Minding the knowledge gap

Produced water management requires robust treatment to minimize environmental risks. **Dan Mueller** of the Environmental Defense Fund discusses the need to increase knowledge of the chemical and toxicological contents of wastewater produced from oil and gas wells in order to understand how to properly treat, monitor, and regulate it.

Oil and gas (O&G) wells produce large volumes of water in conjunction with the extracted hydrocarbons. In many cases, the volume of water exiting the well is greater – and, in some cases, many times greater – than the extracted oil or gas.

The majority of O&G wells in the United States (US) currently being drilled domestically use hydraulic fracturing for well completion, a process that consists of injecting significant volumes of water and chemicals to release oil and gas reserves. Initially, a portion of this injected water-chemical mixture called "flowback" returns to the surface. Formation water, or water that is trapped in the geologic formation along with the oil or gas reserves, also exits the well. Additionally, chemicals are injected throughout the life of a well to maintain production, and a portion of these chemicals returns to the surface as well as degradation or reaction products resulting from the mixture of injected chemicals and chemicals present in the formation water and subjected to the high heat and pressure environment that exists underground. Consequently, O&G exploration and production is just as much a water issue as it is an energy issue. Unfortunately there are significant gaps in current understanding of how to properly treat, monitor, and regulate this water that must be addressed to minimize potential impacts to human health and the environment.

Produced water management

Each year, the onshore O&G wells in the US produce more than 3 billion cubic meters of wastewater each year, according to US Produced Water Volumes and Management Practices in 2012, a report prepared by US-based Veil Environmental for the Groundwater Protection Council in 2015. Of this produced water generated by onshore wells, approximately 93 percent is injected underground mostly in disposal wells, but a portion is also injected as part of enhanced oil recovery operations. However, drivers such as water scarcity in drought-prone areas, lack of disposal wells in reasonable proximity of oil and gas production, or concern of induced seismicity related to disposal wells are pushing O&G producers to consider management options for produced water. These include:

- Use for hydraulic fracturing of subsequent wells
- Discharge to surface water bodies
- Irrigation of non-food and food-chain crops
- Other uses such as livestock and other industrial operations.

For produced water to be used for subsequent hydraulic fracturing operations, little-to-no treatment may be necessary. For the latter three alternate water uses, robust treatment for high-quality effluent will be required.

Reuse challenges

Reuse outside of upstream O&G operations or discharge scenarios that release O&G wastewater back into the environment require an increased level of understanding about this wastewater. Knowledge about the content and characteristics of O&G wastewater is vital to properly designing and operating treatment systems, developing informed permitting policies, and making safe practice decisions.

In order to improve our understanding of the risks of various disposal or reuse methods, significant information gaps about what is known and not known about this wastewater must be addressed. Figure 1 diagrams the primary knowledge gap areas that factor into key issues related to reuse or discharge of produced water and also shows how these knowledge gaps are linked.

Methods gap: Produced water contains a wide range of constituents including inorganics, organics, and radionuclides that present unique challenges for the development and application of appropriate analytical methods.

The 2016 US Environmental Protection Agency (EPA) report "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States" states the following:

"Recent advances in analytical methods for produced water have allowed detection and quantification of a broad range of organic compounds, including those associated with hydraulic fracturing fluid (Section 7.3.4.7 and Appendix E.3.5.). These studies make clear that standard analytical methods are not adequate for detecting and quantifying the numerous organic chemicals, both naturally occurring and anthropogenic, that are now known to occur in produced water." (pp. 7-11 through 7-12).

The report goes on to explain: "Additionally, the list of produced water chemicals identified in this chapter is almost certainly incomplete. As discussed in Chapter 7, chemicals and their metabolites may go undetected because they were not included in the analytical methodology, or because an analytical methodology was not available. Chemical analysis of produced water can also be challenging because high levels of dissolved solids in produced water and wastewater can interfere with chemical detection. As a result, there are likely chemicals of concern in produced water that have not been detected or

Produced water from onshore oil & gas drilling can be treated for reuse in hydraulic fracturing, irrigation, and other industrial operations. Photo by Daniel Azocar, istockphoto reported, and are not included on the chemical list presented in this report." (p. 9-83)

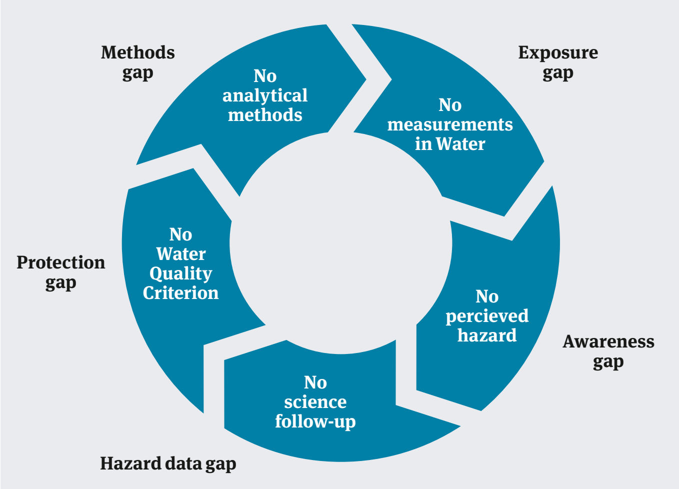
Depending on a well's age or geographic location, produced water can have a salinity ranging from approximately 10,000 parts per million (ppm) to more than 300,000 ppm; or reference, seawater has salinity in a range of 35,000 ppm. The elevated salinity presents challenges for analytical methods developed for testing wastewaters. To account for the elevated salinities, sample preparation must be modified, and/or the sample must be diluted prior to analysis. Diluting the sample prior to analysis may increase detection limits that could result in constituents of concern not being identified even though they may be present at harmful levels.

Additionally, approved analytical methods do not exist for a large number of constituents that oil and gas companies report using in hydraulic fracturing or that may potentially be present in produced water. Based on our review of sources that include the aforementioned EPA study and FracFocus, a national database of constituents reported to be used in hydraulic fracturing, less than 25 percent of the more than 1,600 chemicals identified have EPA-approved analytical methods. Essentially, scientists and regulators are unable to develop the full suite of analytical methods to test wastewater for chemicals because the full suite of present chemicals is unknown. This issue, in turn, leads to questions not only about how to test for constituents of concern but also about how to identify and evaluate potential exposure.

Exposure gap: All too often, the absence of data can be construed as the absence of a problem, but that is not always the case. To identify and evaluate potential exposure pathways from release of produced water, a particular or group of constituents of concern must be known. Knowledge gaps in analytical methods result in the inability to identify exposure issues or even develop research plans necessary to identify and understand the possible exposure pathways.

Awareness gap: Questions about chemical exposure lead to questions about whether contact with those chemicals can cause adverse impacts to health and the environment. Being unaware of the presence or quantity of a potential constituent of concern limits the ability to devote

Figure 1. Produced Water Knowledge Gaps



appropriate time, resources, and attention to understanding impacts if released. These "unknown unknowns" will always be a concern, but even when we do know that a particular constituent may be present, little may be known about how hazardous the constituent may be to our health or ecosystems, an issue that leads to the next knowledge gap.

Hazards gap: Little toxicological information is available for many of the chemicals used for hydraulic fracturing. Again, drawing on information presented in EPA's report on impacts of hydraulic fracturing water cycle on drinking water sources, more than 80 percent of the chemicals in produced water lack chronic toxicity data. Moreover, as stated in the report:

"Without reliable and peer reviewed toxicity values, comprehensive hazard evaluation and hazard identification of chemicals is difficult, and the ability to consider the potential cumulative effects of exposure to chemical mixtures in hydraulic fracturing fluid or produced water may be limited. Although there are other potential sources of toxicity information for many of these chemicals, some of it may be limited or of lesser quality. Consequently, potential impacts on drinking water resources and human health may not be assessed adequately."

Protection gap: The aforementioned knowledge gaps present significant challenges to determining how to best protect human health and the environment from potential impacts that result from intentional release of produced water. While protection means different things to different people, several key questions must be answered in this case:

- How to design fit-for-purpose treatment technology?
- What constituents should be monitored?
- What are the potential short- and long-term impacts (soil, crops, end-users)?
- Are surface and groundwater resources adequately protected from those impacts?

Regulatory programs are instituted in response to known concerns; therefore, knowledge gaps in key areas create significant challenges to assessing the need for regulatory initiatives and for developing sound regulatory policies.

Without regulatory programs that address constituents of concern, no driver is present to develop and validate the analytical methods for these constituents. Thereby, the cycle of unknowns continues.

Advancing science to narrow knowledge gaps

A number of efforts are underway to narrow the knowledge gaps and inform policy and practices efforts to assist with smart produced water reuse. These efforts focus on chemical characterization and toxicological information on produced water.

Advancing the chemical characterization of produced water includes modifying sample preparation techniques to improve detection levels affected by elevated salinities. One goal of a specific research project underway is the evaluation and enhancement of solid phase extraction sample preparation to allow for better identification and quantification of organics constituents. More broadly, this effort is directed at developing techniques to achieve lower detection limits for organic constitutes known or suspected to be present in the O&G wastewater as well as non-targeted analysis to identify unknown organic constituents.

The Environmental Defense Fund recently convened a workshop of toxicological experts to explore the potential application of emerging toxicity assessment tools – including whole effluent tools, high-throughput bioassays, etc. – to better understand risks associated with oil and gas wastewater that may be released. These two key takeaways resulted from this effort:

- There are numerous highly qualified experts from industry, academia, and government that may not traditionally focus on oil and gas issues but who may have the ability to offer unique and productive research and technical expertise in this space.
- Cutting-edge tools exist today that could be utilized to advance the science on produced water toxicity, but further research is required to better understand their potential use and applicability.

Summary

It is important to acknowledge that significant knowledge gaps need to be addressed related to the recycling and reuse of produced water. But just as knowledge gaps in one area lead to knowledge gaps in others, so does filling knowledge gaps in one assists in filling gaps in others. Therefore, narrowing the knowledge gaps in one or more areas will have the positive impact of assisting in narrowing the gaps in other areas. Excellent research is being conducted, and as this research proceeds, acknowledging what is known and not known, what is of concern, and what has been adequately assessed allows for the prioritization of work so that focus can be placed on the most critical knowledge gaps to be filled.

Author's Note

Dan Mueller, PE, is the director of the Environmental Defense Fund's oil and gas exploration and production section, based in Austin, Texas, United States. His efforts are focused on evaluating and developing strategies for addressing the environmental impacts of oil and gas upstream operations, which include surface infrastructure, water sourcing, and water and waste management. Dan is a registered professional engineer with more than 30 years of experience in the environmental field.