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 composition 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 m³) 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 (CaCO₃). 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.

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**Sources**

3. 40 CFR 435.50.

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