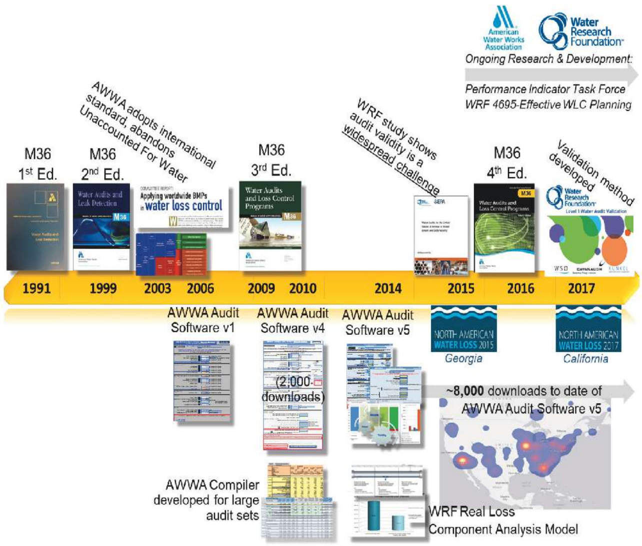
A validated water audit provides useful insight into a system's profile of water loss components — expressed in validity, volume, and value, known as the "3Vs."

Validation Versus Auditing

Validation can occur at graduated levels of effort and outcomes. As defined by WRF project 4639 (2016), Level 1 validation is an examination for correct application of the audit methodology, including errors evident in summary data and confirmation of data grading applications. Level 2 investigates raw data and archived reports at a deeper level to ensure the best sources of data have been used. Level 3 focuses on bolstering data reliability through instrument accuracy tests, pilot leak detection studies, and similar field tests. Currently in California, Georgia, and Hawaii, Level 1 validation is required for annually submitted AWWA water audits. California is presently underway with the largest water audit



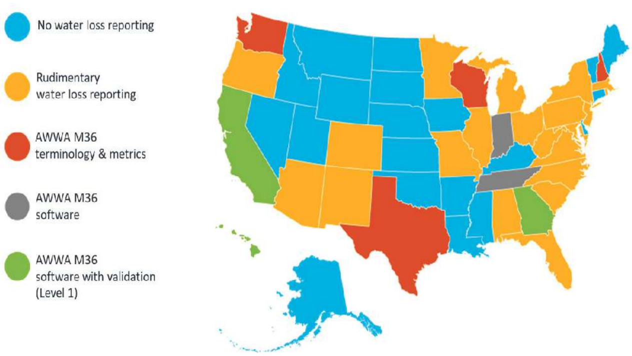
The '3Vs' of the M36 Methodology



State of the art: The evolution of the M36 Methodology

validation program in the nation, involving about 450 urban water systems across the state. A Level 1 validated water audit provides the foundation for developing an economically sound water loss control program focused on the true nature and extent of a system's losses and their financial impact on utility operations. To validate an audit, a water loss expert reviews the data entered and the associated data grades and discusses business and operational practices with the audit preparation team. Validation does not grade data inputs "right" or "wrong"; it merely aligns them with the actual conditions that occurred in the operation of the utility for the audit year. Any discrepancies noted during validation are discussed between the audit team and the validator and documented in a validation report. The initial outcome of Level 1 validation is a documented understanding of the data and business practices informing the water audit. Tangible examples of this include:

- Systems discovering a billing error during its audit validation, subsequently correcting thousands of dollars of lost revenue.
- Systems identifying a source metering configuration creating inaccurate measurement of the volume of water entering the system.
- Systems using the water audit to communicate the need for, and value of, a targeted leakage detection and monitoring capital project, resulting in millions of gallons of water saved.



Water Loss Regulations — State of the States (2017)

A validated water audit provides useful insight into a system's profile of water loss components — expressed in validity, volume, and value, known as the "3Vs." This level of understanding is essential for a utility program to be cost-effective, addressing central questions of how much loss exists by type, what it is costing the utility, and whether the data is sufficiently reliable and actionable.

The Next Wave

Utilities that embrace the M36 methodology and use their validated water loss audits to pursue an economically based water loss control program are true stewards of the resource. Primacy agencies around the U.S. and Canada have begun to adopt this perspective, even where a mandate for auditing and validation does not yet exist. Many states are leveraging their State Revolving Fund (SRF) programs to provide direct technical assistance to utilities in auditing, validation, and program implementation in pursuit of strategic goals for capacity building. And research and development continue.

At WRF, project 4695 is developing guidance on implementing an effective water loss control plan. The outcome of this project (2018) will be a guidance manual on reducing water loss economically in a way that aligns with your utility's strategic goals, local circumstances, and financial parameters. This work is being complemented by efforts underway at the AWWA Water Loss Control Committee. One key effort is a newly formed Performance Indicators Task Force, composed of the WLCC's leadership, which is evaluating the acceptability of historically applied and recommended best practice performance indicators (PIs) for assessment of water loss. The PI Task Force will issue its recommendations by June 2019. In parallel with these efforts, the WLCC is also developing the next generation (version 6) of the Free Water Audit Software (2019), which will embody insights gained from version 5's adoption in thousands of systems across North America. Moving forward, key elements to watch will be regulatory developments and new R&D from AWWA and WRF.

The industry charges ahead with new developments in leak detection and data analytics technology, but the tools for auditing, validation, and economic planning remain the cornerstone for effective water loss control. To find the tip of the spear, come join us in San Diego for the North American Water Loss Conference (www.northamericanwaterloss.org), Dec. 3 to 5, 2017. ■

About The Author

Will Jernigan, PE, is a water loss expert, having worked with more than 1,000 utilities to address complex water loss challenges; he was appointed in 2017 as the U.S. expert to an international task force for developing the ISO water loss standards. Will is a director with Cavanaugh and is co-chair for the 2017 North American Water Loss Conference.

Advancing Alternative Supplies With Sensor Technology

New water brings new challenges, such as overcoming heightened regulatory standards and consumer wariness. To ensure water quality and quell concerns, utilities moving toward alternative water sources might also consider updating their monitoring technology.

By Brent Alspach

Water utilities are increasingly employing alternative sources of supply to meet demand induced by population growth, drought, and even threats to the quality of their existing sources. Such alternative sources may include seawater, recycled wastewater, brackish groundwater, and stormwater, among others. Given the typically poorer quality of these alternative sources relative to more conventional supplies, the benchmarks for treatment, public health protection, regulatory compliance, and public acceptance are more challenging to achieve.

Adopting An Innovation Mindset

Despite the challenges presented by these alternative sources, the need to overcome them and bolster long-term water supply portfolio sustainability is prompting unprecedented innovation in the water treatment industry. Although the need to innovate in order to meet these challenges is born of necessity, adopting an innovation mindset that permeates every aspect of a utility's culture will yield a significant return on investment that transcends any one application.

Sensor Technology: Where Challenge And Innovation Meet

For those utilities expanding into the use of alternative supplies, the intersection of an innovative culture and water quality and treatment challenges is most acute in the development of new instrumentation and sensor technology. Historically, the water industry has been known for its conservative posture, appropriately reluctant to embrace new processes and technologies over the "tried-and-true" mainstays that have successfully protected public health. However, particularly for new sensor and monitoring technology, innovation and the protection of public health are far from mutually exclusive concepts.

Because alternative sources present many of the new water quality and treatment challenges that are driving sensor innovation, utilities that are already treating these supplies represent an ideal proving ground for new technology. Examples of such sensor technology advances may include more effective pathogen detection, online monitoring and detection of emerging contaminants (e.g., pharmaceuticals and personal care products), and/or advanced detection of important water quality metrics yet to be identified.

It is not necessary that utilities risk switching existing sensors and water quality monitoring instrumentation with new and unproven devices but, rather, that they accommodate testing these new devices in parallel. With an awareness of this important potential, forward-thinking utilities may allocate a small area within the treatment plant dedicated to such testing, pre-outfitted with safety features, sample lines, electrical connections, and the availability of internet connectivity for remote access.

Moreover, the utility's organization can plan ahead to commit a small amount of each operator's time to support applied research and development in assisting with such testing. In this way, the sensor technology supplier experiences support at the test site, the operators enjoy the opportunity for continuous learning, and the organization maintains a smart operational staff that is perpetually at the leading edge of new advancements in water quality monitoring: a win-win-win scenario.

The Benefits Of Sensor Advancements

The entire industry gains from this proactive and progressive approach to testing new technologies, as it not only generates useful data to enhance the institutional knowledge of alternative

For those utilities expanding into the use of alternative supplies, the intersection of an innovative culture and water quality and treatment challenges is most acute in the development of new instrumentation and sensor technology.

Although new advanced sensors may cost more than previous generation technology, the potential for optimization and reduced analytical costs may offset the initial expense.

source treatment, but also demonstrates the efficacy of new sensor technology in operational plants, thus expediting the widespread adoption of the most successful advancements. Specific benefits include the following:

- Increased response time — Sensors that collect and analyze samples more rapidly provide the situational awareness needed to manage the unknowns of potentially variable sources of supply. For example, in potable reuse applications, unanticipated and problematic upstream waste discharges could potentially pass through the wastewater treatment process to the downstream advanced potable water treatment plant. Rapid detection of these discharges enables more expedited responses.
- Improved treatment — The detailed data provided by innovative sensor technology can be used to optimize the advanced processes that are commonly utilized to treat alternative supplies. Next-generation sensors may also enhance automation and bolster treatment plant safety.
- Reduced cost — Although new advanced sensors may cost more than previous-generation technology, the potential for optimization and reduced analytical costs may offset the initial expense. Moreover, improved water quality monitoring also may yield economic benefits in terms of avoided costs of plant upsets.
- Better regulations — Additional real-time data that is both more accurate and more precise will likewise enable regulations to be directly related to specific water quality parameters and less based on inferential metrics of treatment process performance. This is particularly true for pathogens; because precise, online, and real-time monitoring technology does not yet exist, the current regulatory paradigm predicates compliance on surrogate parameters that suggest, but do not guarantee, sufficient levels of pathogen reduction.
- Enhanced public health — More precise, accurate, and comprehensive water quality monitoring conducted at frequencies continually closer to real time help facilitate the level of public health protection necessitated by the use of alternative, poorer-quality sources.
- Heightened public acceptance — The ability of improved water quality monitoring to demonstrate that the potable supplies delivered to the tap are of the highest quality can engender the public trust that is essential for the use of alternative water sources.

Although the landscape of utility innovation extends far beyond water quality monitoring, improved sensor technology is one important area in which utilities can make an important contribution to the advancement of the industry generally and to the use of alternative supplies specifically.

Leaders Of Innovation

Although the landscape of utility innovation extends far beyond water quality monitoring, improved sensor technology is one important area in which utilities can make an important contribution to the advancement of the industry generally and to the use of alternative supplies specifically. And while many utilities may be passively willing to test new monitoring instrumentation, those organizations that create and foster a culture of innovation will actively seek opportunities to engage with equipment manufacturers who are pioneering cutting edge advancements, helping to forge the industry's future. ■

Numerous sensors help monitor the desalination of 50 MGD of seawater at the Claude "Bud" Lewis Desalination plant in Carlsbad, CA, a project Arcadis helped design.

About The Author

Brent Alspach is a principal environmental engineer and the Director of Applied Research for Arcadis. He also serves as a Trustee for the American Water Works Association (AWWA) and as president of the American Membrane Technology Association (AMTA).

Sediment Solutions Within Existing Intake Facility Footprint

Sediment and turbidity can be enough to shut down a drinking water treatment plant if the headworks aren't suited to the source water. Learn how one facility near Tacoma, WA, which incorporates fish-handling to further complicate intake operations, secured sustainability through masterful design.

By Isaac Willig, Chick Sweeney, Joe Orlins, Clint Smith, and Greg Volkhardt

The Green River Headworks is a water-diversion and fish-handling facility owned and operated by Tacoma Water. The headworks facilities consist of: a diversion dam, intake structure, settling basin, fish screen structure, backup auxiliary traveling water screen and bypass pipeline, juvenile fish bypass, fish ladder, fish trap and sort facility, and pipelines that convey the screened water to a spill chamber and treatment facilities. The project has been providing drinking water for the City of Tacoma since 1913. Numerous improvements have been made to the facilities over the years; however, construction of a new treatment facility for the Green River Supply (completed in 2015) required modification of the headworks to increase reliability and reduce the frequency of operational outages.

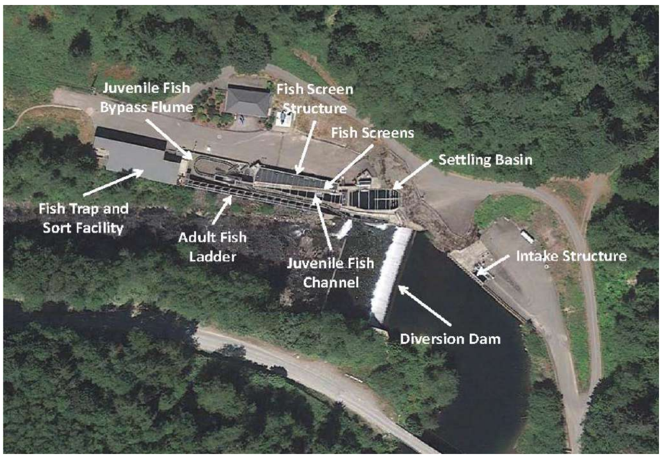


Figure 1. Aerial view showing intake structure and fish-handling facilities

Prior to completion of the new treatment facility, water was diverted year-round when turbidity levels in the Green River were less than 30 Nephelometric Turbidity Units (NTU). When turbidity exceeded 30 NTU or at times when the river carried an excessive debris load, the facility was shut down (the project relies on groundwater well supply during these times). Operating during high river turbidity periods caused significant sediment deposition in the facilities and pipelines, creating the periodic need to dewater the facility for manual removal of the sediment.

With the construction of the new 168-MGD filtration facility, Tacoma Water desired to operate the headworks over a much wider range of stream flows, debris loads, and turbidities than previously. possible. The goals of the headworks intake modification project were to screen water with river turbidities up to 600 NTU, provide passive removal of coarse sediment, and reduce settling material delivered to the filtration facility.

Typically, sediment is removed using large settling basins that provide low velocity over a long distance to allow suspended sediment to settle out. Due to site constraints, there was no room to increase the existing settling basin size or add a new one. A brainstorming session including all involved parties was held to develop innovative solutions. Alternatives were evaluated, and Alden was tasked with carrying the selected alternatives forward to design and construction. These included a guide vane array in the existing settling basin and a sediment eductor system located in the screened water basin on the downstream side of the fish screens.

Guide Vane Array

The guide vane array's purpose was to more evenly distribute the flow exiting an approximately 13-feet-wide by 10-feet-high tunnel into the existing 28-feet-wide by 20-feet-high settling basin to improve settling basin efficiency. The tunnel supplying the settling basin included a curve directly upstream of the tunnel exit. Centrifugal force associated with the flow traveling through the curve produced an asymmetric velocity distribution at the tunnel exit, leading to inefficient sediment settling in the basin. Efficient settling was further impacted by the hydraulic boils that resulted from the lack of transition between the 130 ft^2 tunnel outlet and the 560 ft^2 settling basin.

The vane array consisted of horizontal and vertical vanes in which the spaces between the vanes expand in the downstream direction. The vane spacing at the upstream end of the array was designed to intercept equal amounts of flow exiting the bend and to distribute the flow uniformly over the cross-sectional area of settling basin entrance. This resulted in more uniform and lower flow velocities entering the basin, increasing its efficiency at settling out sediment. The upstream horizontal vane spacing varied from 1.1 to 3.4 feet and expanded to roughly 3.5 feet at the downstream end. Vertical vane spacing expanded from approximately 1.6 feet at the upstream end of the vane array to 3.2 feet at the downstream end. A view of the installed array from downstream is presented in Figure 2.

Figure 2. Downstream end of installed guide vane array

Figure 3. Sediment eductor system installed behind the fish screens

Increasing the settling capability of the existing basin is the most effective means of removing sediment from the system, as settled material in the basin is passively flushed out of the basin into the river by a low-level outlet.

A three-dimensional (3D) computational fluid dynamics (CFD) model was used to develop the guide vane array design as well as quantify the expected improvement in settling basin performance. Particle sizes introduced into the model were based on sediment samples from the river, ranging from gravel size to fine silt. Model results showed that the overall amount of sediment making it past the sediment basin into the screening channel was reduced by a factor of 7 by the vane array for both the average and maximum intake flow conditions. The majority of the sediment expected to enter the intake was sand, which modeling predicted would be 85 percent removed with the guide vane array installed in the settling basin compared to only 14 percent removed without the guide vane array under average diversion flows. The array had little predicted impact on removal of silt-sized material.

Sediment Eductor System

Since some sand and the majority of silt-sized materials would still pass the settling basin and deposit in the facility behind the fish screens, an eductor system was designed to aid removal. The sediment eductor system (Figure 3) consisted of a network of pipes installed on the floor of the basin located behind the fish screens where flow velocities were lower and deposition occurred. This 120-ft by 20-ft area had historically been a maintenance problem, as it had very low velocities leading to accumulation of large sediment deposits as well as poor access for manual sediment removal via vacuum truck. As such, it was a high priority to try and reduce sediment deposition.

The eductor collector pipes have crowns with narrow slits (Figure 3). The pipes were joined to collection headers that ran to a common discharge point along the river shore. The differential head from the water level in the eductor collector pipe basin to the free discharge point along the shoreline generated flow which entrained the sediment through the slits and transported it through the pipe network to the river. The eductor pipe system was split into four separate zones designed to be operated individually and controlled by isolation valves that cycled on and off on a timer.

This eductor did not remove all of the sediment from behind the screens — only that which passed in close proximity to the pipe slits or settled out near the pipes. Corrugated floor plate sections between the collector pipes to assist in directing sediment to the pipe slits were designed, but were eliminated from the initial installation as they would make access more difficult during manual removal of sediment if the eductors were not completely effective. The corrugated plates may be added at a later time if found to be needed.

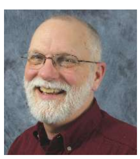
Conclusions

Given the facility site constraints, two novel sediment removal alternatives were developed and constructed to reduce the impact of sediment on headworks operations. The guide vane array substantially increased the efficiency of the existing settling basin within its current footprint, while the eductor system provided an additional passive sediment removal method. These passive removal methods along with other improvements greatly reduced downtime at the headworks facility, increasing operational resilience and saving the utility approximately 56 man-hours of maintenance over the last two years. ■

About The Authors

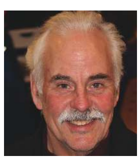
Dr. Joe Orlins is the director of Alden's Redmond, WA, hydraulic engineering and modeling laboratory. He has over 30 years' experience in hydraulic engineering, higher education, engineering and project management, and facilities planning and construction.

Clint Smith, principal engineer at MWH, now a part of Stantec, is a civil, fisheries, and water resource engineer with over 32 years of consulting experience. His background includes the planning, design, and construction of all aspects of fish passage.



Chick Sweeney, senior technical fellow at Alden, has more than 40 years' experience in hydraulic engineering consulting and is a recognized expert in applying field data collection programs and both physical and computer-based hydraulic models to solve facility site selection, design, and permitting problems.

Isaac Willig, senior engineer at Alden Research Laboratory, has 10 years' experience in the hydraulic engineering field, specializing in numerical models to design and analyze hydraulic structures, including spillways, outlet works, and fish passage facilities.



Greg Volkhardt is the environmental programs manager at Tacoma Water. He was the project manager for design of the Headworks Intake Modification Project and has over 30 years' experience working on natural resource issues and salmon recovery in the Pacific Northwest.

Effective Sludge Mixing Through Distributive Mixing Principles

Computational fluid dynamics (CFD) modeling helps wastewater operators derive a formula for highly effective and cost-efficient sludge mixing.

By Sami Sarrouh

Mixing sludge is more complex than mixing other fluids because of its non-Newtonian characteristics. Some manufacturers provide mixing systems for sludge in holding tanks and digesters with varying degrees of success. In order to properly design such systems, it is important to understand the physical characteristics of the fluid and its response to applied forces. Sludge behaves differently at different solids content. To simplify the discussion, we shall categorize sludge solids content, or total solids (TS), from a fluid dynamic aspect according to the following:

- TS ≤ 2 percent — Low content where sludge behavior is not much different from water.
- 2 < TS < 4 percent — Average content where sludge behaves as a non-Newtonian fluid, but not drastically different from water.
- 4 ≤ TS < 8 percent — High content where the solids start to behave as pseudo-plastic fluid. Here the ratio of volatile solids (VS) content to TS becomes a major factor.
- 8 ≤ TS < 12 percent — Sludge is pretty much a semisolid and not achievable without some form of thickening.
- TS ≥ 12 percent — Sludge is dewatered and handled as a solid.

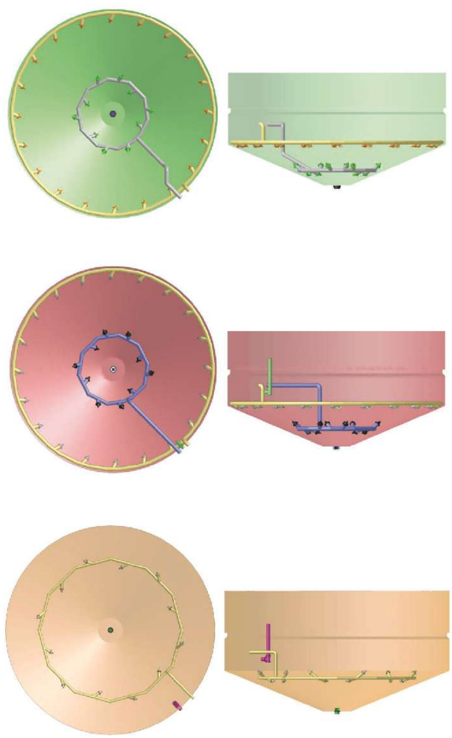


Figure 1. From top to bottom, Design Layouts 1, 2, and 3

TS < 4 percent sludge is not highly viscous and may be handled with ease by most commercial systems. Eight ≤ TS < 12 percent is already thickened sludge and is not typically mixed, as a fluid, in water or wastewater applications. This article will discuss 4 ≤ TS < 8 percent solids sludge mixing in holding or fermentation tanks. Micromixing of such sludge using high-velocity agitation requires a considerable amount of energy due to the high-viscosity sludge, especially in large tanks. Higher sludge concentration slows down settling speed due to particle interactions. Therefore, proper design attempts to achieve macromixing of the sludge by redistributing the sludge three-dimensionally using density currents to further homogenize the volume.

Some sludge may include sand particles. Sand is abrasive and can cause much faster equipment wear, but the solids content required to change flow characteristics is higher than treatment sludge and dependent on particle size. Literature shows that sand slurry exhibits shear-thinning, non-Newtonian behavior for all solids concentrations at low shear rates. However, at higher shear rates, high concentration sand solids suspensions transition from a shear thinning to a shear thickening. Such high shear rates may be present in a pump, for example; therefore, sludge "behavior" may vary considerably with sand content. Accordingly, mixing system design has to accommodate variable conditions and assist in removing potential blockages caused by unforeseen conditions.

Mixing efficiency is determined by the behavior of the fluid interfaces, and knowledge of the dynamics of the interfaces is crucial. The volume enclosed by the outer interfaces between recirculated or influent and ambient sludge, rather than the interfacial surface area between the different sludge, is what determines mixing efficiency. Large-scale dynamics of the outer interface provide the dominant contributions to the mixing efficiency.

The mixer design presented in this article utilizes a combination of dispersive and distributive mixing. The latter, also known as macromixing, relies on swirl created by directed flow that causes laminar thinning of the interfaces, thereby increasing volumetric combination of the sludge. A repeated cutting-and-folding action of the mixture also increases the distribution of different sludge components. The effectiveness of a mixer in distributive mixing is a function of how the influent jets interact with the ambient sludge

Mixing efficiency is determined by the behavior of the fluid interfaces, and knowledge of the dynamics of the interfaces is crucial for the optimization of mixing efficiency.

in a geometric sense. That is, the volume enclosed by the outer interfaces rather than the interfacial surface area is what determines mixing efficiency.

Conversely, the effectiveness of dispersive mixing (micromixing) is dependent on the system's jets' shearing interaction with the sludge. During episodes of high sand influent concentrations, it may be detrimental to have high shear rates because it increases sand particle interactions, making the sludge behave in more of a shear-thickening manner. At an influent concentration of 6 percent or less, the sand is not to be considered of sufficient high concentration to cause the shift from shear thinning to thickening. In this case, the sand has a much higher settling velocity and may accumulate faster at the tank's conical bottom, increasing the concentration there and possibly causing a characteristic change in the recirculation pump suction. The mixing system has to account for sand concentration increasing in the settled sludge at the bottom. In addition, the uniformity of the stress distribution determines the uniformity of the mixing. Without uniform distribution of the shear stresses, it is impossible to guarantee that the same level of mixing is applied to all parts of the tank. Hence, a small number of jet nozzles may not be sufficient to entrain the entire volume of the tank. Turbulence in the region close to the inlet nozzle results in micromixing that cannot be maintained as the flow gets farther from the source in a high-viscosity ambient fluid. Research infers that high jet velocity inlet sources will always revert back to macromixing as the flow gets farther from the source. Thus, the energy cost required to expand micromixing to cover an entire tank would be excessive.

In this case study, solids rheology did not exist for the sludge discharged in the holding tank, but volatile solids were known to be less than 80 percent. Therefore, it was less likely that 4 percent solids would behave as a semisolid and more likely that they would behave as a liquid, making the solids more flowable into the pump suction. In general, CFD results typically suggest a reduced solids settling potential, solely due to calculated high viscosities. If the actual viscosities were different, settling may occur. In addition, there is a difference between water and various wastewater sludge characteristics and settleability. Real-world experience suggests that sludge solids in the design range do settle with time, such as in gravity thickeners, hence the need for mixing systems. Therefore, it is recommended not to base non-Newtonian curvilinear flow conclusions solely on a noncalibrated CFD model utilizing empirical viscosity values. For CFD to be cost-effective, it is best used for comparative performance analysis of design alternatives. Based on the author's experience, it is strongly recommended to utilize a conservative design approach rather than optimize it based on the CFD's results.

A CFD model can provide simulated data needed to optimize a design. The objective of the CFD modeling in this effort was to compare different design layouts rather than to achieve quantitative results. The multiphase flow in a sludge holding tank was modeled using the Euler-Euler multiphase model. Turbulence effects were ignored as the apparent viscosity of the fluid was expected to be high, and therefore, the turbulent regions were expected to be limited to a small volume of fluid near the design's nozzle jets. Therefore, in this case, laminar viscosity effects were expected to be more important than turbulence effects in the majority of the tank volume. Furthermore, the available turbulence models were not validated for use with non-Newtonian fluids. The secondary phase (sand) was modeled as a granular phase including drag force effects on sand particles. Tracking sand distribution was used as a means for evaluating mixing performance. Cohesive sediments were not accounted for in the model. Settled sand was assumed to leave the tank through the bottom outlet.

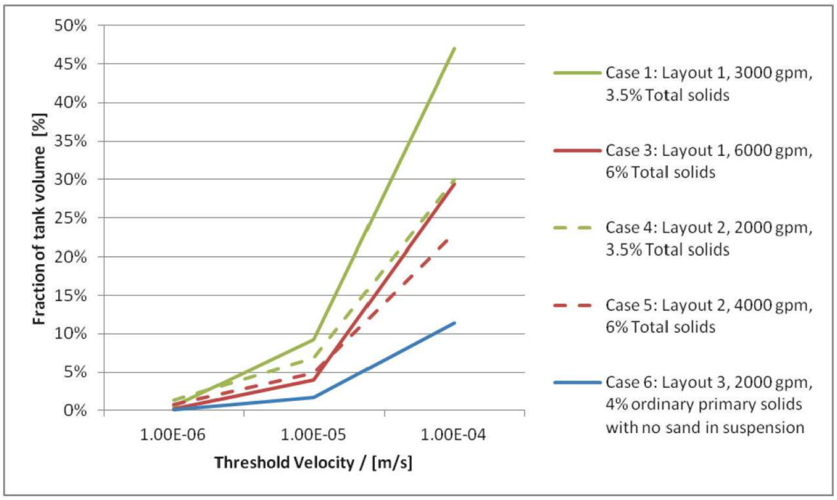


Figure 2. Velocity distribution chart for Design Layouts 1, 2, and 3

As shown in Figure 1, three different mixing design configurations were designed by the author and modeled by Naveen Gopinathrao for a 60-ft-diameter sludge tank with 32-ft water depth at center. Design Layouts 1 and 2 are very similar, with the difference being the inner loop's outward nozzles' direction was reversed in Design Layout 2. Design Layout 3 replaces the two nozzle loops with one intermediate one. Micromixing using high-velocity agitation requires a considerable amount of energy due to the high-viscosity sludge. Therefore, the design attempts to achieve macromixing of

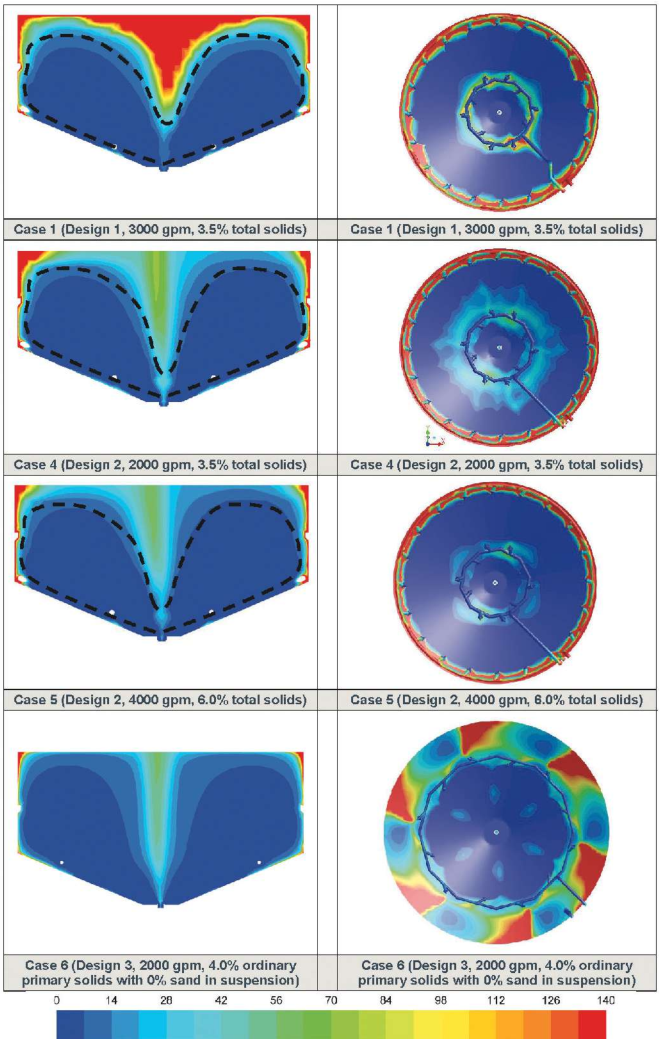


Figure 3. Residence time distribution for Design Layouts 1, 2, and 3

the sludge by distributing the flow in a three-dimensional manner and making use of density currents. Some nozzles push the heavy solids towards the bottom suction where it is combined with lower-density stream lines from the surface. Other nozzles redistribute the sludge to higher regions of the tank.

The mixing system Design Layouts 1 and 2 maximize the effect of density currents that direct the heavier solids towards the suction pipe at the bottom of the cone. The suction inlet is oriented upwards to allow streamlines of lower-density solids originating near the water surface to reach the bottom where it joins the higher-density solids sliding along the conical surface. High-density solids flow by gravity along the sloped bottom towards the recirculation suction pipe aided by momentum imparted by the upper loop nozzles. The nozzles are distributed along the upper cone's perimeter and angled parallel to the conical bottom surface to create boundary layer attachment at the surface of the cone. The nozzles on this upper loop are angled from radial direction. The lower pipe loop is located at about a third of the tank radius. This is the location where all the upper loop's jet paths will intersect. The lower loop has nozzles that are sized to provide the same total flow as the upper loop, although it has fewer nozzles. The lower loop's nozzles are located such that six nozzles are angled up and offset a few degrees from radial, while four nozzles are angled down and offset from radial to continue the solids motion towards the suction pipe.

Modeling Results And Conclusions

The findings show that the mixing system results in a tank with little potential for major sand/solids accumulation. However, it shows that out of the three design layouts modeled, Design Layout 2 with lower recirculating flow rates provides the best mixing with the lowest operational risk and the best ability to recover from unforeseen conditions.

Contour plots of velocity magnitude indicate zones of effective fluid agitation as well as zones of stagnation. Nevertheless, in thick sludge all velocities in the tank are very low due to very high apparent viscosity of the sludge that quickly dissipates the jets' momentum. The velocity distribution in the tank is presented as a chart in Figure 2, which shows the percentage volume of tank where the fluid velocity is less than a defined threshold (1e-6, 1e-5, and 1e-4 m/s in this case). For Case 1 (Design Layout 1 at 3000 gpm), it can be seen that the fluid velocity is less than 1e-4 m/s in nearly 50 percent of the tank volume. The comparison between Cases 1 and 4 versus Cases 3 and 5 shows that Design Layout 2 achieves a better mixing than Design Layout 1, as the volume where the velocity is below 1e-4 m/s is smaller for Design Layout 2 (Cases 4 and 5), although the flow rates for Cases 4 and 5 were two-thirds those of Cases 1 and 3.

Another method used to compare design efficacy involves calculating sludge residence time at various regions within the tank. In a direct comparison between Design Layouts 1 and 2 from the CFD analysis, the potential for sand accumulation in Design Layout 2 is decreased due to lower and better distribution of residence time, although the recirculation flow rate and associated energy is reduced by two-thirds. Thus, a simple reorientation of the nozzles had a significant impact. The better flow distribution resulted in a better residence time distribution — or, in other words, less short-circuiting at various tank regions. In addition, Design Layout 2 performance is such that increasing sludge solids content from 3.5 percent to 6 percent required an increase from 2,000 to 4,000 gpm to maintain relatively similar performance. This indicates that using the 3,000/6,000 gpm flow rates with Design Layout 2 provides the resiliency to help recover from unforeseen operating conditions.

The mixing system design philosophy described in this article has been used successfully in both an alum sludge holding tank application and a wastewater sludge holding tank. The results indicate that proper sludge distributive mixing can reduce recirculation pumping costs by approximately 50 percent while achieving better performance. ■

About The Author

Sami Sarrouh, PE, is vice president and senior technical environmental engineer at T&M Associates. He has over 28 years' experience in applied research, design, and management, working on about 200 different projects in the water and wastewater industry.

A Practical Framework To Improve The Management Of Cyanide In Industrial Wastewaters

Understanding your detection needs when it comes to free cyanide can help you choose the most suitable detection method.

By Dr. Felix Zelder

Cyanide is an essential chemical compound for a large number of industrial processes and products that are part of our everyday lives. Unfortunately, cyanide is also one of the most lethal chemical substances known to mankind. A few hundred milligrams of this compound in solution, or ppm in air, are enough to cause severe to lethal damage in adults if ingested or inhaled. Moreover, it is particularly harmful for aquatic life and habitats.

According to the International Cyanide Management Code, the mining industry consumes about 6 percent of the annual hydrogen cyanide output (>1M metric tons) to remove gold from ore, a process that is more than 100 years old. Cyanide is also used to process foods and produce pharmaceuticals, cosmetics, and plastics. Its ability to form soluble complexes with metals such as zinc, silver, copper, and gold in water, together with its ability to aid anode corrosion and conductivity, makes cyanide an essential component of many electroplating processes.

Why Is The Management Of Cyanide Important?

Each year, the mining and electroplating industries rely on large amounts of useful, but toxic cyanide. Unfortunately, voluntary or involuntary release of this compound into surface waters does occur, posing a severe threat to animals, humans, and aquatic life. In 2000, about 100,000 cubic meters of cyanide-containing wastewater was spilled in Baia Mare (Romania), heavily contaminating the Danube and other rivers in Eastern Europe and affecting the ecosystems, health, and economies of local communities. Tightening regulations imposed by local and regional governments to avoid similar disasters have led to increased cyanide management costs and the reevaluation of internal processes.

For companies in the mining and electroplating industry, proper cyanide management plays a prominent role in decreasing costs, minimizing the chances of provoking environmental disasters, and avoiding bad publicity. In this context, the rapid, accurate, and safe detection and quantification of cyanide in water helps companies to control the quality of their internal processes, comply with regulations, and ensure the absence of toxic substances in their wastewaters.

Current State Of Methods For Free Cyanide Detection

Today, companies interested in the detection of free cyanide in water can choose from a wide range of techniques with variable precision, time consumption, reliability, and equipment requirements. For the exact quantification of free cyanide, techniques such as gas diffusion coupled with amperometric detection offer excellent results, but are rather time-consuming and require specialized equipment. However, colorimetric detection of free cyanide offers an attractive alternative to those interested in binary outputs: It is a semiquantitative method with great versatility in terms of speed, sample preparation, and equipment needed.

Colorimetric detection methods are based on the interaction of free cyanide with an indicator that changes color upon reaction. These methods are simple, less time-consuming, and might not require specialized equipment. They are, however, not necessarily less prone to interferences arising from other chemical species, something that, in many cases, hinders their reliability. Furthermore, several of these methods use harmful compounds, thereby putting the safety of their users at risk. The current market offerings for the colorimetric detection of free cyanide can be divided into three categories based on the technology used.

Chlorinating Reagents (König Reaction)

This traditional detection method is based on the reaction of free cyanide with chloramine T to form cyanogen chloride, which subsequently reacts with pyridine and barbituric acid to form a red-blue dye. Most commercially available free cyanide tests are based on this technology, broadly adopted by the electroplating industry. Users of this method must be aware of their possible exposure to organic solvents, harmful reagents, and highly toxic reaction intermediates.

Silver Nitrate Titration

Commonly used in both the mining and electroplating industry, this method is based on the ability of free cyanide to form complexes with silver in solution. In short, a silver nitrate solution is added to the free cyanide-containing sample, where free cyanide complexes with silver.

	SELECTIVITY	SPEED	SIMPLICITY	SAFETY	EQUIPMENT
CHLORINATING REAGENTS	Low tolerance towards several metal ions, nitrites, sulfides, and thiocyanate	2-15 minutes	Experienced users	Possible exposure to toxic or harmful substances	None and/or dedicated equipment
SILVER NITRATE TITRATION	Low tolerance towards several metal ions, thiosulfate, and thiocyanate	< 15 minutes	Experienced users	Harmful for the environment; can cause irritation if inhaled	Analytical laboratory equipment
CORRIN-BASED INDICATORS	High tolerance towards most interferences except sulfide	< 60 seconds	Nonexperienced users	Harmless reagents	None

Once all free cyanide is consumed, the excess silver ions react with an indicator (rhodamine, dithiozone, and murexide, for example) that changes color once in contact with free silver ions. However, because silver ions can also remove cyanide from other complexed species, the color might disappear after reaching the actual endpoint, thereby leading to false results. Hence, this well-established method requires experienced users and special analytical equipment, and the reagents needed can have limited bench lifetimes.

Corrin-Based Indicators

The most recent technology to detect free cyanide relies on its binding to corrin-based indicators. In this case, the indicator not only senses, but also removes cyanide from the solution. A color change of the immobilized indicator, from orange to violet, indicates cyanide's presence in solution. This method allows for naked-eye detection of free cyanide without specialized equipment, organic solvents, and/or toxic substances. The market availability of this technology is limited, but CyanoGuard AG is currently commercializing test kits based on this method.

Why Is It Important To Evaluate Your Method Of Choice For Free Cyanide Detection?

In many cases, the complexity of your samples might hinder your detection method of choice, leading to false results, unnecessary treatments, and even involuntary disposal of cyanide into surface waters. While most methods perform well in laboratory settings, where the sample composition is known and appropriate equipment is available, their performance might vary in industrial settings. Unfortunately, this is a common situation when testing complex matrices containing known and unknown interfering chemical substances.

When using chlorinating agents, ions such as nitrites and sulfides might interfere with the indicator due to their reactivity towards chloramine T. This is a common situation in

Mining-impaired water in Romania

electroplating wastewaters, where these ions are usually present in high concentrations, often leading to inaccurate readings. Metal ions, such as copper, also interfere with this method and, in many commercial tests, concentrations as low as 1 mg/L are enough to alter the results.

Copper, iron, zinc, and other metal ions can also interfere with the detection of free cyanide when using silver titration methods. In gold-mining processes, where a certain minimal threshold of cyanide is needed to ensure gold extraction from ores, a trustworthy estimation of the free cyanide concentration is essential. Thiosulfate also is known to lead to overestimated concentrations of free cyanide, while the presence of sulfides leads to the appearance of precipitates and renders the detection of endpoints difficult.

Both chlorinating agents and silver nitrate titrations are sensitive to the presence of thiocyanate, a major interfering ion in most free cyanide detection methods. For chlorinating agents in particular, thiocyanate reacts with chloramine T, which is subsequently erroneously detected as cyanide. In many commercial tests, concentrations as low as 1 mg/L can already cause interferences. Moreover, thiocyanate also binds to silver ions, leading to false readings if present in concentrations higher than 10 mg/L. Therefore, determining free cyanide in samples known to contain thiocyanate can be challenging when using these methods.

A few solutions have been proposed to overcome the previously mentioned limitations, with the removal of nitrites using sulfamic acid being one of them. Yet the addition of supplementary reagents to such complicated matrices brings certain risks and can lead to the formation of new interferences. When facing similar cases, diluting the sample remains the safest solution. This option works only for samples with relatively high concentrations of free cyanide and is not recommended when detection limits as low as 0.1 mg/L must be reached.

Corrin-based indicators are a promising new alternative to bypass several limitations of the previously discussed methods. This straightforward technology is rapid, user-friendly, sensitive, and specific for free cyanide. Moreover, it works in both pure water and complex and challenging matrices. The indicator is highly tolerant to elevated concentrations of potentially interfering compounds (e.g., 200 mg/L of nitrite or thiosulfate) and is, therefore, less prone to inaccurate results. Sulfides, the only main interfering ions, can easily be removed through precipitation with ferric chloride ($FeCl_3$) and subsequent filtration prior to free cyanide detection. This technology allows specialized, as well as nonexpert users, to determine free cyanide accurately, using nontoxic materials and minimal equipment.

A Framework To Evaluate Your Free Cyanide Detection Method Of Choice

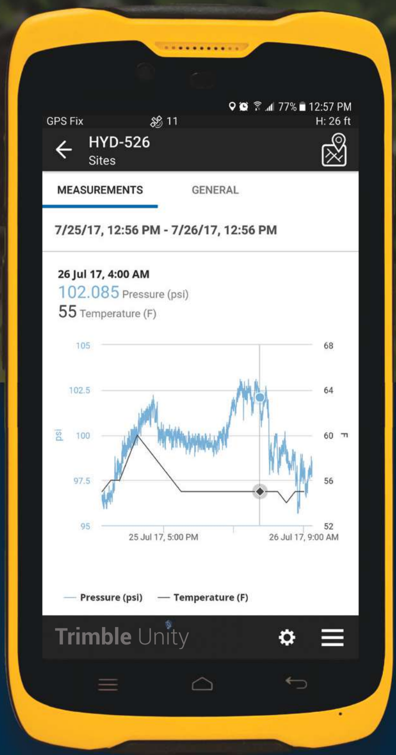
A thorough understanding of the advantages and limitations of currently available free cyanide detection methods enables companies in the mining and electroplating industry to manage cyanide more efficiently, reduce operational costs, and safeguard local ecosystems. To facilitate the decision-making process, we propose actual and potential users to compare free cyanide detection methods in terms of their selectivity, speed, simplicity, safety, and equipment requirements. This framework can help users choose and/or reevaluate their free cyanide detection method of choice, taking into consideration their most critical needs and requirements. ■

References

1. https://www.cyanidecode.org/cyanide-facts/use-mining
2. http://www.toxipedia.org/display/toxipedia/Baia+Mare+Cyanide+Spill
3. Koenig, Robert (2000). Wildlife Deaths Are a Grim Wake-Up Call in Eastern Europe. Science 287(5459):1737-1738.
4. Solutions to analytical chemistry problems with clean water act methods, USEPA Office of Science and Technology (March 2007).
5. ASTM D4282-15. Standard test method for determination of free cyanide in water and wastewater by microdiffusion, ASTM International, West Conshohocken, PA (2015).
6. ASTM D2036-09. Standard test methods for cyanides in water, ASTM International, West Conshohocken, PA (2015).
7. Zelder, F. H., Männel-Croisé, C (2009). Recent advances in the colorimetric detection of cyanide. CHIMIA International Journal for Chemistry 63 (1-2):58-62.
8. Koç, E., et al. (2014). Interference of metals with the determination of free cyanide. Proceedings of 14th International Mineral Processing Symposium, Kusadasi, Turkey 1027-1033.
9. Breuer, P. L., Sutcliffe, C. A., Meakin, R. L (2011). Cyanide measurement by silver nitrate titration: Comparison of rhodanine and potentiometric end-points. Hydrometallurgy 106(3):135-140.
10. Alonso-González, O., et al. (2017). Free cyanide analysis by silver nitrate titration with sulfide ion as interference. Minerals Engineering 105: 19-21.
11. Nagashima, S (1983). Effect of thiocyanate on the pyridine-pyrazolone method for the spectrophotometric determination of cyanide. Analytical Chemistry 55(13):2086-2089.
12. EPA SW-846. Hazardous Waste Test Methods. Method 9014: Cyanide in waters and extracts using titrimetric and manual spectrophotometric procedures (2014).
13. Aebli, Balz; Männel-Croisé, Christine; Zelder, Felix (2014). Controlling binding dynamics of corrin-based chemosensors for cyanide. Inorganic Chemistry, 53(5):2516-2520.

About The Author

Dr. Felix Zelder has been a group leader at the Institute of Chemistry of the University of Zurich since 2006. He specializes in inorganic and bioanalytical chemistry and is the author of more than 11 peer-reviewed papers and review articles on the colorimetric detection of cyanide in various types of samples. He is a scientific partner at CyanoGuard AG.


GPS Fix
11
77% 12:57 PM
H: 26 ft
HYD-526
Sites
MEASUREMENTS
GENERAL
7/25/17, 12:56 PM - 7/26/17, 12:56 PM
26 Jul 17, 4:00 AM
102.085 Pressure (psi)
55 Temperature (F)
105
102.5
100
97.5
95
psi
68
64
60
56
52
25 Jul 17, 5:00 PM
26 Jul 17, 9:00 AM
Pressure (psi)
Temperature (F)
Trimble Unity