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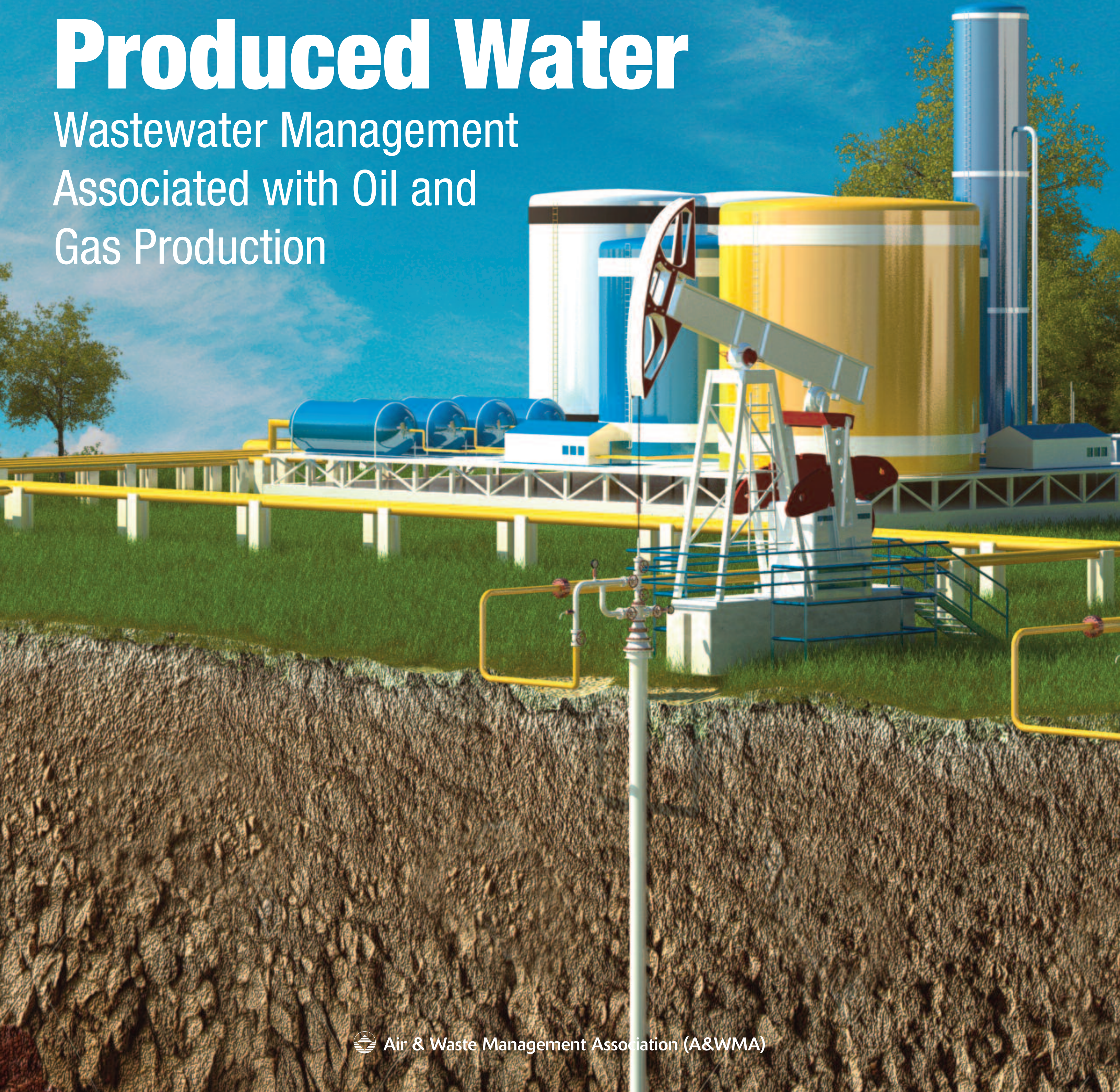
The Magazine for Environmental Managers August 2017

Produced Water

Wastewater Management Associated with Oil and Gas Production



Air & Waste Management Association (A&WMA)

ACE
All That and More

by Scott A. Freeburn, P.E. » president@awma.org

In my May message, I wrote why I thought it would be beneficial for environmental managers to attend A&WMA's 2017 Annual Conference & Exhibition (ACE) in Pittsburgh. Upon returning from this year's meeting, where I had a chance to test out my own recommendations, I realize that I did not do the meeting justice. I believe all of the reasons I gave in May were legitimate, but I undervalued them. Using my earlier message as a general guide, let's look back at this year's ACE.

Seeing Over the Horizon

Starting with the keynote speakers, ACE provided many opportunities to get a look ahead and see what environmental challenges and opportunities might be coming your way. Of special note, Wayne Balta, of IBM, spoke about the challenges of big data, its value to the environmental manager, and how it may be used by citizens, NGOs, and others to analyze environmental risks and consequences. (What may be hard to fathom is the immense scale of the information that will be available in the future. Imagine having at your fingertips all of the information anyone, anywhere has collected about your company—every environmental fact ever documented, every opinion ever published.)

Additionally, many of the more than 380 technical presentations were aimed at providing technological updates. Both industry-specific and general sessions were held on control technologies and measurement, monitoring, and modeling of emissions; waste management; sustainability; and resource conservation. And with multiple sessions designed to specifically address regulatory and legal issues focused on recent and upcoming developments, there was plenty to learn about the future by attending ACE.

Exhibits

I spent quite a lot of time walking the exhibit hall and talking to exhibitors. As I said in May, the exhibition has great value to environmental professionals or any attendee interested in what's new in our environmental business. This year was no exception in that regard, but my chats revealed more. Exhibitors have as many reasons for coming to ACE as there are business plans but, at bottom, there is opportunity that cannot be duplicated anywhere else. A&WMA's Annual Exhibition allows companies to raise their brand awareness, get new leads, and make the valuable face-to-face connections with a select group of current and potential clients. Many exhibitors also believe that exhibiting at ACE is the best way they can support the Association. Exhibitor participation vitalizes our meetings and helps A&WMA facilitate content development, education, and networking for our members and non-member clients throughout the year. That help is much appreciated.

The Association works continuously to make the exhibitor and attendee experience worthwhile. The Association will use the feedback from both the exhibitor and attendee surveys to continue to enhance the benefit of exhibiting for years to come.

Training

I made the claim in May that ACE was a great training bargain. I still believe it, more so than before. The beauty of the meeting is the volume and scope of information that is available to every experience level. In addition to the professional development courses offered on site, several technical sessions included more fundamental training under the general title "How Does It Work?". These training elements were organized by the Young Professionals Advisory Council and were aimed at those new to the profession or thinking about moving their career in a new direction. Students and environmental professionals alike could immerse themselves in a variety of activities, each providing new and surprising educational experiences.

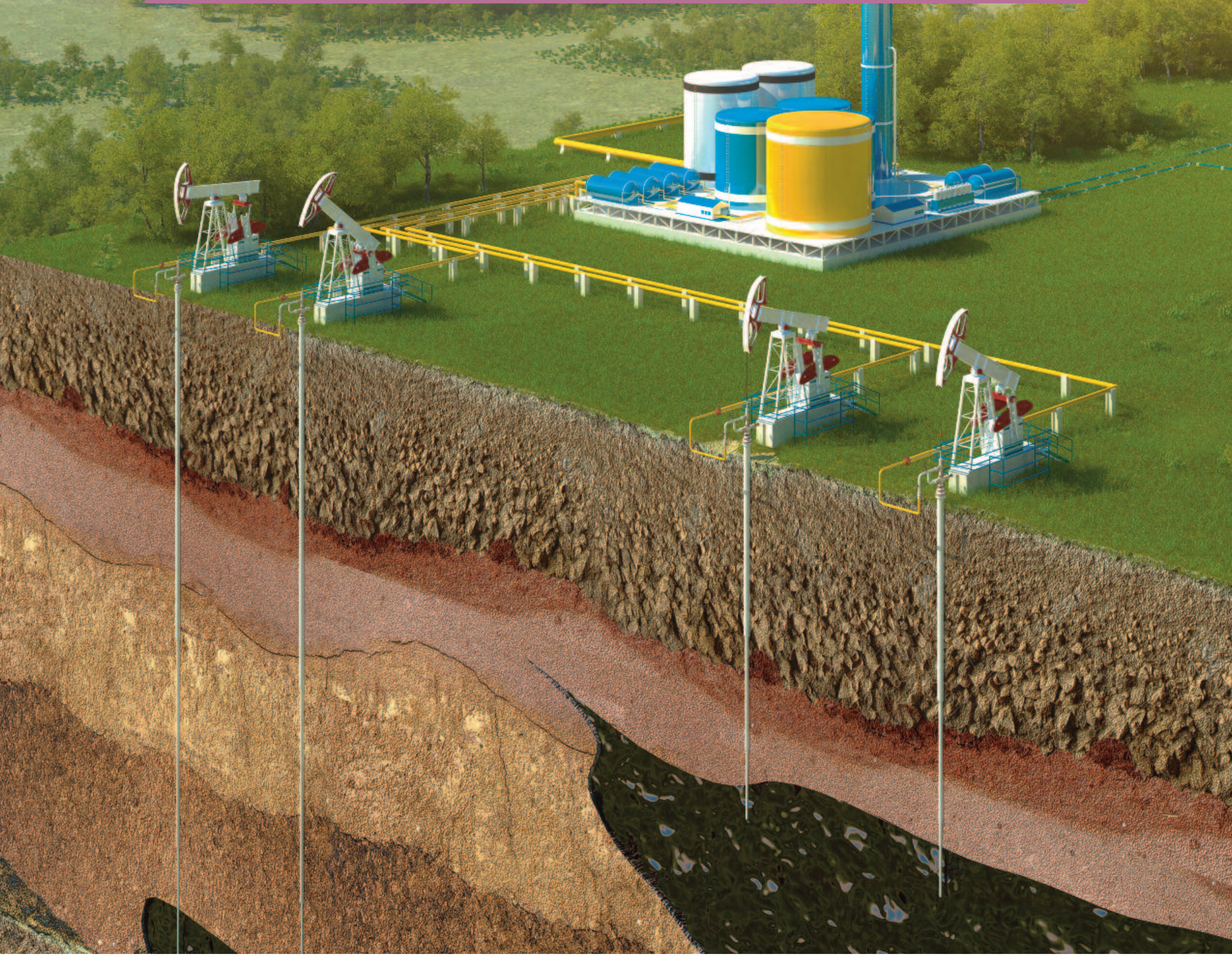
Many of A&WMA's student members also participated in this year's conference, by preparing technical presentations, posters sessions, or taking part in the Environmental Challenge team competition, which gave them a chance to focus their efforts, solve problems, work as a team member, compete, and be judged by working professionals. Where else can a student get that kind of training?

Networking

Networking, in my opinion, is the most undervalued aspect of ACE. Like other elements of a meeting like this, some planning and directed effort provides better results. I find that I learn most around the technical sessions of importance to my work and exhibitors. Last year, an exhibitor entering the U.S. market with a new modeling tool took the time to explain it to me in some detail. From my point of view as an industrial environmental manager, I saw limited value to my immediate problems, but I could see great value to regional air quality planners. The company took the feedback I offered and ran with it and is now working with two West Coast air districts… and that company now places ACE as a very important marketing event on its calendar.

My point is that a single fact or idea can reveal a solution to a problem. Networking increases your likelihood of finding that one fact, especially if you network with purpose and the right group of experts, as you will find at ACE. The long-term payback comes from the new acquaintances you make. Every person you talk to loads your quiver, makes you more knowledgeable, and of more value to your clients and associates. Solving a problem is often a matter of having the right resources and I have met many valuable resources through my ACE attendance over the years.

So, yes, the 2017 ACE was all I said it would be and more. My sincere thanks to the hard work of the 2017 Local Host Committee; the heavy lifting of A&WMA's Councils; and the very determined efforts of the Association's headquarters staff—you all went the extra mile to make this meeting a success. Planning is underway for another great ACE next year. You now know the value attendance can bring to you. See you in Hartford! **em**



Water Management
Associated with Oil and Gas Development and Production

A look at the complex issue of managing water use associated oil and gas production.

The production of oil and gas also produces water, in some cases in greater volume than the oil or gas itself. As referenced in one of the articles in this issue of *EM*, recent studies have estimated that nearly 900 billion gallons per year of wastewater from oil and gas production is generated in the United States. That's a lot of water—using a U.S. population of roughly 326 million people, this equates to 7.5 gallons of produced water generated per person per day. Therefore, oil and gas production is as much about water as it is about energy production.

In the second article, Emily Nicholas, a graduate student at the Colorado School of Mines, offers an excellent perspective on the trends and challenges for the management of produced water. Her discussion draws on both relevant and recent studies that have been conducted in this area.

Next, Daniel Ertel of Eureka Resources and Jerel Bogdan of C&S Engineers detail first-hand knowledge and experience in the design and permitting of a wastewater treatment facility specifically tailored to treat produced water for discharge.

Oil and gas production is as much about water as it is about energy production.

The vast majority of oil and gas wastewater (produced water) is currently being disposed by injection into disposal wells. However a number of issues, including drought, lack of disposal wells, induced seismicity potentially associated with disposal well operations, and competing water demands, are driving the consideration of other means for use or disposal. A range of topics related to potentially doing something else with this water are presented in the articles that follow. This is a complicated issue with various thoughts and perspectives. A&WMA's core purpose to improve environmental knowledge and decisions by providing a neutral forum for exchanging information makes this is the perfect forum for exploring these varied positions.

In the first article, Rick McCurdy with Chesapeake Energy provides a great analysis of issues critical to the evaluation of using produced water for uses outside the oil and gas operations. He discusses issues such as composition of the fluids, operations and conditions that impact the composition, treatment technologies, and cost vs. benefit.

Both the robust treatment processes as well as permitting drivers are discussed.

In the fourth and final article, Dominic DiGiulio and Seth Shonkoff, both with PSE Healthy Energy, address issues currently being evaluated and discussed related to using produced water for purposes, including irrigation of food crops, watering livestock, and aquifer recharge among others. Factoring into the evaluation is what is known and unknown about the constituents potentially present in produced water and the need for more information to better assess risks presented by the varied end uses.

This month's featured topic provides excellent reading and a presentation of the different aspects and perspectives of this emerging and complicated topic. **em**

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Potential Beneficial Use of Water Produced along with **Oil and Natural Gas**

A look at the growing trend to determine if there is a potential beneficial use for water produced along with oil and gas and destined for disposal.

When oil and natural gas are produced, it is common for water to be produced as well. This water can range from near fresh water quality to over-saturated with salts and other minerals. This is true for both conventional oil and natural gas reservoirs, as well as the newer, unconventional plays such as shales.

In 2012, the U.S. oil and gas industry produced 21,180,646,000 barrels—one barrel equals 42 U.S. gallons or 0.159 cubic meters—of produced water. Of this volume, onshore operations accounted for 97 percent, with the remainder being produced offshore. Approximately, 90 percent of the water produced onshore is injected back into the ground via Class II underground injection control (UIC) wells. One half of that water is disposed via deep well injection through operator-owned or commercial disposal wells.

In recent years, there has been a growing trend among the oil and gas industry, state stakeholders, other industries, and academia to determine if there is a potential beneficial use for water destined for disposal. To help determine what other uses might be opportunistic, we need to understand the makeup of produced water.

Composition of Produced Water

While produced water composition can vary, most produced water is a salt brine dominated by sodium chloride. Bicarbonates are usually present as the prevalent form of alkalinity and sulfate concentration can vary from near zero to several thousand milligrams per liter (mg/l). There are often varying quantities of calcium, magnesium, potassium, barium, and strontium as well. Other minerals and metals such as boron, lithium, iron, and manganese are also found in smaller quantities. As these subterranean formations are often under several thousands of pounds per square inch (tens of mega pascals) of pressure, Henry's Law dictates that the water will often contain some quantity of a dissolved gas such as methane, ethane, or carbon dioxide.

Produced water also typically contains organic constituents, such as ammonia or methanol. Ammonia can be naturally-occurring, but methanol is frequently introduced as part of a chemical used during the hydraulic fracturing process or as a gas hydrate inhibitor. Some produced waters also contain minute amounts of naturally occurring radioactive materials (NORMs), such as radium. Finally, in addition to the dissolved constituents listed above, a produced water may contain small quantities of insoluble, suspended materials such as sand. Once the composition of a produced water is known, the next step in potential beneficial use is to understand how it might be used in oil and gas operations, particularly hydraulic fracturing.

Hydraulic Fracturing and Water Use

The development of unconventional oil and gas resources such as shales would not be possible without the technology known as hydraulic fracturing. In this process, a fluid consisting mostly of water is pumped deep underground at very high pressure creating small cracks or fissures in the targeted geological formation. These small cracks allow the trapped oil and/or natural gas to make its way to the wellbore. To prevent these cracks or fissures from closing once the applied pressure is removed, a proppant (usually sand) is pumped with the water-based fluid to keep the cracks "propped" open.

Most of the unconventional wells being drilled today are horizontals, meaning they are initially drilled vertically downward until reaching the targeted formation and then the drill bit is turned to a horizontal orientation and the wellbore is extended for an additional 5,000–15,000 feet (1,524–4,572 meters) through the targeted formation. Hydraulic fracturing of these horizontal wells is a water-intensive process with today's wells requiring anywhere from 5 million–15 million gallons (18,927–56,781 m^3) of water.

To help offset the demand on local fresh water sources, particularly in arid environments, many operators have turned to replacing some percentage of the fresh water used in hydraulic fracturing with produced water. The amount of produced water that can be used depends on the composition of the water and the type of hydraulic fracturing system being utilized.

Hydraulic Fracturing Fluid Systems

Water quality requirements for hydraulic fracturing are largely dependent on the type of fluid system being used. The primary fluid systems used for hydraulic fracturing unconventional wells are:

1. **Slickwater –** a low viscosity fluid designed to carry fine (small) proppant.

2. **Linear gel –** a more viscous fluid designed to transport larger proppants.

3. **Cross-linked gel –** an extremely viscous fluid used for transporting larger proppants and higher concentrations of proppants.

4. **Hybrid –** a mixture of the three above where the first fluid in is a slickwater system, followed by a linear gel and the last fluid being a crosslinked gel.

Slickwater systems are the least complex typically containing only water, a polyacrylamide polymer to help maintain laminar flow during pumping, a biocide to control bacterial concentrations, and a scale inhibitor to prevent water compatibility issues. With this simple composition, the industry has been able to find chemical additives which work with a wide variety of salt and hardness concentrations. Dissolved iron can interfere with these additives so efforts are usually made to oxidize and remove the iron. As most of the chemical additives are surface active agents, there may be a need to filter the produced water to remove any suspended solids.

Linear and cross-linked gels use guar gum (guar), a polysaccharide derived from the guar plant, to build viscosity. When mixed with water, guar produces an observable increase in viscosity that is suitable for helping to transport proppant. For the largest proppant sizes and higher concentrations of proppant, the linear guar gel is "cross-linked" with sodium tetraborate, which works to bind the guar molecules together in a matrix. This process creates an extremely viscous, gelatin-like fluid. These higher viscosity fluids create a few additional concerns for the use of produced water. Guar molecules cannot fully hydrate in water with either a high salt content or high level of total hardness. Additionally, a produced water containing as little as a few mg/l of boron can prematurely cross-link the guar gel in the surface equipment and tanks thus interfering with the hydraulic fracturing operation.

To prevent hydration issues, the use of produced water in linear and cross-linked gels is generally limited to waters with a total dissolved solids (TDS) concentration less than 60,000 mg/l and a total hardness of 20,000 mg/l as calcium carbonate ($CaCO_3$). If the available produced water exceeds these values on both counts, the most economical solution is to dilute the water. If only the total hardness is excessive, techniques such as lime softening or ion exchange can be used to lower the hardness concentration. If boron concentrations are too high, it will need to either be diluted to an acceptable value or removed through selective ion exchange.

Cost versus Benefit

As mentioned earlier, half of all water produced with oil and natural gas in the United States is disposed through deep well injection in operator-owned or commercial disposal wells. The cost of this disposal can vary from \$0.25–\$0.50 per barrel for operator-owned disposal wells that handle water that is piped to them to \$15–\$20 per barrel for water that is trucked long distances to commercial disposal wells. Within this range, there are opportunities in many areas to treat produced water for beneficial use and to save money at the same time assuming there is a demand for this water. Hydraulic fracturing activity and water demand can vary from operator to operator, from play to play and is impacted by commodity pricing for oil and natural gas.

For slickwater fluids, the main objective is the oxidation and removal of iron and the removal of suspended solids. This can usually be done for somewhere in the \$1.00–\$1.50 per barrel range. If using a gel-based system and water quality can be met through dilution with fresh water, the cost is essentially the same as for a slickwater fluid. If it is necessary to remove hardness through lime-softening or if boron must be removed via ion exchange, then the treatment costs can climb into the \$2.00–\$4.00 per barrel range; however, this can still provide a cost savings where commercial disposal is somewhat expensive.

Additionally, beneficially using produced water replaces the need to purchase an equal volume of fresh water thus saving, on average, another \$0.25 per barrel. Operators work diligently to prevent surface spills of produced water to protect the local environment from contact with the various constituents potentially present in the water. The cost ranges mentioned above include liners and containment to guard against the accidental release of produced water.

Summary

While every oil and natural gas operator will have to determine their own economics, if conditions are right, treating and beneficially using produced water can provide a cost savings over conventional, commercial disposal, and a reduction of stress on local water availability in areas prone to drought. This can be a win for both the oil and gas industry, as well as the communities entwined in unconventional resource development. **em**

Rick McCurdy is manager of corrosion, chemicals, and water with Chesapeake Energy Corporation. E-mail: **rick.mccurdy@chk.com**.

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Produced Water and Hydraulic Fracturing

Trends and Challenges in Wastewater Management

An overview of the challenges associated with the reuse and management of produced water generated by oil and gas production.

Following the first commercial hydraulic fracturing operations in 1949, the petroleum industry has been able to effectively enhance oil and gas (O&G) production from both new and old wells. During hydraulic fracturing operations, a mixture of fluid and proppant is injected into the target rock formation to form fractures, which increase permeability near the wellbore. The increase in permeability increases the amount of hydrocarbons produced.

Now that hydraulic fracturing has become a common practice, each well may use millions of gallons of water during operations before O&G production even begins. During production, wastewater is created and routinely disposed of. When operations occur in arid regions where there are already competing demands for water resources, treatment and beneficial reuse can be an alternative to O&G wastewater disposal. Site-specific challenges, such as lack of disposal wells or concerns over seismicity, can incentivize water reuse further and make economically viable solutions unique to each location.

Flowback Water vs. Produced Water

Flowback water and produced water have traditionally been treated as a waste stream of O&G production. Flowback water is fluid returned to the surface after previously being injected (i.e., hydraulic fracturing), and may contain additives used during operations, such as gelling agents, crosslinkers, breakers, and biocides. Produced water is naturally occurring water in the formation brought to the surface with hydrocarbons throughout the lifetime of the well.

When a well begins to produce, the water changes from predominately flowback water to predominately produced water. The change from flowback water to produced water can be gradual, typically a few months or more, depending upon the formation. Ultimately, all water generated is disposed of collectively and is typically classified as produced water.

Flowback and produced waters have different characteristics, meaning that the wastewater stream called produced water changes over time. An example of the variable composition of produced water can be seen in the total dissolved solids (TDS) concentrations summarized in Table 1. Temporal variability of produced water quality can be seen in the Barnett Shale, which often has initial TDS concentrations close to 50,000 parts per million (ppm) and may rise to over 140,000 ppm. Spatial variability can be seen in the comparison of Marcellus Shale and Fayetteville Shale, where TDS concentrations differ by an order of magnitude.

Produced Water Management

Current management of produced water varies by region; however, disposal by means of deep well injection is often the lowest cost option and thus currently used in the vast majority of instances (see Figure 1). Challenges associated with reuse of produced water in the oilfield include bacteria, suspended solids, and scaling. Oilfield technology for well completion and hydraulic fracturing has advanced to accommodate using source water with high levels of TDS.

A common produced water reuse method in the O&G industry is enhanced hydrocarbon recovery, which involves injecting water into non-producing wells to drive hydrocarbons toward a nearby producing well. By injecting the produced water into non-producing wells, much of the injected wastewater remains in the underground formation, and the hydrocarbon production of active wells increases. Enhanced hydrocarbon recovery is common in onshore conventional formations; however, it is not as effective in formations with low permeability, such as unconventional shale. In 2012, enhanced hydrocarbon recovery accounted for approximately

Table 1. Produced water varies in wells by location and over time.

	(PA) Marcellus Shale	(TX) Barnett Shale	(AL) Fayetteville Shale
Average water use per well (million gallons)	5.6	4.0	4.9
"Initial" water produced per well during first 10 days of production (thousand gallons)	500 - 600	500 - 600	500 - 600
TDS concentration range per well (ppm)	40,000 - >120,000	50,000 - 140,000	10,000 - 20,000

Note: Seawater contains approximately 35,000-ppm TDS. *Source:* Adapted from Chesapeake Energy.

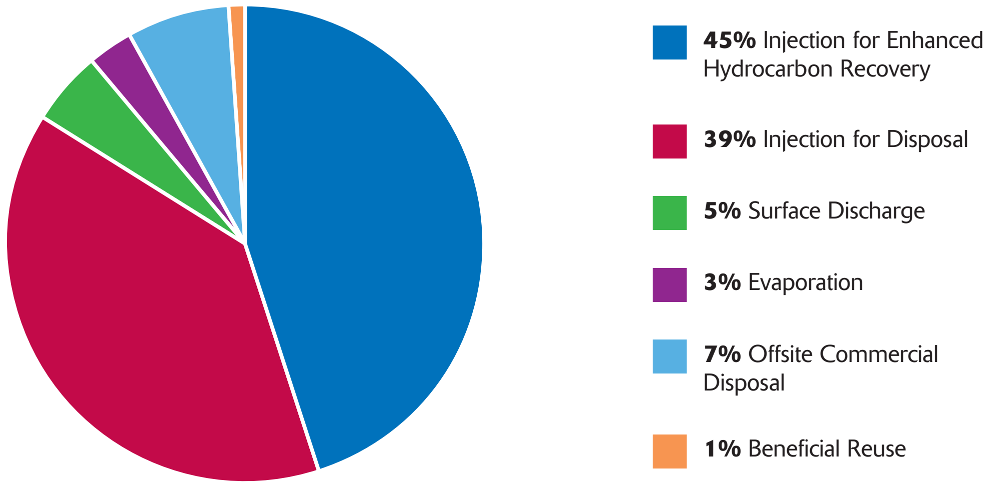

Figure 1. Trends in produced water management in the United States, showing that injection for disposal is a primary method of disposal of produced water.
Source: Adapted from Veil, J. U.S. Produced Water Volumes and Management Practices in 2012; Veil Environmental LLC.

45 percent of produced water management in the United States.

Produced water reuse in the O&G industry from fracturing, dust control, and so forth is the most cost-effective reuse option according to a study by CH2M.[1] Reuse in the O&G industry is a viable option while drilling and fracturing operations are present. As fields become more mature or in times when economic conditions result in decreased drilling operations, other avenues for produced water management must be explored. Other reuse alternatives that may be considered include livestock watering, groundwater recharge, surface water augmentation, and irrigation.

There is general support for beneficial reuse of produced water from stakeholders according to a study conducted by CDR Associates in Colorado.[2] Stakeholders interviewed included O&G industry representatives, regulators, community, and conservation organizations, government officials and researchers. The study concluded that much concern with produced water reuse stems from human and environmental exposure to produced water.[2] Stakeholder involvement, continuing research, and public education will play a large role in properly vetting beneficial reuse options. FracFocus (https://fracfocus.org/) is one educational tool used, as some states require operators to report the chemicals used during fracturing operations to the FracFocus database.

Challenges of Produced Water Treatment

Due to the high concentrations of TDS along with other constituents of concern, reuse options of produced water outside the oil industry, such as streamflow augmentation or irrigation, will most likely require robust treatment including desalination. Even livestock watering which, according to the U.S. Bureau of Reclamation has the least stringent TDS limit of 10,000 ppm, is lower than that of most produced waters (Table 1). Membrane desalination processes, such as reverse osmosis and nanofiltration, have become more economically feasible due to use of energy recovery devices and new generation membranes; however, the membranes themselves are expensive and their lifetime will need to be extended to make the processes viable for treatment of produced water. To ensure desalination processes operate effectively, a thorough pretreatment of the produced water is required. There is ongoing research focusing on engineering an economically viable pretreatment system with conventional biological, chemical, and physical treatment technologies.

Pretreatment challenges stem from various concentrations of suspended solids, oil and grease, dissolved gases and volatile compounds, metals, hydraulic fracturing chemicals, high amounts of organic matter, and in some cases naturally occurring radioactive material.[3] A viable treatment process will be site specific and dependent upon produced water characteristics. The complex nature of produced water, time-varying characteristics, and its tendency to cause scale and corrosion create additional pretreatment costs higher than that of seawater desalination.

Cost of Produced Water

A study by CH2M indicates that desalination is the most expensive management option for produced water, because it will increase current produced water management costs.[2] In Oklahoma, for example, standard source and deep well injection methods are estimated to cost an average of $1.83 per barrel (1 barrel = 42 gallons), whereas treatment with desalination would increase the estimated cost range to between $3.58 and $7.49 per barrel of water (see Table 2).[1] The Bureau of Reclamation estimated a cost range of produced

Table 2. Cost estimates for ten produced water use scenarios in Oklahoma.

Case No.	Management Description	Total Capital ($ millions)	County	Assumed Water TDS (ppm)	Normalized $/barrel
1	Typical Source and Dispose	N/A	Central OK	N/A	1.83
2	Oil & Gas Reuse (treatment cost)	N/A	State Wide	N/A	0.57
3	Produced Water Treatment & Transfer	208	Alfalfa	213,000	1.03
4	Evaporation, low TDS	N/A	Blaine	17,000	1.66
5	Evaporation, high TDS	N/A	Alfalfa	213,000	1.79
6	Desalination for Surface Discharge	22	Beckham	9,000	3.58
7	Desalination for Power Use	88	Pawnee	125,000	4.37
8	Desalination for Power Use	95	Seminole	180,000	4.43
9	Desalination for Industrial Use	35	Grant	227,000	7.41
10	Desalination for Surface Discharge	38	Grant	227,000	7.49

Source: Adapted from Oklahoma Water for 2060 Produced Water Re-use and Recycling Report by CH2M.[1]

Table 3. Estimated cost range for produced water management.

	Cost Range ($/barrel)	
	Low	High
Transportation	0.50	8.00
Water Sourcing	0.25	1.75
Underground Injection	0.07	1.60
Treatment	0.20	8.50
TOTAL (injection only):	**0.82**	**11.35**
TOTAL (treatment only):	**0.95**	**18.25**

Source: Dahm, K.; Chapman, M. *Produced Water Treatment Primer: Case Studies of Treatment Applications, 2014.*

water management, as summarized in Table 3. Most cost variability in produced water management correlates to transportation and potential treatment, giving an overall range of between $0.82 and $18.25 per barrel of produced water.[3] The data strongly indicate that treatment costs must be reduced in order to compete economically with disposal via injection.

One study in Oklahoma looked at the cost of ten water management scenarios (Table 2).[1] The three lowest cost options were reuse in O&G activities, produced water transfer and treatment, and evaporation. The O&G reuse assumed that pipe transfer of produced water exists, which is not the case nationwide. Some places such as Oklahoma and Colorado have existing infrastructure that limits transportation costs. More sparsely populated fields, such as in Wyoming, rely primarily on trucking for water transportation, which can be costly. The produced water transfer and treatment refers to a case that delivers water from a formation in north central Oklahoma, with low water demands and high water production, to Blaine County, which has high water demands for oilfield operations. If the O&G water use is low in areas of high production, evaporation may be a viable option to dispose of produced water. This includes evaporation technology which may also produce a potentially marketable industrial salt byproduct. Evaporation pits can be effective in arid regions; however, less viable for humid climates.

Agricultural needs are seasonal, whereas wells produce water constantly. Agricultural water needs in Oklahoma are for approximately five months each year,[1] meaning produced water would need to be stored for eight months of the year. Additionally, the cost of freshwater in Oklahoma is so low that that treated produced water is not economically competitive.[1] Irrigation may be a viable option in other areas in the United States that have a longer growing season. Crops such as wheat and cotton are currently being studied to learn about toxicity and metal uptake.

Conclusion

Disposal of produced water via deep well injection, where feasible, is relatively inexpensive. Reuse of produced water in the oilfield can be a sustainable option while drilling and hydraulic fracturing are also occurring. Where production is the only activity and drilling and hydraulic fracturing cease, produced water must be managed with an alternate strategy. Most reuse applications outside the oilfield will require robust treatment, which incurs high costs due to pretreatment requirements. To consider beneficial reuse of produced water, it will take site specific knowledge and supporting regulatory framework. With unlimited resources, there are technologies capable of treating any water to any desired quality, but it will take creative thinking to make water treatment technology reliable and economically viable to compete with current disposal methods of produced water. **em**

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Air & Waste Management
Association

2017 Air Quality Specialty Conferences

Get the latest information on technology and solutions for the industry

November 7-9 • Renaissance Long Beach Hotel

Explore advances in measurement technology, data quality assurance, and data uses at the A&WMA's unique specialty conference covering current advances in measurement technology and air quality issues related to greenhouse gas measurements, ambient monitoring, fugitive and area source air measurements, quality assurance, and data uses.

Concurrent sessions feature over 80 presentations and posters covering the latest topics including: Optical monitoring; Instrumentation; Air sensor measurements; Air toxics; Criteria pollutants; Greenhouse gases; Mobile sources; Monitoring networks; PM monitoring and speciation; Quality Assurance; and more.

A vendor exhibit featuring over 20 booths and networking receptions allow for plenty of time to connect with professionals and experts involved in all aspects of the industry. Courses on Continuous Emissions and Monitoring Systems (CEMS) and Quality Assurance will be held on November 6.

Learn more and register online at **www.awma.org/measurements.**

November 14-16 • Sheraton Chapel Hill Hotel

A&WMA's 7th Specialty Conference on issues related to the Guideline on Air Quality Models (40CFR Part 51 Appendix W) corresponds perfectly to the 1-year period after Appendix W promulgation in 2016. The implementation of the changes will be complete and valuable experience will have been gained.

The conference will kick with an explanation of the work EPA is doing now and be followed by sessions on AERMOD model issues, secondary formation modeling advances, comparisons of models to measured data, aerodynamic downwash issues and advances in meteorological data use in modeling.

The popular Town Hall Meeting will feature envrionmental experts from EPA, Georgia EPD, US Forest Service, and law firms discussing successes and challenges of the Guideline revision.

Courses on AERMOD, CAMX and SCICHEM will be offered on November 13.

Register online at **www.awma.org/aqmodels** and find additional information.

A Sustainable Choice for

Unconventional Oil and Gas Wastewater Management/Treatment

When Options Are Limited

A summary of one company's wastewater management activities in support of unconventional oil and gas production in the Marcellus shale play in northcentral Pennsylvania.

Eureka Resources LLC provides comprehensive wastewater management services in support of unconventional oil and gas exploration and production activity in the Marcellus shale region. These services include advanced, centralized treatment facilities that have the flexibility to achieve a range of treatment objectives, such as providing treated water for reuse, generating treated effluent for direct and indirect surface water discharge, and recovering saleable byproducts.

As shown in Figure 1, Eureka has thus far brought three centralized wastewater treatment facilities online in northcentral Pennsylvania (two in Williamsport and one in Wysox), with tentative plans for construction of additional facilities to respond to customer needs, including potential dedicated facilities. The ability to achieve a range of treatment and byproduct recovery objectives is unique relative to most other mobile and centralized treatment facilities in operation in the Marcellus region, and even in other unconventional plays in North America. A majority of the competing facilities are focused on providing a limited level of treatment (e.g., basic physical/chemical treatment for reuse only), which are only viable wastewater management alternatives under a limited set of conditions, namely when there is enough new drilling and completions activity to support reuse.

Eureka was influenced by various drivers to develop their treatment facilities using a design-build-operate model. The complex chemistry of the wastewater generated from unconventional oil and gas exploration and production activity in the Marcellus area, including elevated levels of total dissolved solids (as high as 300,000 parts per million [ppm]), heavy metals, scalants, hydraulic fracturing additives, and technologically enhanced naturally occurring radioactive material (TENORM), presents the primary challenge and served as the biggest driver to Eureka's development of its patent-pending treatment processes. The concentrations of these constituents are near the upper end of the range seen in wastewater generated in other unconventional oil and gas plays.

Geography also played a role. Underground injection disposal is not an economically-viable option in the northern tier of the Marcellus play where Eureka's facilities—and thousands of unconventional gas wells—are located. Regardless, it can be argued that the jury is still out regarding potential impacts of underground injection control (UIC) disposal of large volumes of wastewater associated with unconventional oil and gas activity, including potential seismic impacts. Also, although a relatively abundant supply of surface and ground water is available in the Marcellus shale region to support exploration and production activities, protection of these resources are a concern for numerous stakeholders, and is strictly regulated by the Pennsylvania Department of Environmental Protection (PADEP) and other entities such as the Susquehanna River Basin Commission.

To Eureka, this was a key driver to develop treatment processes capable of generating effluent fit for discharge to surface waters, thus offering the capability of returning clean

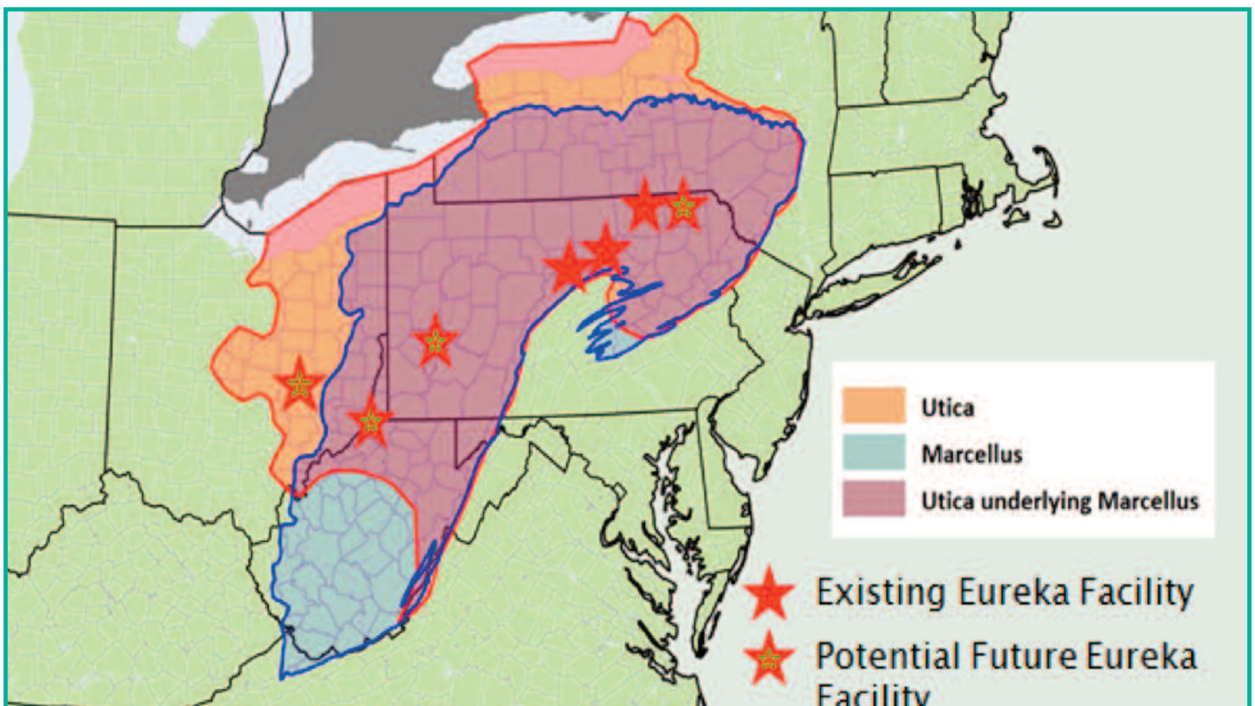

Figure 1. Eureka Facilities Location Map.

Table 1. PADEP WMGR Appendix A De-wasting Standards.

Constituent	Limit	Constituent	Limit
Aluminum	0.2 mg/L	Manganese	0.2 mg/L
Ammonia	2 mg/L	MBAS (Surfactants)	0.5 mg/L
Arsenic	10 µg/L	Methanol	3.5 mg/L
Barium	2 mg/L	Molybdenum	0.21 mg/L
Benzene	0.12 µg/L	Nickel	30 µg/L
Beryllium	4 µg/L	Nitrite-Nitrate Nitrogen	2 mg/L
Boron	1.6 mg/L	Oil & Grease	ND
Bromide	0.1 mg/L	pH	6.5-8.5 SU
Butoxyethanol	0.7 mg/L	Radium-226 + Radium-228	5 pCi/L(Combined)
Cadmium	0.16 µg/L	Selenium	4.6 µg/L
Chloride	25 mg/L	Silver	1.2 µg/L
COD	15 mg/L	Sodium	25 mg/L
Chromium	10 µg/L	Strontium	4.2 mg/L
Copper	5 µg/L	Sulfate	25 mg/L
Ethylene Glycol	13 µg/L	Toluene	0.33 mg/L
Gross Alpha	15 pCi/L	TDS	500 mg/L
Gross Beta	1,000 pCi/L	TSS	45 mg/L
Iron	0.3 mg/L	Uranium	30 µg/L
Lead	1.3 µg/L	Zinc	65 µg/L

water back to the hydraulic cycle—a disposal-level treatment alternative. This treatment capability was seen as particularly important as the Marcellus shale play matures to a point where there is a large inventory of producing wells generating a surplus of produced water, greater than can be reused by dwindling drilling and completions activity. For perspective, nearly 30 million barrels of liquid residual waste (i.e., produced water, fracturing fluids, drilling fluids, servicing fluids, etc.) were generated by oil and gas companies in Pennsylvania during the second half of 2016, according to reporting data released by the PADEP.

Evolving regulatory requirements were also an important driver. In August 2010, the PADEP amended its Wastewater Treatment Requirements to include discharge limits for total dissolved solids (TDS) and chlorides for facilities accepting oil and gas wastewater for treatment and discharge. Before the amendment, treatment facilities handling unconventional oil and gas wastewater in Pennsylvania were only required to treat and remove heavy metals, with no treatment for TDS and chlorides. It did not take long to confirm that dilution was not an adequate management alternative, as elevated levels of TDS and other constituents were observed in Pennsylvania surface waters subsequent to the start of unconventional oil and gas development in Pennsylvania in 2008.

In March 2012, the PADEP issued a new residual waste general permit—WMGR123—which authorizes the processing and beneficial use of processed liquid wastes generated on oil and gas well sites and associated infrastructure. The new general permit provided "de-wasting standards" (see Table 1). Wastewater treated to the standards is considered de-wasted, offering oil and gas companies flexibility to handle and store these waters, including storage in freshwater impoundments having less-stringent design standards relative to residual waste impoundments.

In addition to regulatory drivers, Eureka has established business drivers, including maximizing the recovery of saleable byproducts, offering potential additional revenue streams, applying a level of treatment that allows return of water to the hydrologic cycle, minimizing risks associated with transport/storage of wastewaters, and providing a sustainable choice for oil and gas wastewater treatment when other wastewater management options (e.g., UIC injection, reuse-level only treatment) are not available or are limited.

Eureka's Centralized Treatment Process

A summary of Eureka's centralized treatment process is illustrated in Figure 2. The patent-pending treatment process employed by Eureka is comprised of the following unit processes:

Wastewater Receiving/Segregation and Pretreatment:
- Receiving water storage
- Primary clarification/oil removal
- Methanol rectification
- Oil separation/recovery
- Coagulation/flocculation physical/chemical treatment
- Secondary clarification
- Physical/chemical sludge thickening and dewatering

Secondary Treatment—Thermal treatment:
- Pretreated water storage
- Mechanical vapor recompression (MVR) distillation
- Concentrated brine storage
- MVR crystallization
- Distilled water storage

Tertiary Treatment—Distillate Treatment (Patent-Pending):
- Membrane biological reactor (MBR) treatment, with nutrient removal
- Ion exchange
- Reverse osmosis (RO) treatment

The actual unit processes installed at each facility will depend on customer needs, with flexibility being paramount. For example, Eureka recently modified the waste and air permits for the Second Street facility in Williamsport to include methanol rectification, and is in the process of modifying the Wysox facility's permits to include methanol rectification. This capability, which allows for the recovery of saleable methanol byproduct, was added in response to increasing levels of methanol in unconventional oil and gas wastewater generated in the region, typically used for such purposes as seasonal freeze protection and dehydration of gas gathering lines. The recovered methanol byproduct purity is typically near 98 percent, and is primarily sold for reuse in oil and gas applications. Eureka has also obtained a WMGR029 permit at the Second Street facility, allowing for the management and recovery of waste oil.

The mechanical vapor recompression (MVR) crystallization process is a thermo-mechanical distillation process that relies on the use of electric-driven blowers to compress, and thus, increase the pressure and temperature of vapor produced from a boiling pot of pretreated oil and gas brine wastewater ("mother liquor"). The mother liquor is concentrated to a point where crystallization of high-purity sodium chloride product occurs, which is later recovered, dried, and packaged for sale for various uses, including pool salt and deicing salt.

Valuable Lessons Learned

During the selection, design, and operation of MVR crystallization technology to treat high-TDS wastewater, currently in

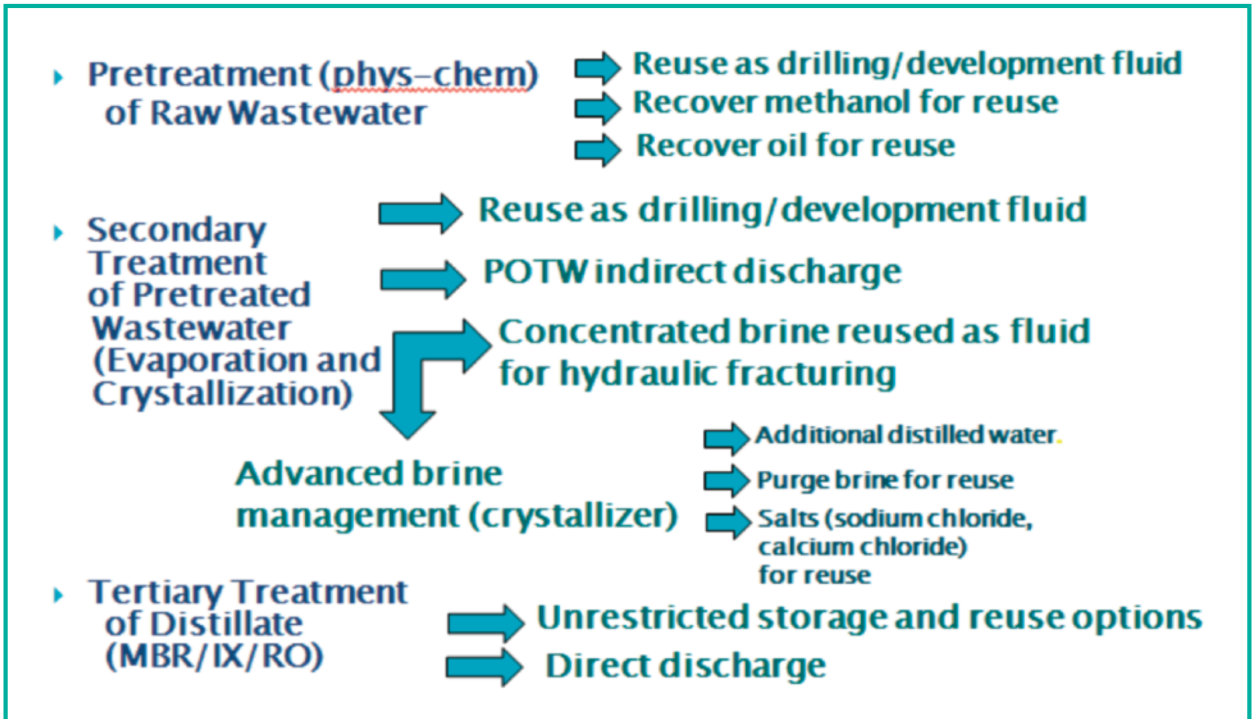

Figure 2. Treatment Approach for Maximizing Recycle and Benefcial Reuse.

place at the Wysox facility, Eureka accumulated a robust list of "lessons learned," some of which are noted below.

Vendor Selection

Application of crystallizer technology for treatment of oil and gas wastewaters is extremely limited. Much of the existing design and operating experience for MVR crystallizers is based on salt solution mining operations, which generate sodium chloride feed brines with lower impurity variability. Several elements came into play during the vendor selection process, including considerations of domestic versus foreign vendors, compression system technologies, turn-down capability, building code/certification compliance, materials-of-construction considerations, and boundary limit considerations.

Safety

Inclusion of a crystallization process significantly increases the level of mechanical complexity and can incorporate both high temperature and pressure vessels. Safety considerations must be factored into the design of the crystallizer and operators must be educated and trained on safe operating protocols.

Byproduct Quality Control

The characteristics of the mixed brine oil and gas wastewaters can be extremely variable with elevated concentrations of constituents that can complicate treatment, including various alkali earth metal chloride salts (e.g., sodium, barium, strontium, calcium, and magnesium chlorides), radionuclides, and organics. It is important to understand the range of variability associated with the oil and gas wastewater that will be received at the wastewater treatment facility, so that the required pre-treatment system and residuals management strategies can be selected and designed to generate optimum crystallizer feed quality necessary to achieve and maintain optimum byproduct quality.

Condensate Management

Management options for the distillate produced by a crystallizer is an important design consideration. Options include recycle and/or direct or indirect discharge. All options require consideration of onsite storage requirements. Direct or indirect discharge may require additional treatment following crystallization due to the presence of elevated levels of inorganics (e.g., barium and strontium), volatile organics, ammonia nitrogen, and other constituents that can become present in the distillate.

Byproduct Market Development

In order to develop a reliable market for byproducts, an understanding of the market for the byproducts is required. There will likely be a need to demonstrate product quality equivalency which necessarily requires extensive byproduct testing. There will also likely be a need for targeting and engaging potential customers ahead of time, obtaining necessary regulatory approvals for sale of the byproducts,

Table 2. CRSD effluent characterization analyte list.

Analysis	Method Name
TOC	EPA 415.1
Aldehydes	SW-846 8315
VOCs	SW-846 8260B
SVOCs	SW-846 8270C
Pentatonic and Hexanoic Acids	Targeted Library Search 8270C
Pesticides	SW-846 8081A
PCBs	SW-846 8082
Organic Acids	SW-846 8015B
Alcohols	SW-846 8015B
Glycols	SW-846 8015B
2 Butoxyethanol	SW-846 8270C
TPH C8-C40	SW-846 8015B
30 ICP Metals	SW-846 6010B
Mercury	SW-846 7470A
Hexavalent Chromium	SW-846 7196A
Trivalent Chromium	SW-846 6010B
Sulfate, Chloride, Fluoride, Bromide	EPA 300
Ammonia	EPA 350.2
TDS	SM 2540D
Ra 226 and Ra 228	EPA 903.0 and 904.0

and implementing necessary QA/QC procedures and plans. In order to develop a reliable market for byproducts, investment in equipment to obtain/assure byproduct quality may be necessary. Such equipment may include conveyance, processing, packaging, and storage facilities.

Eureka has completed coproduct and beneficial use determinations as required by the PADEP for sodium chloride salt generated by the crystallizer at the Wysox facility, in support of various uses. The core of the evaluations focused on demonstration of chemical equivalency of Eureka's byproduct salt with comparative salt products sold commercially in bulk and packaged forms for various uses. In support of an offtake agreement for commercially-sold pool salt, Eureka brought a semi-automated salt drying and packaging system online at the Wysox facility in January 2017, capable of bagging 20 tons of evaporated salt byproduct per hour.

The MVR crystallizer also generates a heavy, mixed-chloride brine, enriched with calcium chloride at a concentration of 18 to 22 percent. Eureka is currently marketing the purge byproduct to the oil and gas industry as a base for drilling and completion fluids, while concurrently evaluating and pilot testing additional treatment of this mixed-chloride brine to recover other useable byproducts, such as commercial-grade dry calcium chloride and lithium, and/or to generate a higher purity/higher concentration liquid calcium chloride byproduct.

Eureka has developed a patent-pending process for generating de-wasted water from the distillate generated from the MVR crystallizer process at the Wysox facility, and is currently the only oil and gas treatment facility in Pennsylvania capable of achieving the dewasting standards set forth in the PADEP's WMGR123 permit. Eureka received approval from the PADEP in November 2014 of the de-wasting capability following an extended demonstration.

In addition to the de-wasting demonstration, Eureka has also worked with the Center for Responsible Shale Development (CRSD) to conduct an even more robust characterization of the Wysox facility effluent in an effort to support CRSD's development of a performance standard for nonconventional oil and gas activities for discharging treated wastewater to surface waters. The CRSD is an independent 501(c)(3) non-profit organization whose mission is to support continuous improvement and innovative practices through performance standards and third-party certification. Additional performance testing results for the analytes included in Table 2 demonstrated that the treatment process at the Eureka Wysox facility was performing as intended and achieving a high-quality effluent capable of meeting strict CRSD surface water discharge performance standards.

Summary

The drivers behind the development of Eureka's treatment processes are numerous and largely influenced by region-specific factors. However, the oil and gas industry is currently undergoing a similar evolution in other unconventional plays around the world in response to region-specific drivers. Wastewater characteristics, regulatory drivers, proximity to viable and stable UIC disposal, need for water reuse, regional sensitivity of water and geologic resources, overall regional risk tolerance, level of availability and participation of third-party service companies, and marketability of saleable byproducts are just some of the variables that are being integrated into decisions concerning the types of wastewater management/treatment resources deployed to manage unconventional oil and gas wastewater. What may work for one play, may not necessarily work for another. **em**

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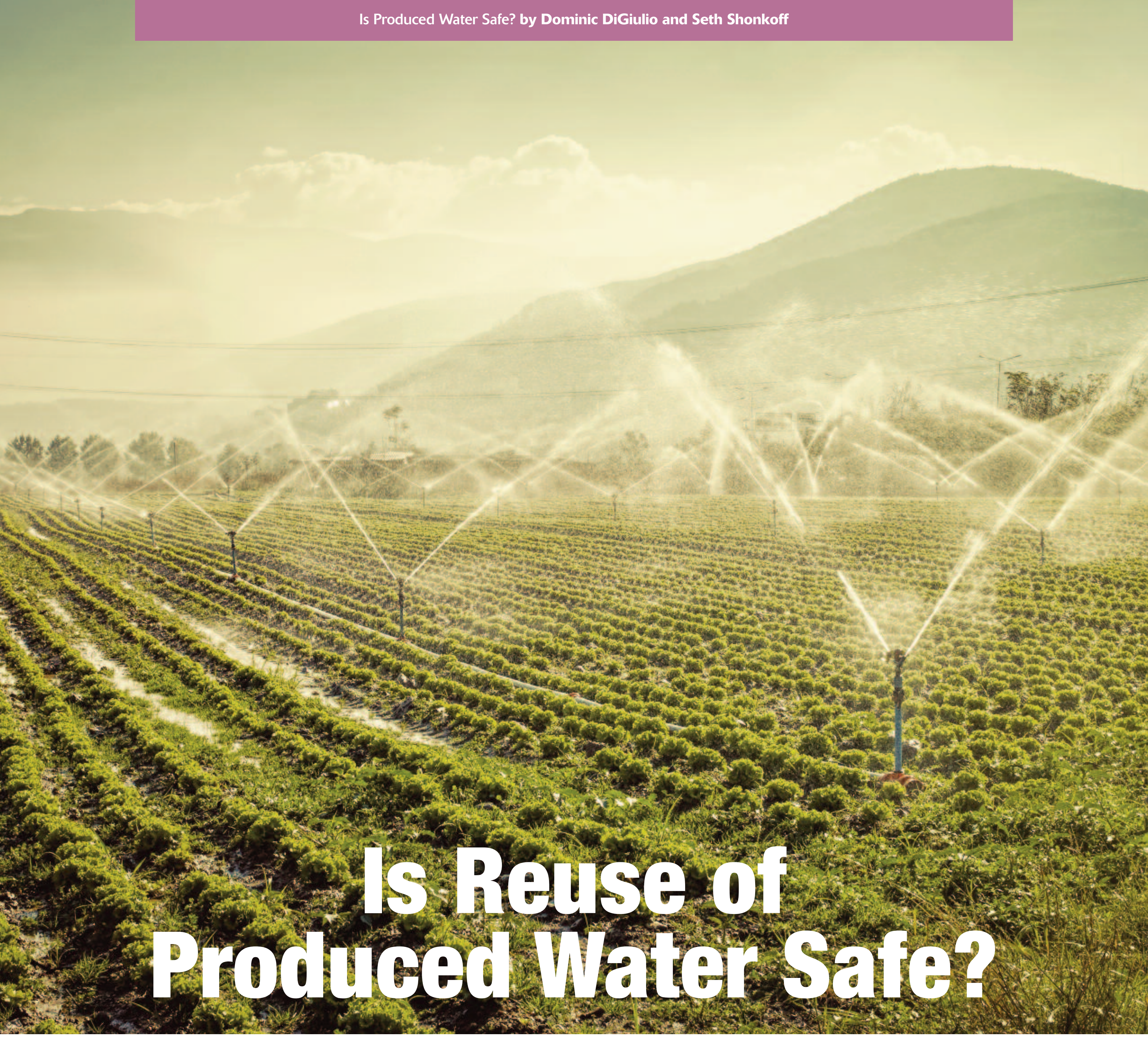

Is Reuse of Produced Water Safe?

First, Let's Find out What's in it

This articles considers the risks associated with reusing produced water from oil and gas production.

A proportion of produced water from conventional and unconventional oil and gas development is currently being reused to irrigate food crops, water livestock, recharge aquifers, create and maintain wetlands, and suppress dust, among other uses. Produced water is also sometimes treated at wastewater treatment plants (WWTPs) and discharged to surface water. As oil and gas field produced water is increasingly used, questions have arisen as to whether it is safe.

To answer this question, assessments of the chemical risks of reusing produced water must be undertaken and require the following: the identification and quantification of chemical compounds present in produced water (e.g., major ions, metals, organic compounds); sufficient information on the physiochemical (e.g., Henry's Law constants, solubility, vapor pressure, etc.) and biological (e.g., anaerobic and aerobic biodegradation, bioconcentration in humans, animals, and other biota) properties of compounds present in produced water; and adequate information on mammalian and ecological (e.g., aquatic) toxicity to estimate safe aqueous concentrations for protection of human health and the environment.

The fundamental question then is: do these conditions exist to properly evaluate risk posed by the reuse of produced water or discharge of partially treated produced water to land or water bodies?

Sources of Chemicals in Oil and Gas Produced Water

Chemical compounds present in produced water are sourced from four broad categories:

- **Chemical additives,** such as strong acids, corrosion inhibitors, biocides, scale inhibitors, iron control, and clay stabilizers used during routine oil and gas development operations (e.g., drilling and routine maintenance).[1,2]

- **Additional additives,** such as gelling agents, foaming agents, crosslinkers, breakers, friction reducers, pH adjusters, and biocides used during well stimulation treatments (e.g., hydraulic fracturing and matrix acidizing).

- **Geogenic substances,** such as salts, heavy metals, radium, and hydrocarbons, brought to the surface during development.

The Need for Chemical Disclosure

Identification of the compounds in produced water logically begins with the requirements for disclosure of chemical additives used downhole during oil and gas development. Regulations in 21 of 27 oil and gas producing states now require the disclosure of chemicals used for hydraulic fracturing—many through the voluntary FracFocus (http://fracfocus.org/) Chemical Disclosure Registry developed by the Ground Water Protection Council.[3] It is unclear why disclosure for chemicals used during hydraulic fracturing is not required in all oil and gas producing states.

Disclosure, when required, is limited to chemicals that are not considered proprietary, which introduces significant uncertainty to risk assessment. Stringfellow et al.[4] reviewed 1,623 hydraulic fracturing treatments entered into FracFocus for an estimated 5,000 – 7,000 hydraulic fracturing treatments known to have occurred in California between 2011 and 2014 (reporting rate ~23% – 32%) and found that 3,071 of 45,058 (~7%) of entries for additives were considered propriety. Similarly, Shonkoff et al.[2] assessed chemicals used in steam injection oil fields in California that provide produced water to food crop irrigation and livestock watering and found that 46 percent of the compounds were reported as proprietary.

California appears to be the only state that requires disclosure of chemicals used for acid well stimulation treatments, including matrix acid stimulation and acid fracturing. There is considerable overlap in the chemicals used for routine maintenance acidizing (i.e., activities conducted in most oil and gas wells) and matrix acid stimulation,[5,6] suggesting the need for expanded chemical disclosure for all acid treatments.

The South Coast Air Quality Management District in Southern California is the only regulatory agency in the United States that requires disclosure of chemicals used routinely during conventional oil and gas activities. There is extensive use of chemicals during routine oil and gas development operations (e.g., drilling, cementing, wellbore clean-outs, scale and corrosion control). The frequent overlap between chemicals used during hydraulic fracturing and these routine operations, as well as the observed larger number of chemicals used in these routine operations compared to those used in hydraulic fracturing,[1] suggests the need for chemical disclosure to be expanded to routine operations.

The Need for Chemical Analysis of Produced Water

While disclosure of chemicals used in routine operations and hydraulic fracturing and acidizing treatments is of considerable value in identifying compounds that could be present in produced water, actual chemical analysis of the waste stream prior to discharge of produced water is important from public health and environment perspectives. In some cases, produced water has been analyzed for inorganic composition (i.e., major ions, heavy metals, and radioactive elements) and to some extent for known organic additives. However, more comprehensive analyses of organic compounds present in flowback and produced water is only in nascent stages.

The use of innovative analytical methods has resulted in the detection of organic compounds not routinely analyzed for or detected using standard U.S. Environmental Protection Agency (EPA) methods. Advanced methods for detection of organic compounds includes high-performance liquid chromatography with tandem mass spectrometry (HPLC–MS/MS),[7,8] liquid chromatography quadrupole time-of-flight mass spectrometry (LC/Q-TOF-MS),[9-12] two-dimensional gas chromatography mass spectrometry (GCxGC-MS),[13] GCxGC-MS coupled with time of flight analysis (GCxGC-TOF-MS), and ultra-high resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS).[14]

The Need for Monitoring and Analysis of Chemical Transformation Products

Continued development of analytical methods is necessary to not only identify exotic organic compounds in produced water, but also to identify abiotic and biotic transformation products of these compounds. Strong oxidizers used during hydraulic fracturing may mediate abotic reactions forming a variety of compounds in flowback and produced water, especially in saline water, such as halogenated benzenes, pyrans, alkanes, and acetones.[13]

For example, Leuk et al.[14] detected numerous iodinated organic compounds in flowback samples (> 800 formulas in one sample alone). The large numbers of iodinated compounds detected are of particular concern given the greater toxicity of iodinated disinfection byproducts compounds compared to their chlorinated and brominated counterparts.[14,15]

Examples of biologically mediated transformation include the biocide 2,2-dibromo, 3-nitrilo propionamide used in nearly one quarter of hydraulic fracturing treatments, which biodegrades to dibromoacetonitrile, a more toxic and persistent biocide.[16] Alkoxylated nonylphenols, disclosed in around half of all hydraulic fracturing treatments, biodegrade to the relatively persistent endocrine disrupting compounds octylphenol and nonylphenol.[16]

The Need for More Complete Toxicological and Environmental Profile Information

There are also significant data gaps on physicochemical properties, biodegradability, and toxicity of a large number of compounds used in and associated with routine operations and hydraulic fracturing and acid stimulation.[1,4,16-18]

For instance, in an attempt to assess the mobility, persistence, and toxicity of 659 organic compounds known to be used for hydraulic fracturing, Rogers et al.[17] noted that experimental data on biodegradation existed for only 312 compounds (47%) of which only 47% (or 22% of the total number of compounds) were relevant for anaerobic conditions expected in subsurface media because of the high biological oxygen demand of additives.

Yost et al.[19] noted that chronic oral reference doses and cancer oral slope factors existed for only 83 and 23 of 1,076 compounds (or 8% and 2%, respectively) identified by EPA as used for hydraulic fracturing and 72 and 32 of 134 compounds (54% and 24%, respectively) detected in produced water. These findings along with other studies[17,18] have identified gaps in toxicity information necessary to assess potential impact on public health.

The Need for More Information on Effectiveness of Treatment Prior to Reuse

Full identification of compounds in produced water and associated toxicity is necessary to evaluate the effectiveness of wastewater treatment facilities prior to discharge to surface water. For instance, Ferrer and Thurman[9] detected the quaternary amine biocide alkyl dimethyl benzyl ammonium chloride (ADBAC) in flowback water. ADBAC is not effectively removed by conventional wastewater treatment and has been detected in surface water and sediment downstream wastewater sources.[20,21]

Field studies on wastewater treatment of produced water in Pennsylvania indicate exceedance of maximum contaminant levels (MCLs) and incomplete removal of organic compounds[22,23] prior to discharge to surface water. A large portion of compounds used in routine operations and in hydraulic fracturing and acid treatments are acutely toxic to aquatic life[1] necessitating estimation of safe aqueous concentrations prior to discharge to surface water.[24] In the San Joaquin Valley of California, produced water used to irrigate food crops and water livestock is treated only by running it through a walnut shell filter with unknown effectiveness of removing chemicals of concern and associated transformation products.

Evidence of Impact

There are a number of recent studies indicating cause for concern with discharge or reuse of produced water. Warner et al.[25] detected elevated radium 226 (^{226}Ra) and radium 228 (^{228}Ra) having activities of 8,759 and 2,187 Bq/kg (both >2 orders of magnitude above background), respectively in sediment near the effluent of a WWTP in western Pennsylvania. These activities are higher than requirements for management of technologically enhanced naturally occurring radioactive material (TENORM; http://www.tenorm.com/regs2.htm), which range from 185 to 1,850 Bq/kg in the United States and require disposal in a licensed radioactive disposal facility. Radium is a known human bone, liver, and breast carcinogen[26] with bioaccumulation factors in freshwater fish, invertebrates, mollusks, and shells ranging from 100 to 1,000[25] and a half-life of 1,600 years.

Akob et al.[27] detected elevated ^{226}Ra in sediment near a Class II disposal well receiving hydraulic fracturing wastewater in West Virginia in which produced water was previously stored in impoundments. Kassotis et al.[28] and Orem et al.[29] also investigated impact to this watershed with the former finding high levels of endocrine disrupting chemical activity in surface water extracts and the later finding numerous chemicals

In Next Month's Issue…

Environmental Management: A New Administration Takes the Reins

The Trump administration has set course on a new direction for U.S. policy on air and waste management. The September issue will provide an overview of new Administration priorities for the U.S. Environmental Protection Agency (EPA), as well as perspectives on those priorities from state, industry, and environmental groups.

associated with hydraulic fracturing in surface water and sediment.

Disinfection of water containing elevated levels of halides from upstream disposal of produced water can lead to the formation of trihalomethanes (THMs), haloacetonitiles (HANs), and halonitromethanes (HNMs). Hypochlorous acid/hypochlorite can oxidize bromide to hypobromous acid/hypobromite and react dissolved organic matter to form bromated THMs, HANs, and HNMs, which are more genotoxic and cytotoxic than their chlorinated counterparts.[30] Chloroamination can lead to the formation of iodinated THMs, HANs, and HNMs, which are even more genotoxic and cytotoxic than brominated disinfection byproducts[31,32] and are potentially tumorigenic.[33] Elevated bromide concentration during chloroamination promote the formation of the potent carcinogen N-nitrodimethylamine (NDMA).[34-36]

Hladik et al.[37] detected THMs, HANs, and HNMs, including dibromochloronitromethane (DBCNB), in surface water downstream of produced water discharge. HNMs as a class are mutagenic in Salmonella assays and potent genotoxicants in mammalian cells.[32] In laboratory studies, Parker et al.[38] demonstrated that elevated (>0.35 mg/L as N) ammonium concentrations present in produced water can cause de facto chloramination during chlorination resulting in NDMA. Ammonium salts are widely used during hydraulic fracturing. Parker et al. (2014) also demonstrated that elevated levels of bromide and iodide during drinking water disinfections causes a shift in THM, HAN, and HNM formation toward brominated and iodinated analogues at wastewater volume fractions as low as 0.01%.

Conclusion

In conclusion, while a number of impacts of produced water reuse have been identified, organic compounds used in oil and gas development are not sufficiently disclosed, identified, and quantitated in produced water. As such, there are significant data gaps in information on the physicochemical and toxicological properties of compounds used downhole and likely present in produced water. Given this, it is clear that conditions do not currently exist to properly evaluate the risks posed by the reuse of produced water or discharge of partially treated produced water to surface water. Policies and research agendas should be promulgated that set a course to systematically assess the risks of produced water reuse to ensure that appropriate monitoring and treatment options exist prior to a further expansion of this practice. **em**

California appears to be the only state that requires disclosure of chemicals used for acid well stimulation treatments.

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Regulatory Reform and Relief in the First Hundred Days

A summary overview of the first 100 days of the Trump Administration with regard to environmental actions and regulation.

Historically, the term, "Hundred Days" was associated with Napoleon's March 1815 escape from exile on the island of Elba, his return to France at the head of a reinvigorated French Army, through his defeat at the Battle of Waterloo in June 1815, and the restoration of the French monarchy. What began with so much promise ended anticlimactically (unless, of course, you were bearing arms). The term is now casually applied to the first 100 days of any new U.S presidential administration.

As is common in American politics, a more liberal administration is often followed by a more conservative administration. Following the Inauguration, the new Trump Administration issued a plethora of Executive Orders, presidential memoranda, and policy statements to the executive departments and agencies under its control. In addition, in concert with the U.S. Congress, the Administration employed the processes and procedures of the Congressional Review Act to register congressional disapproval of a host of newly-minted regulations issued by the previous administration. These changes can be made legislatively, without the necessity of adhering to the more exacting requirements of the Administrative Procedure Act (i.e., the public notice of a proposed rulemaking, the solicitation of comments, and the development and publication of the agency's rulemaking determination), which can be tedious and time-consuming.

With regard to environmental regulation, President Trump has issued Executive Orders to expedite federal environmental review, direct the U.S. Environmental Protection Agency (EPA) and the U.S. Corps of Engineers to reexamine their 2015 redefinition of "Waters of the United States", consider anew the cost of regulation, delete unneeded regulations, and implement new regulatory reforms. More generally, the Administration has directed the agencies and executive departments to submit proposals for the reform and reorganization of the executive branch, require the use of U.S. products and materials in federally-licensed projects and use American workers, and enhance the production of domestic energy from onshore and offshore federal lands and territories. Similarly, a decidedly different approach is being taken with respect to climate change, and the need to impose new climate change mandates and requirements on the U.S. economy and federal and state governments. To develop new plans and approaches to regulation, the Administration and the agencies are soliciting public comments and suggestions.

Working with Congress, legislation has been enacted to revoke a number of rules, such as the U.S. Department of the Interior's stream protection rule, new federal acquisition regulations, new procedures to implement the Federal Land Policy and Management Act, and new wildlife management rules affecting Alaska. The Consolidated Appropriations Act of 2017, which funds the federal government until October 2017, included many directives from Congress to the agencies. With respect to EPA, Congress stated that it never intended the Solid Waste Management Act to apply to animal or crop waste, and that it supports efforts to codify the law as it applies to agricultural byproducts. In addition, Congress expressed its view that EPA should expeditiously implement and streamline its new coal combustion waste management authority.

Recently, both the Department of the Interior and EPA have solicited comments from the public and the regulated community regarding which existing regulations should be considered for deletion, replacement, or modification and amendment. On April 13, 2017, EPA published a notice in the *Federal Register*, entitled "Evaluation of Existing Regulations" that solicited comments on EPA's regulatory programs.

Notably, many critical comments were filed regarding the agency's waste management and remediation rules and policies. EPA's RCRA hazard waste management system rules have been in place for many years, and indeed the 1980 generator rules have only recently been revised. The Corrective Action program is nearly as old, and impacts the assessment and cleanup of thousands of sites around the nation. The Superfund (i.e., CERCLA) cleanup process, which is a companion to the RCRA Corrective Action program, albeit one that is concerned with "hazardous substances" and not "hazardous waste", has also received its fair share of comment. The cleanup of Superfund sites tends to move slowly through an elaborate process encompassing several cleanup phases, a process that is usually measured in years after the immediate environmental threats have been addressed.

Finally, the Trump Administration, through the U.S. Department of Justice, has asked the courts, chiefly the U.S. Court of Appeals for the District of Columbia Circuit, to postpone pending oral argument in a number of important cases in which the validity of major environmental rules has been challenged. These requests have been granted to allow the Administration sufficient time to familiarize itself with the issues before the court. **em**

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2017 Student Award Winners

A&WMA takes great pride in supporting the future environmental leaders of our world. For more than two decades, the Association has awarded scholarships to the most promising environmental students on the basis of academic record, plan of study, career goals, recommendations, and extracurricular activities without consideration of sex, race, national origin, financial need, age, or physical disability. On the following pages you will find a list of the winners of the 2017 International ECi Competition, the 2017 A&WMA Annual Conference & Exhibition Student Poster winners, and the 2017 A&WMA Scholarship recipients—some of our best and brightest future environmental leaders.

ECi Competition Winners

1st Place: Louisiana State University
2nd Place: Virginia Tech
3rd Place: University of Florida
4th Place: Michigan State University

Student Poster Winners

Undergraduate

1st Place: Rocio Sanchez
2nd Place: Morgan Mitchell
3rd Place: June Hyung Lee

Master's

1st Place: Barbara Riberio
2nd Place: Jeong-Min Park
3rd Place: Seongwoo Lee

Ph.D.

1st Place: David Herman
2nd Place: Shams Tanvir
3rd Place: Shooka Khoramfar

Platform Papers

1st Place: Mohsen Ghafari
2nd Place: Seyedmorteza Amini
3rd Place: Arash Abri

Doctoral Dissertation Paper

Jublee Jasmine

Master's Thesis Paper

Kaveh Farhadi Hikooei

Scholarship Winners

Milton Feldstein Memorial Scholarship for Air Quality Research

Mohsen Ghafari

Dave Benferado Scholarship for Air Pollution Control and Waste Minimization Research
Shooka Khoramfar

Richard Stessel Memorial Scholarship for Solid and Hazardous Waste Research
Sunita Baiya

Jacqueline Shields Memorial Scholarship for Waste Management Research and Study
Rania Mona Alqaralleh

In recognition of excellence in air quality research and study
Chih-Hsiang Chien
Warren Kadoya
Neeraj Prakash
Travis Tokarek
Dongyu Wang
Milad Yavari
Sara Zabihi

In recognition of excellence in environmental management research and study related to air quality
Jordan Baker
Apoorva Pandey
Katherine Wolf

In recognition of excellence in waste management research and study
Olufemi Oladosu
Ashley Wagner

In recognition of excellence in sustainable development research and study
Ruzmyn Vilcassim

Exceptional Education Contributor Award
Harry Klodowski


Harry Klodowski

AUGUST

This Month in History (and other fun facts)

Did You Know?

August was named in honor of **Augustus Caesar**. It has 31 days because Augustus wanted as many days as Julius Caesar's month of July.

August's gem is peridot, and its flower is gladiolus.

Dutch: Augustus

French: Août

Irish: Lúnasa

Swedish: Augusti

Welsh: Awst

This Month in History

August 1, 1774: British scientist Joseph Priestley re-discovered oxygen (the gas), verifying the discovery of it by German–Swedish chemist Carl Wilhelm Scheele.

August 31, 1803: Lewis and Clark started their expedition to the West by leaving Pittsburgh, Pennsylvania.

August 5, 1914: Cleveland, Ohio, installed the first electric traffic light.

August 25, 1916: The U.S. National Park Service was created.

August 4, 1977: U.S. President Jimmy Carter signed legislation creating the U.S. Department of Energy.

August 23, 1991: Tim Berners-Lee, inventor of the World Wide Web, opened the WWW to new users.

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