In This Issue: Size Matters At EPA | Replacing The Right Main At The Right Time

A VertMarkets Publication

Water Online

www.wateronline.com

Digital Magazine

Drinking Water Edition

THE BIG FRACKING QUESTION

Is Drinking Water At Risk?

FEATURED ADVERTISERS

DID YOU **MISS US** AT **WEFTEC?**

HERE ARE THE HIGHLIGHTS:

Ovivo Bongo™ Series
Double Aperture Fine Screens
Our brand new Bongo™ Series was a breakout star of the show. Flexible, cost effective and efficient.

AEROSTRIP® Aerators
AEROSTRIP® fine bubble diffusers have the highest proven energy-efficiency and longest documented service life in the world.

Ovivo® MBR
Our membrane Bio-Reactors allow for the production of the highest quality effluent, in a very compact footprint.

OVIVO INNOVATIONS @ WEFTEC

VIDEO

Bongo™ Series | AEROSTRIP® Aerators | Ovivo® MBR

VISIT OUR WEBSITE TO LEARN MORE ABOUT ALL OF OUR INNOVATIONS

200 YEARS OF HERITAGE:

EIMCO WATER TECHNOLOGIES | CHRIST | BRACKETT GREEN | JONES+ATTWOOD | Copa LIMITED

CALL US AT **1.855.GO.OVIVO**

VISIT US AT **OVIVOWATER.COM**

AEROSTRIP® is a registered trademark of Aquaconsult Anlegenbau GmbH Austria.

Kevin has the answers that improve billing cycles AND your customer service.

PEOPLE AND ANSWERS
NEPTUNETG.COM/BILLING

NEPTUNE TECHNOLOGY GROUP

WATCH THE VIDEO

flowIQ®

Kamstrup

PRECISION TO THE LAST DROP

INCREDIBLY ACCURATE WATER METERING.
REMOTELY.

Precision engineering, automated production, and trusted customer support make all the difference.

Learn how Kamstrup's flowIQ® smart ultrasonic water meters can improve your operations at www.flowIQ.com.

AMR STARTER KITS AVAILABLE

Kamstrup Water Metering • Atlanta, GA • www.flowIQ.com • info-us@kamstrup.com

The Complete Biogas Flow Measurement Solution

KROHNE

achieve more

Precise results even in difficult applications, wet or dry. OPTISONIC 7300 from KROHNE is the answer.

The OPTISONIC 7300 two-beam ultrasonic flowmeter offers outstanding long-term measurement stability and high-performance across a wide flow range.

The OPTISONIC 7300 features device and process diagnostics plus a built-in flow calculator for pressure and temperature compensation and methane content too. It can measure gases with high CO^2 content, wet gas, or gas with free condensation present. Available in 2" to 24" sizes, the full bore flow sensor is maintenance free and does not create a pressure drop. Factory calibrated, the device measures precisely for years without any maintenance or recalibration.

So whatever your gas measurement needs, 90 years of research and development into flow metering technology mean that you can rely on us.

KROHNE – process instrumentation is our world.

Email: info@krohne.com
Tel: 1-800-FLOWING
us.krohne.com

See video here...

Get product info here...

us.krohne.com

In This Issue: Size Matters At EPA | Replacing The Right Main At The Right Time

A VertMarkets Publication

Water Online

www.wateronline.com

Digital Magazine

Drinking Water Edition

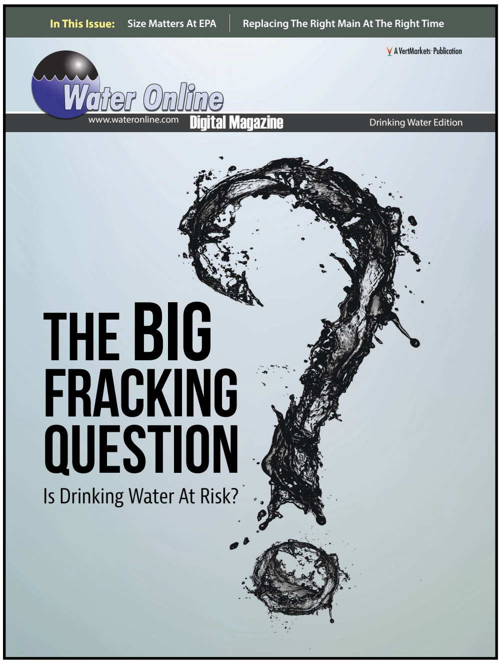
THE BIG FRACKING QUESTION

Is Drinking Water At Risk?

Water Online
The Magazine

CONTENTS

December 2014
Interactive
Digital Magazine



Advertiser Index

Advertiser	Page
AMTA	21
Kamstrup	15
KROHNE	5
McElroy Manufacturing Inc.	11
Myron L Company	13
Neptune Technology Group	9
OVIVO	7
Xylem	18,19

Editor's Letter

3 **Size Matters At EPA**

Industry Insight

4 **Water Utilities Push For AMI And AMR Standardization**

Through research organization collaboration and teamwork, a number of major U.S. utilities are fighting for freedom of choice in advanced metering infrastructure (AMI) and automatic meter reading (AMR).

White Paper

8 **The Big Fracking Question: Is Drinking Water At Risk?**

Understanding the impacts of hydraulic fracturing ("fracking") on source water, in both quantity and quality, is of vital importance to industry, the economy, and society. The latest research on the subject is presented, along with possible solutions to help overcome known and potential problems.

Case Study

14 **Replacing The Right Main At The Right Time**

The 100-year main replacement cycle isn't always best – it can lead to replacing mains that have years of remaining useful life.

Regulatory Analysis

17 **The Nationwide Impact Of California's Hexavalent Chromium Regulations**

California recently became the first U.S. state to regulate hexavalent chromium in drinking water. Will others follow suit?

Water Online The Magazine

101 Gibraltar Road, Suite 100
Horsham, PA 19044
PH: (215) 675-1800
FX: (215) 675-4880
Email: info@wateronline.com
Website: www.wateronline.com

CHIEF EDITOR
Kevin Westerling
(215) 675-1800 ext. 120
kwesterling@vertmarkets.com

EDITOR
Laura Martin
(215) 675-1800 ext. 124
lmartin@vertmarkets.com

PUBLISHER
Travis Kennedy
(215) 675-1800 ext. 122
tkennedy@vertmarkets.com

ASSOCIATE PUBLISHER
Patrick Gallagher
(215) 675-1800 ext. 129
pgallagher@vertmarkets.com

PRODUCT MANAGER
Bill King
(215) 675-1800 ext. 100
bking@vertmarkets.com

MANAGING EDITOR
Michael Thiemann
(814) 897-9000, ext. 340
michael.thiemann@jamesonpublishing.com

PRODUCTION DIRECTOR
Dianna Gross
(814) 897-9000, ext. 255
dianna.gross@jamesonpublishing.com

DIRECTOR OF AUDIENCE DEVELOPMENT
Martin Zapolski
(814) 897-7700, ext. 337
martinz@jamesonpublishing.com

DIRECTOR OF ONLINE DEVELOPMENT
Art Glenn
art.glenn@jamesonpublishing.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.

Size Matters At EPA

The U.S. EPA seems to have a size issue. The agency plays a tremendously important role in protecting the environment and has a strong historical track record, but the scope of the job, coupled with the agency's own ambitions, has progressed to the point that the EPA may be too small to get the job done effectively.

Some may scoff at that notion, seeing the EPA as another bloated government entity plagued by inefficiencies and decisions made from ivory towers — essentially, the typical arguments against "big government." That perception is not without some merit; I'm certain there are countless frustrations among water and wastewater professionals at every level, pointing to policies and procedures that don't work on a practical level. "Get out of the way," is the rallying cry.

I would argue, however, that the EPA needs to be more present than ever considering the escalating threats to water quality and supply such as hydraulic fracturing ("fracking"), climate change, and a host of contaminants emerging from agricultural and industrial processes.

Despite being shorthanded and missing goals, the EPA hasn't slowed its ambition. In fact, the agency is taking on more responsibilities.

The recent and still-surging growth of fracking has overwhelmed the EPA, according to the federal Government Accountability Office (GAO). In a June 2014 report, the GAO concluded that "[the] EPA is not consistently conducting [key] oversight and enforcement activities for class II programs" — a class that includes fracking wells. The report further stated that "[the] EPA does not consistently conduct annual on-site state program evaluations as directed in guidance because, according to some EPA officials, the agency does not have the resources to do so."

The GAO also criticized the EPA in a September 2014 report on the lax handling of hazardous chemical discharges. The EPA hasn't updated its list of regulated "priority pollutants" since 1981; meanwhile, a cocktail of pharmaceuticals, personal care products, and other byproducts of industrial manufacturing has been passed unchecked through wastewater treatment plants and into waterways. As with fracking, the GAO cites a lack of resources as the reason.

EPA Agenda

Despite being shorthanded and missing goals, the EPA hasn't slowed its ambition. In fact, the agency is taking on more responsibilities.

One of the latest (and most controversial) initiatives is the expansion of the "Waters of the United States" that fall under EPA's jurisdiction. The EPA wants to regulate more waterways, much to the dismay of many farmers, businesses, and residential landowners. Critics call it overreach, while the EPA claims expansion is necessary to maintain and improve water quality. Overreach or not, it is still the EPA trying to do more when the GAO says it is already undermanned.

The EPA also recently finalized its *Climate Change Adaptation Plan*, published on October 31, 2014, which details 10 agency-wide priorities to be implemented for new projects across the nation, designed to ensure "adaptive capacity" — readiness and resiliency — in preparation for climate change impacts. Part of that task is the ongoing monitoring and evaluation of the implementation plan to be developed by each EPA program (e.g., Office of Water), regional office, and partner. To me, it sounds like yet another labor-intensive endeavor.

Consider these factors together, and it appears the EPA is not too big at all but rather too small. Granted, the agency may be able to handle all of its chores by improving efficiency and changing procedures — in so doing, perhaps curtailing some "big government" characteristics and complaints — but in the absence of such changes, growing environmental threats and EPA initiatives seem to suggest that the EPA is destined to fall short of its lofty goals.

Kevin Westerling
Chief Editor
editor@wateronline.com

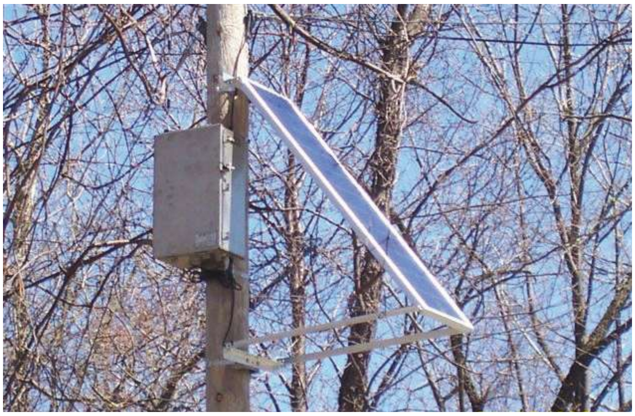
Water Utilities Push For AMI And AMR Standardization

Through research organization collaboration and teamwork, a number of major U.S. utilities are fighting for freedom of choice in advanced metering infrastructure (AMI) and automatic meter reading (AMR).

By David Hughes

In many technical industries, the interoperability of devices is commonplace. For example, buying a printer for your home computer is usually done without much consideration about how the unit plugs into the computer or what language the printer employs to engage the computer system. Such is not the case for obtaining meter readings from today's AMR (via mobile radio collection) and AMI (via radio and cellular collection) systems. The water meter industry has made meters compatible with most AMR and AMI devices that collect meter readings. However, this is where most systems stop being compatible. It is not possible to easily take an AMR transmitter and match it to another manufacturer's data collection system.

With the growing use of external devices such as acoustic monitors for leak detection, pressure and water-quality monitors, automated valves, and other monitors on the horizon, utilities have limited options. The reluctance shown by vendors to offer interoperability is accompanied by a parallel issue of standards in general for AMR and AMI devices. How manufacturers differ in their devices with regard to batteries, wiring, housing, and transmitting power is not easy to discern without a heavy investment in consultants, pilots, and the time-consuming acquisition of self-knowledge from multiple sources.



As AMI becomes more common, utilities seek flexibility from equipment providers.

This is a somewhat alarming situation for a technology that can cost hundreds of thousands of dollars with a promise of lasting 15 to 20 years and providing essential billing and customer service data. This issue was recognized by the Water Research Foundation. It generated a research project to investigate and look for a solution through its emerging issues program. The goals of this innovative Water Research Foundation project are to identify requirements and specification criteria for water utility AMR/AMI systems and to outline approaches to develop and implement standards that address water utility needs.

Collaboration Is Key

The project to assemble utilities, prioritize their needs, and look for a way toward standards and interoperability was granted to American Water and its Innovation group. From the beginning, investigative research relied heavily on utilities and their views on the most important issues in this area. Water utilities, including the City of Houston, East Bay Municipal Utility District (EBMUD), Scottsdale, United Water, DC Water, LA Water & Power, and Las Vegas Valley Water District, are among more than 50 utilities that have been actively engaged in the project to date. The project's tasks were made easier through the support of many utilities — they recognized that there needs to be a better way than to simply go back to the same vendor because the effort to change is made so difficult. The inertia within AWWA Standards to start such an effort and the view of most vendors to not change continued to drive the project in its development stages to rely on the collective utility knowledge and the research team to progress the work. The effort by the water utilities is not unlike the experience in the electric industry, where utilities provided the initial drive.

Nonetheless, opportunity has been provided for vendor input. Project co-principal investigator Ike Moss, from Khafra Services, a former executive for an AMI firm, reached out to vendors and interviewed those who responded during the time that utilities were prioritizing their needs for both AMR and AMI. Most recently, vendors were invited to a free open workshop at the Water Smart Innovations 2014 conference with additional webinars and workshops planned. Vendors appear poised to assist with the development of some standards, as there are clear cases where some materials (such as wiring and transmitter plastic housing) used by the vendors employ common standards. But it remains apparent that, to progress, standards and interoperability, utilities will need to continue to drive the effort.

It is highly recommended that utilities continue to work together and promote the completion of standards that can be readily agreed upon and communicated within the utility community.

To that effort, it is recognized that establishing criteria in a standard format will not be effective. What is envisioned is the use of a utility network that promotes communication between utilities; utilities looking to bid AMR and AMI systems would incorporate the standard language under development into requests for proposal (RFPs) that are issued. As this practice becomes more common, the specification language may become standard by default. With respect to interoperability, utilities will be instructing vendors that commitment to interoperability demonstrated within their bid response (including providing access to data to the utility and third-party meter data management vendors) will be a factor in bid evaluations.

The project team and project advisory committee have also been successful in identifying a potential sponsor of the committee, which will continue after the June 30, 2015 end date of the project that has been extended by the Water Research Foundation to allow the project to be sustained beyond its original year-long run. A tie-in to the importance of interoperability has been recognized as a key component to advancing AMI and its role in water conservation. Utilities will continue to argue that the proprietary stance that allows vendors to maintain their current customers prevents growth into more advanced systems and prevents some utilities from entering the AMI/AMR field to the extent that is seen in other industries where open architecture and interoperability are encouraged.

Giving In To Demand

There are some signs of change that offer encouragement. A few vendors have indicated a willingness to open up their architecture. New meter data management system operators are gaining access to multiple AMI/AMR collection systems so that end data can be combined into a single system for the end users, the utility, and the water customer. There appears to be an increase in the variety of AMI-connected devices to improve distribution system operation that will increase the demand for choice among utilities. To date, many of the acoustic monitoring devices (with varying levels of cost and effectiveness) are locked into just one vendor, but this trend may be reversing. Customer shutoff valve technology and customer portal access are two new features where utilities will likely demand choice.

In the next six months, the project team is poised to continue polishing language to be made available for utilities, continue to build a network to allow utilities to communicate the language, and discuss other related issues and conduct webinars and workshops to help grow this effort. As a Water Research Foundation project, a written report will be produced, but the key output may be the continuance of the working committee and the resulting distribution of the specification language and push for interoperability.

The work carried forward by this project is not complete. It is highly recommended that utilities continue to work together and promote the completion of standards that can be readily agreed upon and communicated within the utility community. That operation should also continue to update vendors on the intent and resolve of utilities to drive the industry to a set of standards and the promotion of interoperability. The utility standards group (self titled AMI-ABLE) is expected to be set up as a working committee inside the Alliance for Water Efficiency organization (subject to board approval) in December 2014. ■

David Hughes is the manager of water research for American Water in the Innovation and Environmental Stewardship department. He works on numerous projects for the Water Research Foundation as an investigator and an advisor. He also serves on the Innovative Infrastructure Research Committee, a cooperative formed by the EPA, Water Research Foundation, and Water Environment Research Foundation.

OVIVO

DID YOU MISS US AT WEFTEC?

HERE ARE THE HIGHLIGHTS:

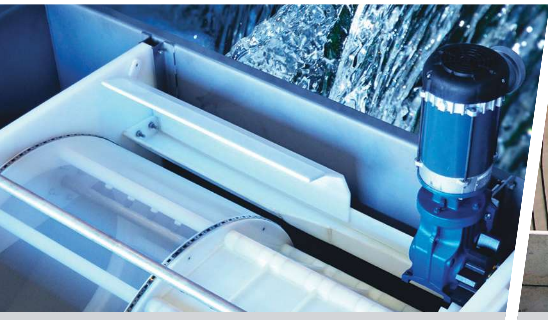
Ovivo Bongo™ Series
Double Aperture Fine Screens
Our brand new Bongo™ Series was a breakout star of the show. Flexible, cost effective and efficient.

AEROSTRIP® Aerators
AEROSTRIP® fine bubble diffusers have the highest proven energy-efficiency and longest documented service life in the world.

Ovivo® MBR
Our membrane Bio-Reactors allow for the production of the highest quality effluent, in a very compact footprint.

OVIVO INNOVATIONS @ WEFTEC

VIDEO


Bongo™ Series


AEROSTRIP® Aerators

Ovivo® MBR

VISIT OUR WEBSITE TO LEARN MORE ABOUT ALL OF OUR INNOVATIONS

200 YEARS OF HERITAGE:

EIMCO WATER TECHNOLOGIES | CHRIST | BRACKETTGREEN | JONES+ATTWOOD | Copa LIMITED

CALL US AT 1.855.GO.OVIVO

VISIT US AT OVIVOWATER.COM

AEROSTRIP® is a registered trademark of Aquaconsult Anlegenbau GmbH Austria.

The Big Fracking Question: Is Drinking Water At Risk?

Understanding the impacts of hydraulic fracturing ("fracking") on source water, in both quantity and quality, is of vital importance to industry, the economy, and society. The latest research on the subject is presented, along with possible solutions to help overcome known and potential problems.

By Blaise Ekechukwu and Jafar Soltan

In an attempt to proffer a solution to the global high demand for energy, energy production has been increased with the introduction of hydraulic fracturing for accessing low-permeability, organic-rich shale formations and tight gas sands, with the resultant increase in natural gas production. These benefits of hydraulic fracturing have led to exemption of flow-back fluids from regulatory bodies in the U.S. and mandates within the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act (SDWA). Hydraulic fracturing, a non-conventional method of drilling, is believed to have negative effects on source water. This article addresses the purported impacts of hydraulic fracturing processes on source water, the mechanism of the contamination of source water, the possible solutions to these negative impacts of hydraulic fracturing, and the need for further investigation and scientific research on the behavior of hydraulic fracturing fluids with the aim of identifying potential risks to source water.

Hydraulic fracturing functions as a double-edged sword: it permits the extraction of oil and natural gas in an unconventional reservoir with low permeability, but also carries significant environmental risk.

Hydraulic fracturing functions as a double-edged sword: It permits the extraction of oil and natural gas in an unconventional reservoir with low permeability but also carries significant environmental risk. To summarize the practice, hydraulic fracturing is a well-stimulation technique used for the extraction of oil and natural gas in unconventional reservoirs with low permeability, such as shale, coal beds, and tight sands[1]. To understand the environmental risks associated with hydraulic fracturing, also known as fracking, a brief overview of the fracking water cycle is below.

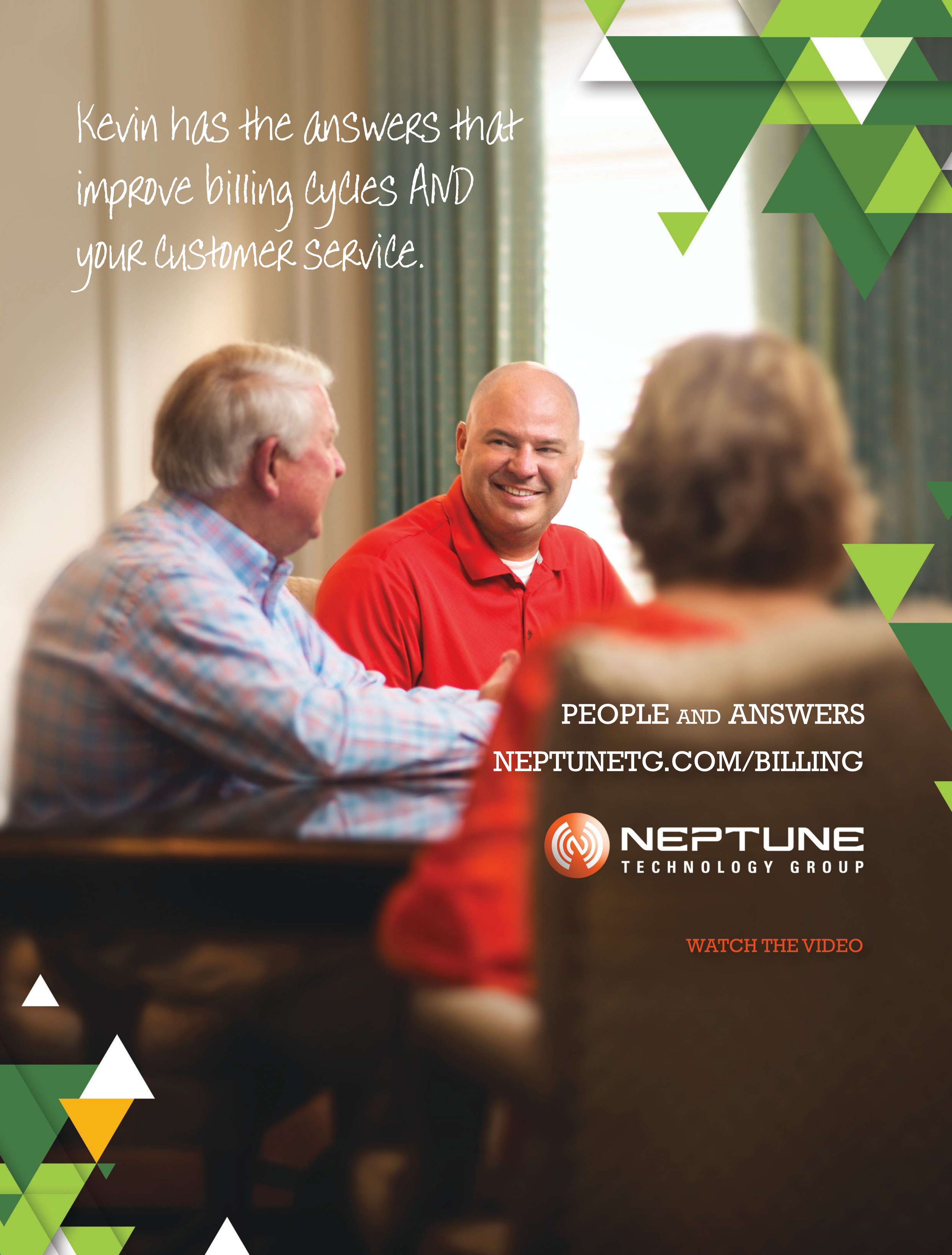
Hydraulic Fracturing Water Cycle

The hydraulic water cycle is divided into five stages[2], as shown in Figure 1.

1. Water acquisition
2. Chemical mixing
3. Well injection
4. Flow-back and produced water
5. Wastewater treatment and waste disposal

The large volume of water needed for fracking is transported to the site, followed by the mixing of the water with chemicals and sand (proppant) at the well site. The well injection process as shown in Figure 2 involves the injection of engineered fluids or chemicals and granular materials into the well at high pressure between 15 to 100 psi (pound force per square inch) to shatter petroleum reserves and stimulate the flow of oil or natural gas to the surface[1]. After the fracturing of the well, the injection fluids are forced out under pressure. The flow-back fluids are either re-injected to Class II injection wells, recycled at the site, or transported to wastewater treatment facilities[2].

Regardless of the high resource potential and economic benefits of the process, there is growing concern about the negative potential environmental impacts and human health implications, which may include groundwater and surface water contamination, land destruction, air pollution, geologic disruption, greenhouse emissions, and radiation[1,3]. The risk of hydraulic fracturing is more focused on its impact on source water and the potential contamination route, which would be the area of focus in this report. Although it is believed that hydraulic fracturing poses a risk to water resources, the extent of the risk and/or damage already inflicted are yet to be properly


Kevin has the answers that
improve billing cycles AND
your customer service.

assessed due to insufficient scientific information and understanding of the mode of the risk[4].

Potential Risks Of Hydraulic Fracturing To Source Water

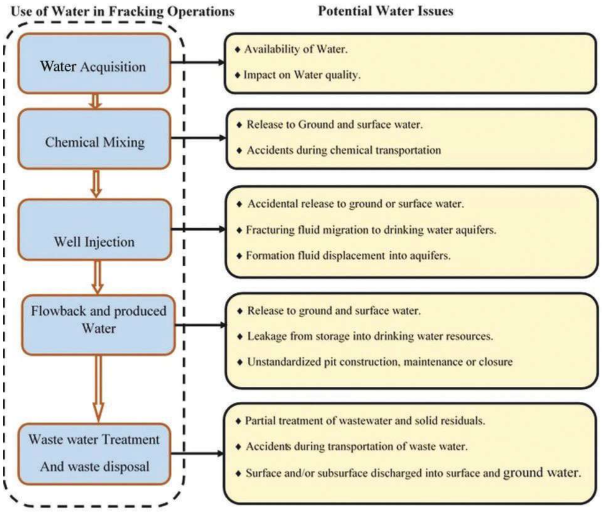
The risks associated with hydraulic fracturing to source water include:

Water scarcity: Despite the consumption of high volumes of water, the total volume consumed is relatively small compared to the existing water resources in Canada[4]. Also, in the U.S., the quantity of water withdrawn for hydraulic fracturing is only about one percent of the total freshwater when compared to usage by thermoelectric-power generation, which consumes approximately 40 percent of the total freshwater withdrawal[6,7]. However, in areas with dry climates like Texas, Colorado, and California, the use of water for hydraulic fracturing could compete with other water needs, leading to local water shortages which subsequently degrade water quality.

Stray gas contamination: Stray gas (fugitive hydrocarbon gases) contaminates shallow aquifers, leading to salinization of shallow groundwater from hydraulic fracturing fluids through leaking shale gas[3].

Spills and leaks: Surface leaks and spills of flow-back and produced water through insufficient pit lining, onsite spills, overflow, or breaching of surface pits during shale gas operations mainly occur near drilling locations[3]. They contaminate soil, surface water, and shallow groundwater.

Figure 1. Water use and potential concerns in hydraulic fracturing operations (adapted from EPA, 2011[2])



Toxic and radioactive accumulation: The disposal of treated flow-back and produced wastewater containing naturally occurring radioactive materials (NORM) may lead to accumulation of radium in stream sediments downstream of the disposal sites[5]. The radiation poses environmental and health risks.

Insufficient treatment and unauthorized discharge of untreated water from shale gas operations: This was revealed by joint U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (FWS) studies, as in the case of Acorn Fork Creek in southern Kentucky in May and June 2007, which linked the deaths of aquatic species to the disposal of untreated wastewater[10]. It was also observed that effluent discharges from treatment sites in Pavillion, WY were known for their high salinity levels (120,000 mg/L), high toxic metals (strontium and barium) and radioactive elements (radium isotopes), and organic makeup (benzene and toluene)[11].

Figure 1 presents the hydraulic fracturing water cycle and the potential source water issues.

Potential Threat To Surface Water Sources

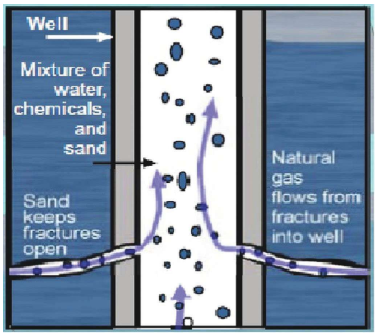
Surface water contamination from hydraulic fracturing fluid may occur during treatment, storage, or disposal processes when there are accidental spills, leakages, or leaching into the nearby surface water[1]. Hydraulic fracturing wastewater also poses a threat to surface water because it contains other chemicals (metals, dissolved solids, organics, and nucleotides other than the fracking additives) that could overflow, spill, or leach into the groundwater and contaminate nearby rivers or streams[1]. When they are treated, the total dissolved solids (TDS) remain high, and the remaining salts are used as road salts, which enter surface waters.

Potential Threat To Groundwater Sources

The anticipated groundwater contamination mechanism is related to flow-back waters and hydraulic fracturing fluids, which could lead to upward leakage of natural gas along well casings or natural fractures that allow entry of gas into fresh water aquifers or into the atmosphere[3]. Further studies are needed to

verify this claim. In addition, the natural geochemical processes allow the gas to be assimilated by the fresh water aquifer, which reacts and may liberate natural contaminants such as metals and hydrogen sulfide, leading to degradation in water quality[4]. This claim has not been substantiated, as there have not been any baseline monitoring and assessment of the assimilation capacity in potential shale gas regions to ascertain the release of these contaminants[4]. Other proposed possible mechanisms include:

Figure 2. The hydraulic fracturing process (adapted from EPA , 2011[2])



- Oxidation of fugitive methane through sulfate-reducing bacteria. This initiates the reductive dissolution of oxides in the aquifer, which may mobilize redox-sensitive elements (manganese, iron, or arsenic) and reduce the quality of groundwater[3].
- High concentration of halogens in saline waters could lead to the formation of toxic trihalomethanes (THM), though there is no data related to stray gas contamination from shale gas wells[3].
- There is evidence of cases of naturally occurring saline groundwater in areas of shale gas development in the Appalachian Basin, which makes the quantification of contamination from antropogenic sources of groundwater pollution difficult[3].

Possible Solutions

1. Previous studies show that stray gas contamination happens within less than 1 km (3,281 ft.)[12,13] of the well site. Based on this, enforcing a safe zone of 1 km between an existing drinking water well and proposed shale gas sites is reasonable.
2. The impact of natural gas irrespective of naturally occurring, or leakage from, shale gas could be addressed by mandatory baseline monitoring using modern modeling tools for the characterization of the chemical and isotopic compositions in areas of shale gas development[3].
3. Full disclosure of the hydraulic fracturing chemicals used for open and scientific discussion and investigations[3] is recommended.
4. A zero discharge policy on untreated wastewater and developing adequate treatment technologies will prevent surface contamination[3]. In addition, developing remediation technologies for adequate treatment and safe disposal of wastewater will alleviate environmental issues associated with hydraulic fracturing processes[3].
5. The water scarcity issue could be remedied using the highlighted means:
   - By good water management practices coupled with improved characterization and monitoring of the drainage basin in the region of shale gas development, the challenge of water use could be avoided[4].
   - The use of saline, mineralized, and other forms of marginal water or other types of liquid-like gel for hydraulic fracturing will limit the use of fresh water resources for shale gas development[3]. For instance, in the Horn River Basin of British Columbia, Canada, saline groundwater of TDS (30,000 mg/L) is treated, which removes hydrogen sulfide and other gases, and the treated water is used for hydraulic fracturing[9].
   - The use of acid mine drainage (AMD) for hydraulic fracturing could mitigate the AMD discharge, which could be blended with flow-back waters, leading to the formation of Sr-barite salts that neutralize some of the contaminants in both fluids[8].
   - Withdrawing water during the peak period and storing until it is needed[4].
   - Recycling of flow-back water.

Conclusion

With the debate on the negative impacts of hydraulic fracturing to environment and human health, there is need for further research on the behavioral activities of hydraulic fracturing chemicals/additives and the mechanism of contamination of source water. Such research would identify the potential risks associated with hydraulic fracturing processes and provide means of mitigating the contamination of source water. ■

References

1. McBroom, M. (2013). *Effects of induced hydraulic fracturing on the environment: commercial demands vs. water, wildlife, and human ecosystems*. Oakwood, Canada: Apple Academic Press. Retrieved from http://www.ebrary.com on September 10, 2014.

2. U.S. Environmental Protection Agency (2011). *Plan to study the potential impacts of hydraulic fracturing on drinking water resources*; EPA/600/R-11/122/November; U.S. Environmental Protection Agency:

Washington, D.C., U.S.A.

3. Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., and Kondash, A. (2014). *A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States*. Environmental Science & Technology [0013-936X] Vengosh, Avner 48 (15), 8334-8348.

4. *Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction*. (2014). Environmental impact of shale gas extraction in Canada. Retrieved from http://www.ebrary.com on September 11, 2014.

5. Warner, N. R., Christie, C. A., Jackson, R. B., and Vengosh, A. (2013). *Impacts of shale gas wastewater disposal on water quality in western Pennsylvania*. Environmental Science Technology, 47 (20), 11849-11857.

6. Nicot, J. P., Scanlon, B. R. (2012) *Water use for shale-gas production in Texas*, U.S. Environmental Science & Technology, 46 (6), 3580−3586.

7. Murray, K. E. (2013). *State-scale perspective on water use and production associated with oil and gas operations*, Oklahoma, U.S. Environmental Science & Technology, 47 (9), 4918−4925.

8. Kondash, A. J., Warner, N. R., Lahav, O., and Vengosh, A. (2014). *Radium and barium removal through blending hydraulic fracturing fluids with acid mine drainage*. Environmental Science & Technology, 48 (2), 1334−1342.

9. Rivard, C., Lavoie, D., Lefebvre, R., Séjourné, S., Lamontagne, C., and Duchesne, M. (2014). *An overview of Canadian shale gas production and environmental concerns.* International Journal of Coal Geology, 126(0), 64-76.

10. Papoulias, D. M., and Velasco, A. L. (2013) *Histopathological analysis of fish from Acorn Fork Creek, Kentucky exposed to hydraulic fracturing fluid releases.* Southeastern Naturalist, 12,90−111.

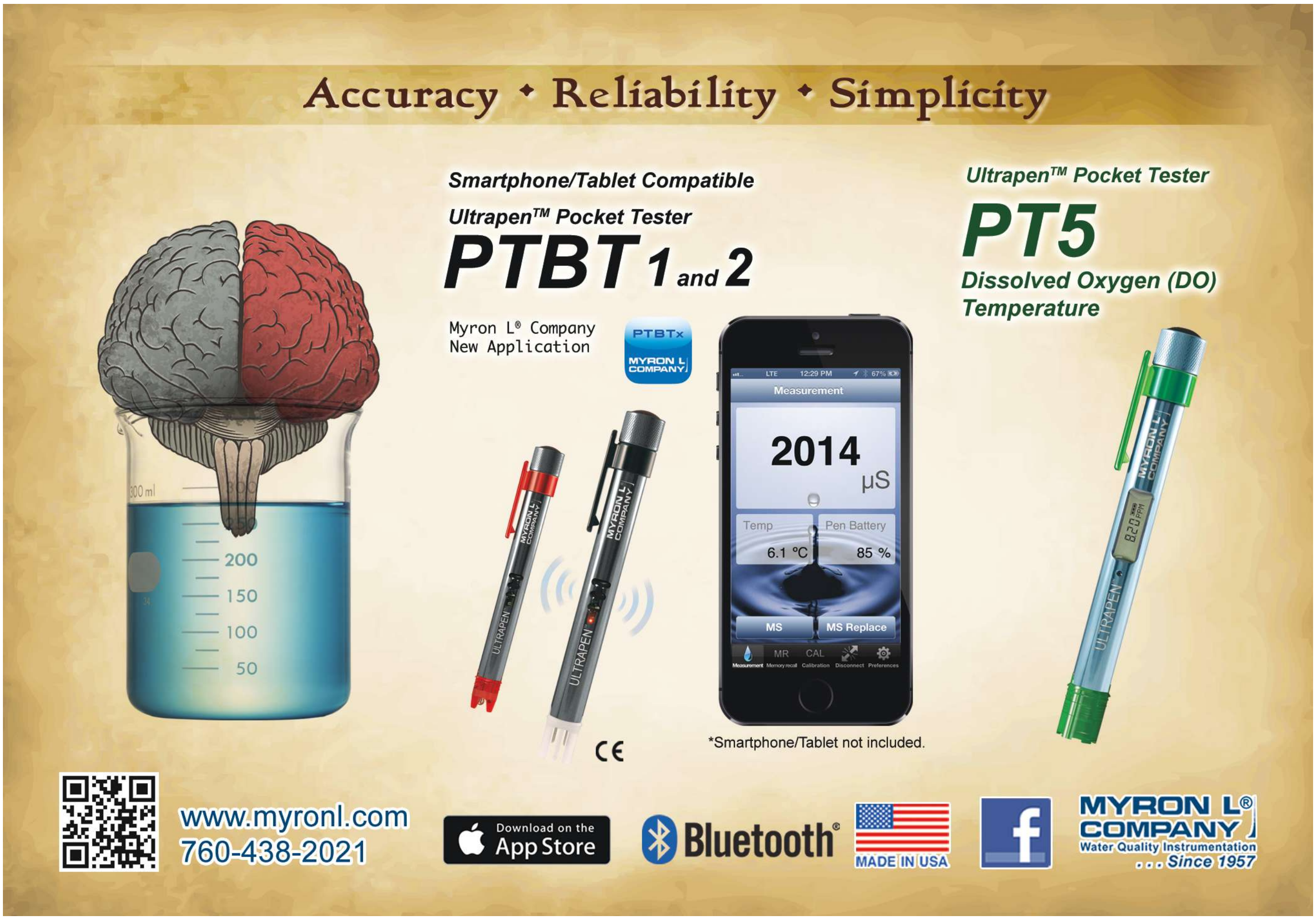
11. Ferrar, K.J., Michanowicz, D.R., Christen, C.L., Mulcahy, N., Malone, S.L., and Sharma, R.K. (2013) *Assessment of effluent contaminants from three facilities discharging Marcellus Shale wastewater to surface waters in Pennsylvania*. Environmental Science & Technology, 47 (7), 3472−3481.

12. Osborn, S.G., Vengosh, A., Warner, N.R., and Jackson, R.B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences of U.S.A., 108, 8172−8176.

13. Jackson, R.B., Vengosh, A., Darrah, T.H., Warner, N.R., Down, A., Poreda, R.J., Osborn, S.G., Zhao, K., and Karr, J.D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. Proceedings of the National Academy of Sciences of U.S.A., 110 (28), 11250−11255.

Blaise Ekechukwu *is a graduate student at the University of Saskatchewan (Saskatoon, Canada), pursuing his master of engineering degree in the department of chemical and biological engineering. His interest is in industrial waste treatment systems and engineering process design.*

Jafar Soltan, *P. Eng., is an associate professor of chemical engineering in the department of chemical and biological engineering at the University of Saskatchewan. An important focus of his research is the development of catalysts to enhance the reaction of ozone with emerging pollutants in water.*



Replacing The Right Main At The Right Time

The 100-year main replacement cycle isn't always best – it can lead to replacing mains that have years of remaining useful life.

By Ryan Flynn

With an interest in keeping rates low and a desire to effectively manage an aging distribution system, municipalities are beginning to utilize asset management principles and condition assessment testing to strategically replace the right mains at the right time.

Tacoma Water, a regional water purveyor serving approximately 300,000 people in Tacoma, WA and neighboring communities, was founded in 1893 and owns and operates over 1,200 miles of distribution water mains. The distribution system comprises a mixture of cast iron, ductile iron, and asbestos cement water mains.

To address an aging distribution system, Tacoma Water implemented a main replacement program in 1995. Funding for the program was steadily increased over time with the goal of reaching a 100-year replacement cycle for distribution mains. By the 2011/2012 biennium, the main replacement had a biennial budget of $18 million and was replacing 10 to 12 miles of distribution main per year.

Selection of main segments for replacement was largely based on the age of mains, material class, and frequency of main breaks. Further, entire material classes such as asbestos cement were considered to be at the end of their useful life based on a handful of significant main breaks.

The issue with the sole reliance upon a 100-year replacement cycle is that it does not take into account the risk of not replacing the mains.

While the conventional 100-year replacement cycle can be easy to communicate to the public and policy makers, reliance on this cycle can lead to replacing mains that have years of remaining useful life. The issue with the sole reliance upon a 100-year replacement cycle is that it does not take into account the risk of not replacing the mains.

Tacoma Water continues to have a very flat break rate, approximately 4 breaks per 100 miles of main each year. This suggests that current failures are random and not affected by age.

Asset Management Plan

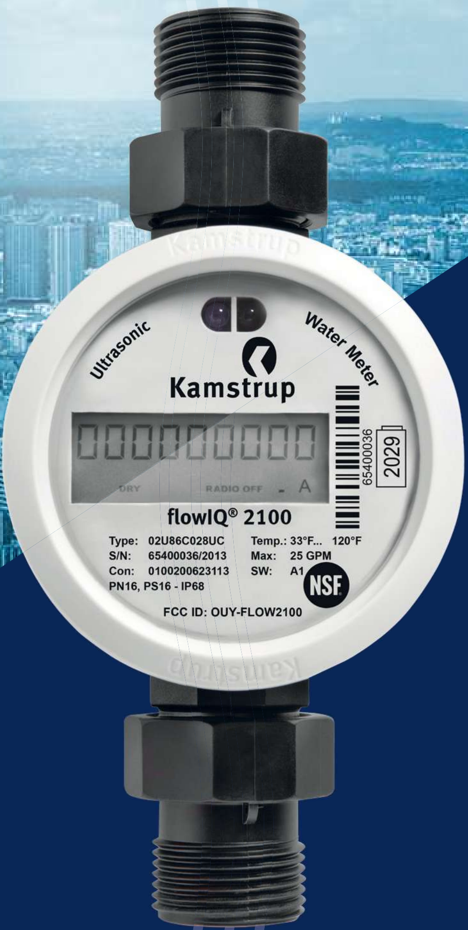
In 2011, to quantify risk and better answer the question of "What if you don't replace it?" Tacoma Water developed a strategic asset management plan (SAMP) for distribution mains. The SAMP integrated two key asset management principles:

1) understanding and accounting for risk; and
2) managing assets to the lowest life cycle cost.

Understanding And Accounting For Risk

Utilizing the risk equation, where risk equals the likelihood of failure times the consequence of failure, Tacoma Water developed criteria for the likelihood and consequence of failure for each main segment. Development of the criteria included:

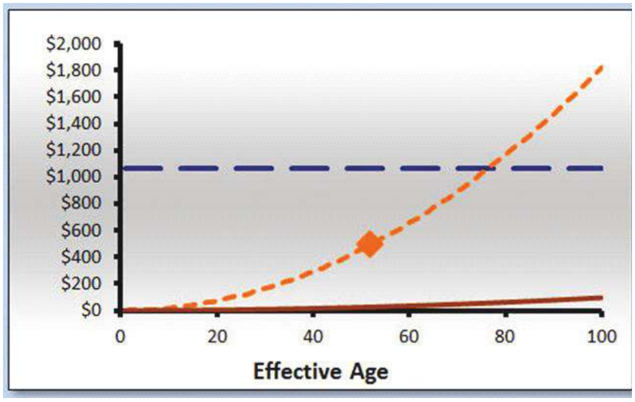
- Plotting failure curves for each main class based upon Tacoma Water's maintenance and main break records. No longer do we have a 100-year replacement cycle as the basis for selecting mains. Main classes thought to have no remaining useful life, such as asbestos cement, are now considered to have remaining life based upon failure curves generated through this exercise.
- Interviewing staff to determine which main segments "kept them up at night" with concern for what a main failure might look like.
- Identifying areas within the distribution system with a high consequence of failure, such as geologic hazard areas, areas of known or suspected contamination, and areas with high customer cost impact.
- Establishing costs for minor, major, and catastrophic failures and determining the probability of such failures based upon Tacoma Water's records. Tacoma Water conducted an assessment of costs associated with main breaks. From 2004 through 2014, Tacoma Water experienced 516 main breaks, with the average cost of a main break equaling


Ultrasonic
Water Meter
Kamstrup
000000000
DRY
RADIO OFF
A
flowIQ® 2100
Type: 02U86C028UC
S/N: 65400036/2013
Con: 0100200623113
PN16, PS16 - IP68
Temp.: 33°F... 120°F
Max: 25 GPM
SW: A1
NSF
FCC ID: OUY-FLOW2100
65400036
2029

$4,441.22. Ninety-five percent of the main breaks during the period cost less than $10,000.

Managing Assets To The Lowest Life Cycle Cost

The criteria are then inserted into Tacoma Water's life cycle cost model (shown below), which evaluates each of the 56,000 main segments in the distribution system to determine the optimal time for replacement. For each main segment, a remaining economic life is generated, indicating estimated time until the annual risk cost of operating a main is equal to the annualized cost of the asset's replacement.



Tacoma Water's life cycle cost model.

Optimal replacement timing is determined to be the age at which the annual risk cost of the asset (shown in orange) is equal to or greater than the annualized replacement cost of the new asset (shown in blue). The annual risk cost of the new asset is represented by the brown line.

The intersection of the orange and blue lines indicates the optimal time for replacement. Operating an existing water main beyond this intersection means the utility is taking excess risk. Whereas replacing the main prior to the intersection means the value of the asset will not be fully realized.

Incorporating Condition Assessment

The output from the economic model provides a prioritized list of main segments based on their remaining economic life. As the prioritized list was generated using a generalized failure curve developed from the maintenance and repair histories for their respective material class, further analysis is conducted to ensure the replacement of the main segments is warranted.

Pipe breaks can be prevented if the right data is collected before they happen.

To confirm the replacement recommendations, Tacoma Water utilized non-invasive acoustic condition assessment technology to conduct condition assessment testing on cast iron and asbestos cement water mains. The assessment technology was selected based upon the short time by which the analysis was completed and the ability of the technology to conduct analysis without service interruption to customers.

By combining the output of the economic model with condition assessment technology, Tacoma Water is provided with quantifiable data that can be used to develop business case justification for main replacement projects. In addition, and perhaps even more important, is that replacing main segments can be deferred if the condition assessment indicates replacement is not warranted at this time. In doing so, our rate payers are able to realize more value from existing assets rather than replacing assets too early.

Through the use of asset management principles by implementation of the SAMP and use of condition assessment technology, Tacoma Water is able to optimally time the replacement of our water mains. In so doing, Tacoma Water will have reduced the capital budget for the main replacement program from $18 million during the 2011/2012 biennium to $9 million in the 2015/2016 biennium. ■

Ryan Flynn has worked for Tacoma Water since 2006. As a senior principal engineer with the distribution engineering section, Flynn is responsible for the main replacement program and serves as the lead for the distribution main strategic asset management plan.

The Nationwide Impact Of California's Hexavalent Chromium Regulations

California recently became the first U.S. state to regulate hexavalent chromium in drinking water. Will others follow suit?

By Dr. Philip Brandhuber

On July 1, 2014, California became the first state in the nation to regulate hexavalent chromium — Cr(VI) — in drinking water. The California Department of Public Health set a maximum contaminant level (MCL) of 0.010 mg/L (10 µg/L) for Cr(VI). This regulation is in addition to the existing California unique MCL of 0.050 mg/L for total chromium — Cr(tot). Total chromium is defined as the sum of the trivalent chromium — Cr(III) — and Cr(VI) species. Outside of California, Cr(VI) remains unregulated, but non-California drinking water utilities must meet the less stringent Cr(tot) MCL of 0.100 mg/L established by the U.S. EPA. The EPA has not announced if it will introduce a national Cr(VI) regulation, but it is likely that a Cr(VI) regulation will be promulgated in the future. The purpose of this article is to familiarize readers with the possible regulation and treatment of Cr(VI) in drinking water.

Chemistry And Sources Of Chromium

Chromium is the earth's 21st most abundant element. It can enter water through the erosion or dissolution of chromium-bearing rocks or minerals as well as through man-made contamination. In natural water, chromium exists in two oxidation states. The oxidized species, Cr(VI), is a negatively charged ion and highly soluble at the pH range of drinking water. The chemistry of the reduced species, Cr(III), is more complex. Depending on pH, it can be a negatively charged ion, an uncharged molecule, or a positively charged ion. At moderate pH (7-9), Cr(III) forms an insoluble hydroxide. Soluble Cr(III) can also associate with organic matter or metal oxides. Hence, while Cr(VI) is quite soluble in water, a large portion of Cr(III) in water may be in particulate form. In natural systems, the presence of manganese-bearing minerals can oxidize Cr(III) to Cr(VI), while the presence of natural organic matter tends to reduce Cr(VI) to Cr(III).

Strong oxidants, like free chlorine, commonly used by utilities for disinfection, can affect chromium speciation by oxidizing Cr(III) to Cr(VI). The kinetics (speed) of the reaction is relatively slow under conditions seen in drinking water plants, but the reaction may become important in distribution systems where Cr(III) can have several days to oxidize to Cr(VI) under the influence of the residual disinfectant. Understanding the extent of this problem is the subject of current research.

The national occurrence of chromium in drinking water is being studied. A 2004 investigation by the Water Research Foundation (WRF) of 400 utilities found an average raw water Cr(VI) concentration of 1.1 µg/L. In anticipation of a possible regulation of Cr(VI), the EPA is requiring utilities to monitor Cr(tot) and Cr(VI) in their treated water as part of the Third Unregulated Contaminants Monitoring Rule (UCMR3). The monitoring period started in January 2013 and will close in December 2015. Through July 2014, the EPA reports that of 2,640 monitored systems, 66 percent detected Cr(tot) (reporting level = 0.2 µg/L), and 87.6 percent detected Cr(VI) (reporting level = 0.03 µg/L). The reader should note that these reporting levels are far lower than the California Cr(VI) MCL. If the EPA establishes a national Cr(VI) MCL similar to California's, it is estimated that 2 to 4 percent of all drinking water systems will be impacted.

Chromium's Health Effects

The movie *Erin Brockovich* heightened the public's sensitivity to chromium, but the movie did not accurately reflect chromium's risks. Trivalent chromium is not harmful to humans at low concentrations. In fact, it is a micronutrient necessary for good health. The EPA classifies Cr(VI) as a carcinogen via exposure by inhalation, but the adverse health effects of low level Cr(VI) exposure via ingestion are less clear. Much of the debate about Cr(VI)'s human health risk centers on how effectively ingested Cr(VI) is detoxified by the gastrointestinal tract. At present, the EPA has not finalized its findings regarding the health risks of Cr(VI) via ingestion, although the State of California independently concluded that ingestion of Cr(VI) in water at levels greater than 10 µg/L represents an unacceptable public health risk.

FLYGT
a xylem brand

IN THE TRADITION OF GROUNDBREAKING INNOVATIONS COMES… FLYGT EXPERIOR™

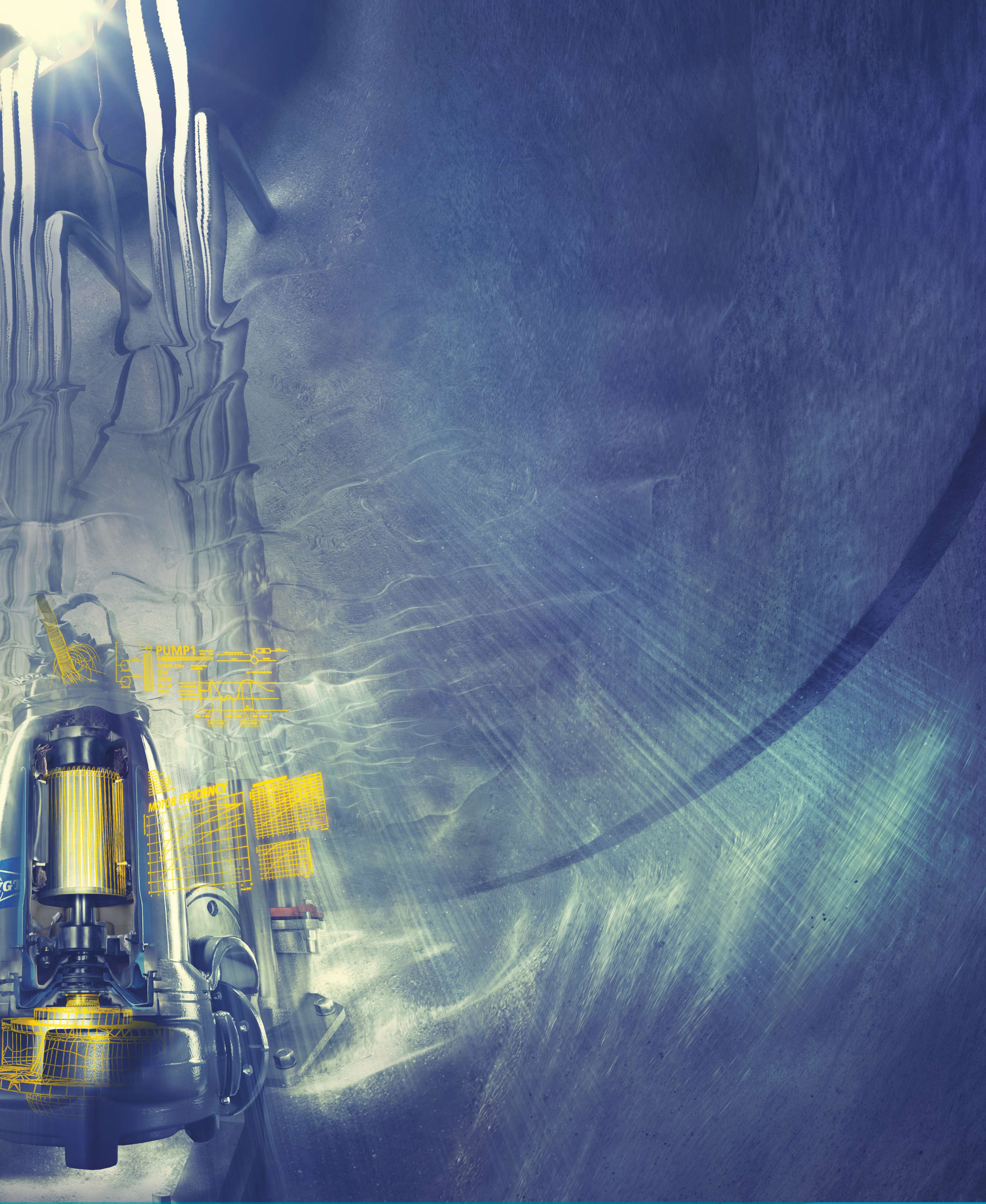
Welcome to a new era in wastewater pumping. Where engineering excellence and a pioneering spirit combine with an unmatched understanding of your needs. The result is Flygt Experior, a uniquely holistic experience that combines state-of-the-art hydraulics, motors, and controls.

Today, Flygt Experior combines N-technology hydraulics and its adaptive functionality, premium efficiency motors and SmartRun – the all-new intelligent control. Flygt Experior comes from years of listening to you and applying our knowledge and expertise, to develop the most reliable and energy-efficient wastewater pumping. It is therefore the ultimate in our commitment to you.

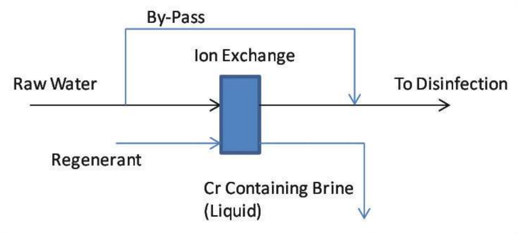
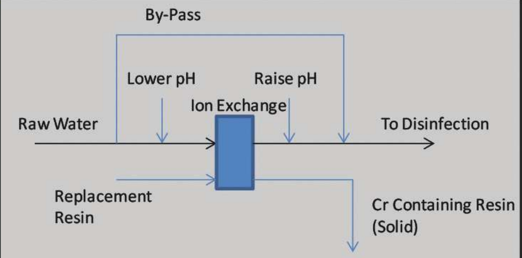
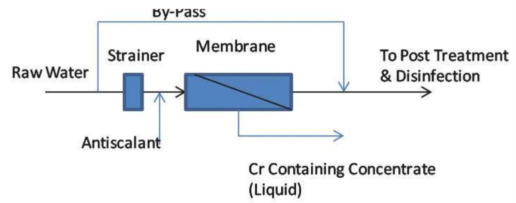
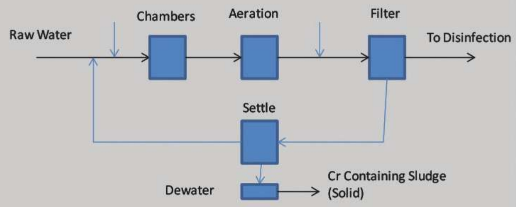
Flygt Experior™
Inspired by you. Engineered by us.

flygt.com/FlygtExperior
Flygt is a brand of Xylem, whose 12,000 employees are dedicated to addressing the most complex issues in the global water market. Let's solve water.

flygt.com/flygtexperior



xylem
Let's Solve Water

Technology		Basis of Operation	Impact of Lower Chromium MCL (20 ug/L => 5 ug/L)	Treatment of Arsenic	Issues to Consider
Strong Base Anion Exchange		Regeneratable ion exchange resin removes Cr(VI)	More frequent regenerations Larger brine volume requiring disposal Large capacity treatment system required; less by-pass flow	Separate arsenic treatment process probably required	Disposal of Cr containing brine
Weak Base Anion Exchange		Disposable ion exchange resin removes Cr(VI)	More frequent resin replacement Large capacity treatment system required; less by-pass flow.	Separate arsenic treatment process probably required.	Large pH changes needed Cost of resin Leaching of resin
NF/RO Membrane		Membrane 'filters' chromium from water	Large capacity treatment system required; less by-pass flow Greater water loss Additional concentrate requiring disposal	Capable of treating arsenic	Disposal of Cr containing concentrate. Water loss may be unacceptable
Reduction Coagulation Filtration		Ferrous iron converts Cr(VI) to Cr(III) Cr(III) precipitates as solid and is removed by filter	More chemical required More solids produced	Theoretically possible but not demonstrated	Complex system Large footprint

Detection Of Chromium In Drinking Water

Chromium can be accurately measured to sub-part per billion concentrations using widely available analytical techniques. Total chromium concentrations are determined by inductively coupled plasma — mass spectrometry (ICP-MS) per EPA Method 200.8. Hexavalent chromium is measured by ion chromatography followed by spectroscopic detection per EPA Method 218.7. There is no accepted method for direct measurement of Cr(III). Instead, Cr(III) concentrations are calculated by difference, subtracting the Cr(VI) concentration from the Cr(tot) concentration.

Technologies For The Treatment Of Chromium In Drinking Water

Currently few utilities in the U.S. operate a full-scale treatment system specifically designed to remove Cr(VI) from drinking water. However, there have been a number of bench and pilot level studies evaluating chromium treatment technologies. Based on the results of these studies, there are four Cr(VI) treatment technologies capable of meeting California's 10 µg/L MCL:

- Strong base anion exchange (SBA)
- Weak base anion exchange (WBA)
- Nanofiltration/reverse osmosis membranes (NF/RO)
- Reduction/coagulation/filtration (RCF).

NF/RO membranes remove Cr(VI) by forcing contaminated water under pressure through a semi-permeable membrane. Hexavalent chromium, along with other dissolved contaminants, is retained by the membrane through a combination of size exclusion and electrostatic repulsion effects. Depending on the specific design of the membrane, rejection of up to 95 percent of Cr(VI) is possible. As with all NF/RO systems, they are hydraulically inefficient. A typical recovery (the ratio of water produced to water treated) is 75 to 80 percent. Hence, membrane systems are undesirable in arid sections of the country where water resources are scarce. In addition, disposal of the

residual (waste) stream, in which most contaminants are concentrated to four to five times their background level, is often problematic.

SBA exchange removes Cr(VI) by passing the contaminated water through a bed of polymeric resin with chloride ions attached to charged functional groups integrated into the resin. The negatively charged Cr(VI) ions displace the chloride ions, attaching the Cr(VI) ions to the resin while releasing chloride ions into the treated water. Once the resin is exhausted, and there are no additional sites on the resin to take up Cr(VI), the resin is regenerated with a high concentration sodium chloride solution. The chloride ions reattach to the resin, and Cr(VI) is released into the salt solution for disposal. A similar process is used to treat arsenic and nitrate in drinking water. Pilot testing has found that SBA is more effective in removing Cr(VI) and less sensitive to the presence of co-occurring ions, like sulfate, than when used for arsenic or nitrate treatment. Several thousand bed volumes of throughput may be obtained when treating Cr(VI) before regeneration is needed. Multiple regenerations with the same sodium chloride solution are also possible. Hydraulically, SBA is very efficient, obtaining greater than 99 percent recovery. The waste stream produced by SBA is classified as a hazardous liquid waste. It consists of a highly concentrated saline solution containing Cr(VI) and other ions removed by the SBA process. Additional processing of the residuals stream is required if a hazardous liquid classification is to be avoided.

WBA exchange also removes Cr(VI) by passing the contaminated water through a bed of polymeric resin. Unlike SBA, the WBA technology is not regenerated and operates as a single-use disposable medium. Throughputs of well over 100,000 bed volumes have been demonstrated by pilot tests. The term ion exchange is somewhat of a misnomer for this technology, since the throughput far exceeds the ion exchange capacity of the resin. In fact, it appears Cr(VI) is removed by reduction and precipitation of chromium on the resin. An important drawback of this technology is its sensitivity to pH. To be effective, the technology must operate at pH 6 or less. Generally, the pH of the water must be depressed for treatment and then raised to produce a non-corrosive stable water for distribution. Given the quality of most drinking water sources, substantial quantities of chemicals are needed to make these adjustments. Operating as a single-use disposable medium greatly simplifies problems with disposing of the treatment residuals, but this advantage is off-set by the technology's need for chemical handling facilities along with its considerable chemical consumption.

RCF is a multi-step treatment process in which Cr(VI) is converted to Cr(III), and the Cr(III) is then removed by filtration. Specifically, ferrous iron (Fe(II)) in the form of ferrous sulfate or ferrous chloride is used to reduce Cr(VI) to Cr(III). At moderate pH, the Cr(III) precipitates as chromium hydroxide, $Cr(OH)_3$ by the following partial reaction:

$$CrO_4^{2-} + 3Fe^{2+} + 8H_2O \Rightarrow Cr(OH)_3\downarrow + 3Fe(OH)_3 + 4H^+$$

A coagulant is used to aggregate Cr(III) into flocs suitable for removal via sedimentation followed by filtration with deep bed media or low-pressure membranes. The RCF process is widely used for industrial chromium treatment and is similar to the conventional treatment process used by many drinking water utilities. Hence, drinking water utilities are quite familiar with the basic design concepts, equipment, and chemicals used by this process. The RCF process produces a non-hazardous residuals stream that can be handled and disposed of in the same manner as residuals from a conventional treatment plant. However, the RCF technology uses multiple unit processes and chemical feeds that by necessity take up a large footprint. The RCF process also requires a good deal of operator attention. For these reasons, the technology is better suited for surface water systems, which typically treat a small number of sources at a central location, rather than groundwater systems, which typically consist of multiple, widely distributed wells located on small sites.

Looking Ahead

The State of California has established an MCL for Cr(VI) in drinking water of 0.010 mg/L. The MCL applies only to California, and there is no national MCL for Cr(VI). The U.S. EPA is in the process of determining if a national Cr(VI) regulation is justified. No date has been set by the U.S. EPA to announce a regulatory determination for Cr(VI). If Cr(VI) is regulated by the U.S. EPA at a level similar to California's, about 2 to 4 percent of all utilities nationally will be impacted. While the drinking water industry has little experience in treating Cr(VI), a number of studies have been performed investigating Cr(VI) treatability. Four technologies, NF/RO, SBA exchange, WBA exchange, and RCF, are effective for controlling Cr(VI) to the California MCL. The most suitable technology for any individual treatment situation will vary, but it is greatly influenced by the disposal scenario for the treatment residual. ■

Dr. Philip Brandhuber is a professional associate at HDR Engineering in Denver, CO. Brandhuber is HDR's expert in the treatment of inorganic contaminants in drinking water using advanced technologies. He can be reached at Philip.Brandhuber@hdrinc.com.