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Produced Salt Water: The Next Resource Play?
Solving Oil Industry Problems via Paradigm Shifts, New Technologies, Markets, and Community Partnerships

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Abstract

This article (of conventional text and presentation) proposes looking at produced water as a commodity, namely purified water suitable for use in gray water and potable water applications. The rationale and justifications are presented, along with an overview of the elements necessary for a formal plan to roll-out a drilling program to drill and produce purifiable connate water (for convenience, referred to as salt water, but which contains an array of chemicals as well as biofilm, hydrocarbons, emulsions, and colloids).. This article includes technological, logistical, economic, and stakeholder considerations, but it does not go into depth with respect to regulatory compliance, namely EPA. Compliance with drinking water and EPA standards will be addressed in a future article. The shift from hydrocarbons to purifiable salt water as the primary objective constitutes a paradigm shift, and as such, it also constitutes a significant opportunity for geologists, many different types of engineers (chemical, petroleum, mechanical), environmental scientists, and chemists.

Water Issues: Multi-Pronged Challenges and Opportunities

The formerly uneconomic unconventionals and resource plays have revolutionized the oil industry, with the dynamic convergence of demand and new technologies, primarily horizontal drilling and hydraulic fracturing. Tight gas, shale gas, oil shale, and liquids-rich, low-permeability plays are now often economically viable, and they are being produced in higher volumes than ever before. Along with the higher volumes of oil and gas are higher volumes of salt water, which, to this point, are expensive to transport and inject in disposal wells.

There are other issues compounding the problem. The need for water for drilling and stimulation (hydraulic fracturing), plus the need to dispose of massive quantities of produced fluids has brought to the surface a number of challenges and opportunities:

Challenges:

- Addressing community outrage at the diversion of water used in agriculture and for personal use to drilling and hydraulic fracturing;
- Quelling fears of contamination of aquifers and surface water with drilling and hydraulic-fracturing chemicals and proppants, not to mention produced water;
- Investigating in an open manner instances of seismicity in the vicinity of drilling, hydraulic fracturing, and injection well operations.

Opportunities:

- Finding ways to optimize the use of water
- Avoiding surface water and groundwater where possible
- Recycling and reusing frac water and produced water
- Improving existing technologies for purification
- Improving existing systems of gathering and processing produced water in order to improve economics
- Minimizing and eliminating injection and disposal wells where possible by finding ways to reuse and recycle
- Making a radical paradigm shift and starting to prospect for brine reservoirs (with associated gas and oil) with optimal qualities for purification to gray water and potable water quality
- Develop joint ventures with communities in need of water to prospect for, drill, and produce salt water (with associated gas and oil) for the express purpose of providing usable water where surface and groundwater supplies have been depleted.

Produced Water Purification: Finally Economic? A Closer Look

Purifying salt water, brine, and produced water has been a "must" in Saudi Arabia for many years. Consequently, desalination technologies are well-developed there, and there is not an aversion to consuming water derived from non-freshwater sources.

In the future, it is clear that arid and/or water-depleted areas of the U.S. will possess motivation to explore purification. In anticipation, the Global Petroleum Research Institute (GPRI), Texas A&M University, College Station, has an ongoing project to purify seawater from the Gulf of Mexico, findings of which are published in "Conversion of Oil Field Produced Brine to Fresh Water"# (GPRI, 2003).

Within ten years, counties in west and south Texas, western Oklahoma and Kansas will be completely out of water. This is what a number of hydrologists and scientists have been warning for several years, but that prognosis is likely to worsen if the current extreme drought continues as expected.

Ironically many of those same counties, which will be completely out of potable water, are generating and disposing of as many as 100,000 barrels of produced water per day. The water is often produced in conjunction with 1 – 5 barrels of oil per 100 barrels of water, along with associated gas, often around 50 MCF per day. Companies are paying as much as $5 per barrel to dispose of flowback and produced water, on top of the cost of chemicals to combat the scale and corrosion that inevitably accompany high production of water containing high concentrations of naturally-occurring sodium, chlorides, calcium, magnesium, barium, iron, sulfates, and more.

Given the expected freshwater catastrophe, it seems that communities and producers would be highly motivated to work together. The big sticking point until now has been economics. It is expensive to purify water, and traditional membrane ultrafiltration, reverse osmosis, and distillation are expensive.

However, at this point, much of the produced gas in these wells is being flared, because the price of gas is too low to justify the construction of gas gathering, compressors, and more. It is an obvious waste of energy, which is one problem. Another compelling problem has to do with the EPA emissions regulations which are attempting to address the problems of greenhouse gases. Methane is one of the worst, and so to flair methane is not only economically wasteful, it is also bad for the environment. Fines and shutdown orders may be issued to those who continue to flare gas.

It is an obvious partnership that requires careful planning and research. The problem with a high "ops tempo" in the oil field is that operators do not necessarily have time to step back and focus on economically generating fresh water. Thanks to the time constraints of oil and gas leases and joint ventures, often all a company can do is to keep up with current obligations

Further, to do what will be necessary to convert produced water trucking and disposal via permitted salt water disposal (SWD) wells, it will be necessary to drill wells, put into place a chemical treatment plan, to build infrastructure (pipelines and water gathering systems), not to mention the central distillation or reverse osmosis purification centers. All will require a capital investment.

The same companies that are spending $5 per barrel on water disposal would need to spend the same amount on processing / purification. In fact, it might theoretically cost $7 / barrel. However, if they could sell the purified water to communities for 10 cents per gallon ($4/barrel), then their costs go from $5 to $3 / barrel, and if they are disposing of 100,000 bbls per day, that adds up to $200,000 per day of cost savings.

If there is a way to reduce the amortized capital investment, plus daily operating costs to achieve a total cost to $3 / barrel, then, hypothetically, at $4 / bbl, one could look at $1/bbl profit. At 100,000 bbls / day, that is $100,000 day net revenue, and $3 million per month.

Granted, $36 million per year profit does not make a Fortune 500 company; it can be scaled-up.

We need geologists who use their understanding of a play to determine the best places to drill for thick salt-water reservoirs and to find ones that do not have extremely high concentrations of chlorides, sulfates, etc.

We also need chemical and mechanical engineers who can optimize existing technology in purification to gray water or potable water standards, via distillation units, reverse osmosis, or other processes.

We will need mechanical engineers to design the water gathering systems.

We need chemists and corrosion control engineers to deal with the water gathering system, which will be under constant assault from scale, corrosion, and paraffin.

Right now, there are no provisions for produced water sales in typical oil and gas leases. One can argue that the costs of dealing with produced water outstrip revenues; so there is no reason to compensate the mineral owner. However, I would like to change that--see new contracts developed that provide a royalty for produced water sales – perhaps 3 percent, even though the operations could operate at a net loss, with essentially the only benefit to the operating company being a way to reduce operating costs.

For large-scale salt-water recovery projects, it will be a good idea to partner with municipalities in order to develop appropriate infrastructure of the right size and scale. It may be necessary for a municipality to pass a bond issue in order to fund the pipelines, lifting stations, and storage. Ostensibly, the same communities that have purchased water from other municipalities or private entities would be more than willing to purchase from the new source.

Produced Water Quality: Issues

Basic Reservoir Quality – Permeability, porosity, mineralogy via routine core analysis, pressure transient analysis, drill cuttings analysis and petrographic analysis (thin section, scanning electron microscopy, x-ray diffraction, image analysis)

Water quality issues can be subdivided into a number of categories for evaluation (Bennon et al., 1996):

- Ionic composition / clay swelling
- Chemical contaminants
- Suspended solids
- Scale and precipitate potential

- Oil/paraffin content
- Non-condensable gas content
- Bacterial content

Common issues with injection and with production are related to water-quality issues. Some of the more widespread issues include the particulate plugging, fines migration, clay swelling, corrosion, and scale:

Particulate plugging: A schematic of the particulate plugging process in porous media is illustrated in Figure 1 (Bennion et al., 1996). The plugging process is characterized by the entrainment of larger particulates on the surface of the formation interface directly at the wellbore, comprising an “external” filter cake.

Fines Migration: Many authors have documented phenomena associated with fines migration. Major factors to consider in relation to fines migration include: Fines generally tend to migrate only in the wetting phase. This means that fines mobilization around oil-wet injectors may be less problematic than the equivalent situation in a water-wet formation.

Clay Swelling: Figure 2 (Bennion et al., 1996) provides a schematic illustrating the crystal structure of smectitic (montmorillonite) clay. A negative charge imbalance in the clay structure is stabilized by the substitution of a positively charged cation into the gap between the individual clay crystals. If an insufficient concentration of these ions is present in the brine contacting the clay, water, due to its polar nature, can also substitute itself into the gap.

When mutual repulsion between the charged, disperse counter-ion clouds exceeds the attractive Van der Waal forces holding the clays in an attracted, flocculated state, the particles disperse or deflocculate.

Other problems associated with producing high volumes of salt water include scale, corrosion, and bacterial film. For that reason, any economic evaluations and projections should take into consideration a higher-than-normal cost for chemical treatments and inhibitors (Steiger, 2007).

Further, the super-concentrated resulting brine will need to be disposed, probably through Class II injection wells, which means that making salt water a desirable “resource play” does not obviate the need for disposal wells, but it does significantly reduce the need.

It is good to keep in mind that one can harvest the precipitates – mainly chlorides, but perhaps other valuable chemicals may be included. That could constitute another revenue flow and make the new paradigm even more environmentally friendly.

The Road to Community Alliances

In order to make the transition from simple oil and gas exploration and production to a blended purified or recycled produced water co-production model, it is important to work with communities. Some of the key steps include the following:

- Share Common Goals and Objectives: Identifying constituency goals and objectives is very important.

- Build Trust: Openness will allow individuals, communities, and companies to develop effective communications.

- Ethics and Technology: Views about technology must be discussed so that they are mutually understood. Is the prevailing view that technology can be inherently good or bad? Or, is it an agency issue? Is technology neutral, but the active agent, the person in charge, the one who has the ethical obligation to use technology for good or for ill?

- Innovative Alliances: To be effective, teamwork and new alliances will be necessary. Adversarial relationships that exist today (e.g., Sierra Club, etc. vs. oil companies operating in the Marcellus in Pennsylvania), will quickly be perceived as unproductive. Alliances will include communities, shareholder activists, company leaders, technical professionals, educational groups, and landowners.

Water Wars: Inevitable If We Do Not Work Together?: A severe drought over a large part of the western U.S. has spurred outrage on the part of individuals who oppose hydraulic fracturing ("fracing") and has spurred environmental activists to protest the diversion of surface water for use in well stimulation. It also has encouraged companies to accelerate their adoption of recycling (Klimasinska and Efstathiou, 2012). Conflicts over control of scarce resources have precipitated numerous wars. In the future, the reality of water shortages will continue to lead to skirmishes that can escalate to full-fledged war. Technology combined with political wherewithal can make a huge change.

Conclusion

Produced water can be purified to the point that it can be used by municipalities for the same uses as gray water. With additional steps, it is possible to process it to be potable. The technologies exist, and it is possible, given the right conditions, the economics can be very positive. With economic purification of produced water, it is possible to change paradigms and not simply look at produced water as a "waste" product simply to dispose in the nearest injection well. Instead, a paradigm shift would look at producing connate water / salt water as the primary target, and the produced gas as fuel for the purification operations. High volumes of produced salt-water purification can constitute a part of a solution to help replenish depleted and often non-renewable natural resources, namely groundwater.

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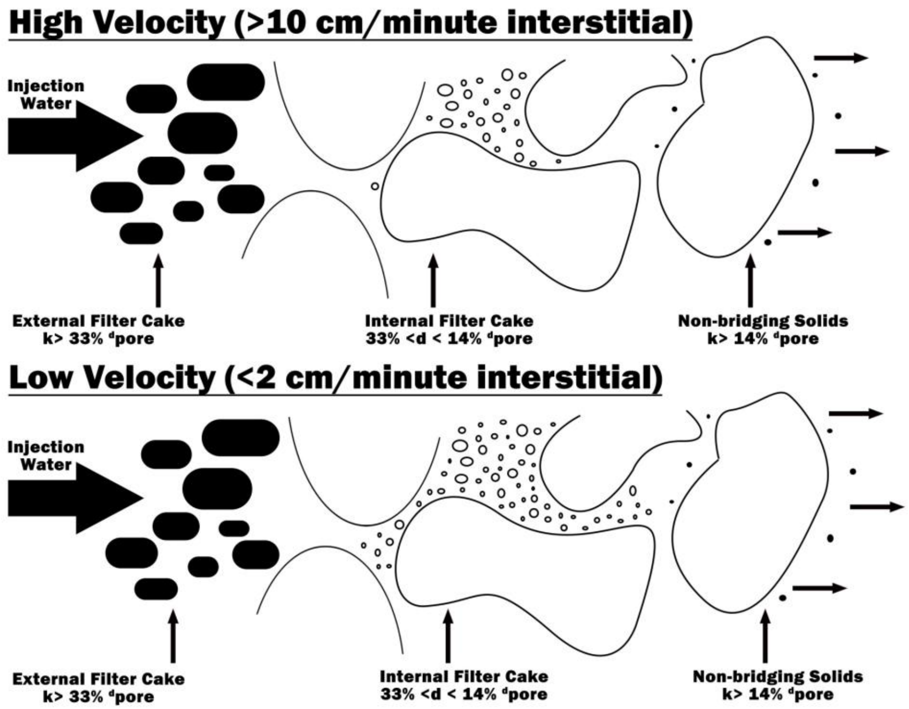

Figure 1 : Mechanism of suspended solids entrainment.

Figure 1. Mechanism of suspended solids entrainment (from Bennion, et al., 1996).

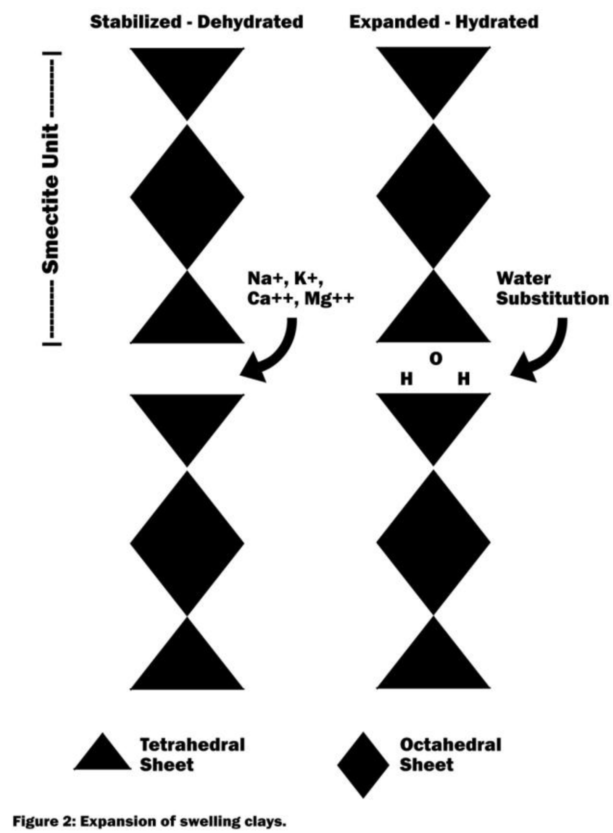

Figure 2. Expansion of swelling clays (from Bennion, et al., 1996