MAY 2018

Workshop
HIGHLIGHTS

Flowback and Produced Waters

Opportunities and Challenges for Innovation

Each year, billions of barrels of produced water—the water from underground rock formations and well operations that is brought to the surface during oil and gas extraction—are generated from oil and gas fields across the United States. Produced water typically contains high concentrations of salts and other compounds, and currently the majority of this water is disposed of by injecting it deep underground. However, drawbacks to this management method, including the risk of inducing earthquakes and the expense of transporting produced water to injection sites, as well as increasing needs for alternative water sources to stressed local aquifers in some regions, have driven interest in exploring other options for dealing with produced water. At a May 2016 workshop, representatives of federal and state government, industry, non-governmental organizations, and academia gathered at the National Academies of Sciences, Engineering, and Medicine to discuss opportunities and challenges for managing produced water, particularly the reuse of produced water.

Produced water is generated during the extraction of oil or gas and represents water that was trapped naturally in the rock formation. Other fluids which are often a mixture of water and some chemicals may be injected into certain types of oil and gas deposits at high pressures to generate fractures in the rock that can aid the flow of oil or gas to the wellbore (Figure 1). Some of this injected fluid also returns to the surface together with the oil or gas and is called flowback water. In this summary, both the naturally occurring water in the rock formation that returns to the surface and flowback water are referred to as produced water, which is the greatest volume byproduct associated with oil and gas production (see Box 1).

Deciding what to do with produced water is a challenge. The water could contain contaminants such as salt or other materials that have leached naturally from the surrounding rock or may contain oil, grease, or other chemicals introduced from the drilling process. The quality and quantity of produced water also varies greatly from site to site, and even over the lifetime of a single well.

Box 1. What is Produced Water?

Produced water is the water that exists naturally in the underground rock formations for thousands to millions of years together with oil and gas resources. This water is brought to the surface as a byproduct of oil and gas extraction. This water has a chemical composition unique to the rock formation in which it exists.

Flowback water is water that is injected underground as part of the process of hydraulic fracturing and is used to help extract oil or gas from particularly impermeable rock formations. This water may also return to the surface, together with the oil or gas, and associated produced water.

Both flowback and produced water are referred to as produced water in this document.

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Produced water has to be managed by some combination of treatment, storage, discharge, disposal, or use, subject to compliance with federal and state regulations. At present, most produced water (~90 percent) is managed by underground disposal (Figure 2). About half of the injection occurs into rock formations that lie below drinking water aquifers and is intended for permanent storage. The other half is reused for injection into oil and gas reservoirs to enhance recovery of the oil or gas. However, water shortages in some areas of the United States have led to growing interest in the potential for reusing produced water for cooling, agriculture, or industrial applications after appropriate treatment to necessary standards, rather than injecting the water for permanent disposal as a waste product.

In addition, a few areas of the country have been experiencing felt earthquakes that have been triggered by injection of this wastewater. This 'induced' seismicity occurs when the wastewater injection changes the stress on a fault in the subsurface. Reducing or eliminating the volumes of produced water injected for permanent disposal could reduce the risk of generating these seismic events.

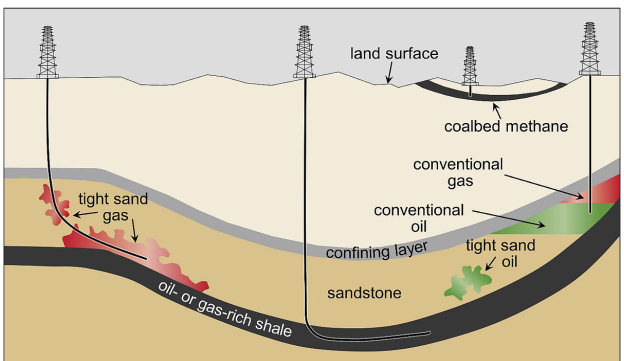

Figure 1. This figure shows oil and gas development via a vertical well on the far right (so-called "conventional" well), and several wells producing from other types of oil and gas formations: a vertical coalbed methane well (second from right); a horizontal well producing from a shale formation (center); and a well producing from a tight sand formation (left). The latter two rock types—tight sand and shale—have low permeability which hinders the flow of oil or gas to the wellbore. Horizontal or directional drilling, together with hydraulic fracturing, is a technology which injects a mixture of water and specific chemicals to generate additional fractures in the rock to increase its permeability and improve the flow of oil and gas to the wellbore. Source: EPA, 2015; presented by Kyle Murray of Oklahoma State University.

Figure 2. Approximately 90 percent of produced water is managed by underground injection using pipes such as those pictured, which are connected to deep injection wells. Credit: Mr. PK via Shutterstock

VARIATIONS IN THE QUALITY AND QUANTITY OF PRODUCED WATER

The variability in geologic formations across the United States drives large variability in both the amount of produced water and its chemical composition. For example, the Bakken shale play, located in North Dakota, produces water that is high in salinity; in contrast, produced water in California generally has a low salt content. Further, the Bakken currently produces more water than is needed for hydraulic fracturing; in contrast, the Eagle Ford shale play in Texas produces only about one-third of the water needed for hydraulic fracturing.

In addition to differences in geologic formations, every well and field has a life cycle, over which there is a peak and a decline in the generation of oil or gas and of produced water. These variations mean that the most appropriate approach or technology for managing produced water in a single oil or gas field can vary during its lifetime. Several participants at the workshop expressed the view that any produced water treatment or management technology will need the flexibility to address variations in water quality and quantity (Figure 3).

CHARACTERIZING THE CHEMICAL COMPOSITION OF PRODUCED WATER

There is significant uncertainty in the chemical composition of produced water, and at present the complete chemical composition of these waters is not typically analyzed. This is in part due to costs and the challenges of working with these types of fluids and the purpose of such analyses.

Further, although technologies exist to treat water of almost any composition to a desired standard, a set of common definitions of what "clean" water is for different end uses and agreement regarding laboratory approaches or standards to develop these definitions do not exist. For example, there are few buffer solutions with a composition similar to produced water, making it difficult to calibrate analytical machines such as pH meters. Researchers sometimes dilute produced water to make it easier to handle, but this can lead to difficulties in detecting trace elements such as arsenic or radium. Furthermore, treating produced water also has associated costs and specific infrastructure needs, which can vary depending upon the volumes and composition of the water being treated.

Workshop discussions also emphasized that the water quality of natural systems may change seasonally. If produced water is to be treated to supplement these existing natural supplies, the treatment approach may be a moving target that needs to be evaluated in the context of a specific use at a specific time. Without produced water standards, meeting the needs of the end user will be difficult because a single treatment approach to all potential use situations may not be viable.

To help build a repository of information about the chemistry of produced water, one participant shared that the United States Geological Survey (USGS) is working to develop a brine laboratory that specializes in measuring high-salinity solutions, and is also developing a produced waters database. This database currently contains data on parameters including the total dissolved solids (TDS), pH, calcium, and trace metal levels for 165,000 different produced water samples from wells across the United States. Other participants emphasized that pressing research is needed to develop rapid, accurate analytical tests of the quality of produced water, in order to pinpoint specific treatment options for potential applications.

Figure 3. Treatment of produced water for one or more beneficial end uses requires knowledge of the water composition and the water quality required for the end use. Produced water composition from a particular oil or gas field may also vary over time. Credit: Avatar_023 via Shutterstock

MANAGING PRODUCED WATER AT LOCAL SCALES

Although factors such as risk, cost, and liability have made the practice of managing produced water by injection into deep disposal wells the most common approach thus far, interest is growing in keeping the water at the surface for other uses.

In areas of the United States that are facing water shortages, the potential use of treated produced water represents an opportunity to tap a much-needed water resource. In other locations, the increased frequency of induced seismic events is motivating efforts to explore reuse as an alternative means of managing large volumes of produced water.

PLANNING COMMITTEE FOR THE WORKSHOP ON FLOWBACK AND PRODUCED WATERS: OPPORTUNITIES AND CHALLENGES FOR INNOVATION: **Steven P. Hamburg** *(Co-Chair),* Environmental Defense Fund, Belmont, MA; **Kris J. Nygaard** (*Co-Chair*), ExxonMobil Upstream Research Co., Spring, TX; **Brian J. Anderson**, West Virginia University, Morgantown; **Melissa Batum**, Bureau of Ocean Energy Management, U.S. Department of the Interior, Washington, DC; **Susan L. Brantley** (NAS), The Pennsylvania State University, University Park; **Akhil Datta-Gupta** (NAE), Texas A&M University–College Station; **Joe Lima**, Schlumberger Services, Inc., Denver, CO; **Daniel Lind**, Bureau of Safety and Environmental Enforcement, U.S. Department of the Interior, Washington, DC; **Jan Mares**, Resources for the Future, Washington, DC; **Elena S. Melchert**, Office of Fossil Energy, U.S. Department of Energy, Washington, DC; **Bridget R. Scanlon** (NAE), Bureau of Economic Geology, The University of Texas at Austin; **Craig Simmons**, Flinders University, Adelaide, South Australia; **Elizabeth A. Eide** (*Director*), **Ed J. Dunne** (*Program Officer*), **Camly Tran** (*Associate Program Officer*), **Nicholas D. Rogers** (*Financial and Research Associate*), **Courtney R. DeVane** (*Administrative Coordinator*), **Eric J. Edkin** (*Senior Program Assistant*), **Brendan R. McGovern** (*Senior Program Assistant*), National Academies of Sciences, Engineering, and Medicine.

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ABOUT THE ROUNDTABLE ON UNCONVENTIONAL HYDROCARBON DEVELOPMENT

Launched in 2015, the Roundtable provides a neutral forum where representatives from government, industry, academies, and nongovernmental and international organizations can critically examine the facts about the scientific, engineering, health and safety, regulatory, economic, and societal aspects of unconventional hydrocarbon development.

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For more information, contact the Board on Earth Sciences and Resources at 202-334-2744 or visit http://www.nationalacademies.org/besr. *Flowback and Produced Waters: Opportunities and Challenges for Innovation* Workshop Highlights can be purchased or downloaded from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; (800) 624-6242; http://www.nap.edu.

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