

Proposal

Treatment Approach Oil and Water DO Mix After All

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Abstract / Executive Summary

Oil-produced and gas-produced water recovery technology can include pretreatment followed by membrane filtration (a combination of micro-filtration, ultra-filtration and/or reverse osmosis). This produced water recovery treatment method is similar in process and technology to that being used in brackish groundwater and seawater desalination. Produced water can be treated and reused as an alternative to fresh water sources.

Oil and Water DO Mix After All

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Hypothesis and Long-Term Objective

Reclaimed produced water from crude oil production and gas production activities can serve as a beneficial water supply.

Specific Aims to Address

- Water management strategies need to be used in the oil and gas industry to protect the environment and to minimize the amount of waste produced.
- A major cost component of crude oil and gas production is associated with produced water treatment and/or disposal.
- To meet the continuing global demand for energy while conserving potable water supplies and practicing good environmental stewardship.
- Identify contemporary treatment technologies, participants, and resources necessary for reclamation and reuse of produced water.

Recommended External Reviewers*

Global Petroleum Research Institute (Texas A&M University)
University of Texas Bureau of Economic Geology
Railroad Commission of Texas
Denton County Texas
Research Partnership to Secure Energy for America
Department of Sociology Sam Houston State University
Texas Department of Transportation
North Central Texas Council of Governments
Center for Transportation Research (University of Texas)
Texas Transportation Institute (Texas A&M University)
Texas Commission on Environmental Quality
Texas Water Development Board
Region C Regional Water Planning Group

*These entities have been contacted, but may not have committed to perform the peer review function.

Introduction

According to recent environmental research in energy assets, oil and gas represent 63% of the world's energy supply.¹ Although environmental sympathies are trending "green," there is no quick end in sight for consumption. Our global community will continue to rely heavily on crude oil and gas production for the foreseeable future.

Oil and gas drilling and production operations, including well construction, drilling, completions and stimulations such as fracturing operations affect large volumes of increasingly precious water supplies. In some cases, fresh water is used; but in most cases, brackish water is produced. This salty water, present in an underground hydrocarbon-bearing formation, is brought to the surface when crude oil or natural gas is mined.

A major cost component of crude oil and gas production is associated with the treatment and/or disposal of, and the transportation and disposal of, water resulting from the mining of crude oil and gas (hereinafter referred to as "produced water"). These costs continue to increase. But what if produced water could serve as a beneficial water supply?

This proposal suggests that reclaiming produced water is a viable application for consideration. With proper application of existing technologies and with interlocal cooperation, what once would have been considered wastewater can be treated, reclaimed, and reused.

Background and Significance: Current State of Knowledge

Oil and Gas Produced Wastewater

Oil, gas and water exist in underground reservoirs. As crude oil and gas is produced from the reservoir, it frequently is accompanied by produced water which carries a high concentration of dissolved solids and minerals. This produced water might be present naturally or it could be water that was injected into the reservoir to maintain pressure for drilling or production. As an oil or gas field matures, the proportion of produced water increases.

The American Petroleum Institute estimates that in 1995, onshore oil and gas exploration and production operations in the United States produced 756 billion gallons of water (18 billion barrels).² Texas generates more produced water than any other state in the United States and it is estimated Texas' produced water exceeds 500 million gallons per day.^{3a & 3b}

In the United States on average there are 7 barrels of water produced for every barrel of oil produced. Texas' Permian Basin averages more than 9 barrels of produced water for every barrel of oil produced, representing an estimated 400 million gallons of produced water per day that has to be transported and/or disposed of in an environmentally acceptable manner.⁴ Beneficial reuse of any viable portion of produced

¹ Environmental management in oil and gas exploration and production – An overview of issues and management approaches – Joint E&P Forum/UNEP Technical Publication 1997.

² API 2007, Waste Management: Exploration and Production Waste, <http://www.api.org/aboutoilgas/sectors/explore/waste-management.cfm>.

^{3a} Burnett, D. 2007. Recovery of fresh water resources from desalination of brine produced during oil and gas production operations. Global Petroleum Research Institute report prepared for the United States Department of Energy. College Station, Texas: Harold Vance Department of Petroleum Engineering, Texas A&M University.

^{3b} National Energy Technology Laboratory: Advanced Membrane Filtration Technology for Cost-Effective Recovery of Fresh Water from Oil and Gas Operations

⁴ Burnett, D., *ibid*.

water, and/or an economically feasible reduction in disposable volume of produced water, would be advantageous for local communities in North Central Texas.

Disposal by Water Hauling

Generally speaking, water used during oil and gas well fracturing operations has to be trucked in for the well stimulation activity and trucked away for disposal afterwards. Likewise, a great majority of the produced water has to be trucked away for disposal. There can be a high number of trucks on local and county roads causing traffic congestion concerns. These trucks can travel at all hours of the day which can be disturbing to local residents. Heavy vehicular traffic requires increased road maintenance to repair damages caused by trucks, amounting to additional incurred cost to the local communities and counties. The trucks hauling produced water also have an affect on air quality when they emit vehicular exhaust into the atmosphere.

The costs associated with transportation and disposal of produced water continue to increase. Treating produced water for beneficial reuse and conserving potable water usage during well fracturing operations can reduce the number of trucks used to haul water over local and county roads, and can result in lower road maintenance costs and improved air quality.^{5a}

According to The Truck Safety Coalition, “Pavement damage is caused almost entirely by heavy trucks, not by passenger cars. One legal 80,000 lbs. Gross Vehicle Weight tractor-trailer truck does as much damage to road pavement as 9,600 cars.”^{5b}

For the purposes of this proposal, investigation of transportation issues and costs of disposal should include:

- Review of accelerated pavement tests
- Determination of number of trucks to volume of water produced
- Establish vehicle repetitions before road deterioration
- Cost of maintenance per mile of road
- Figure out road rehabilitation cost
- Estimate road preventative maintenance cost
- List design life expectancy of roads
- Agree on life expectancy of roads (paved and unpaved) before and after reduction in heavy vehicular traffic
- What percentage of county roads are paved and unpaved
- Determination of exhaust emissions before and after reduction in truck traffic
- Additional issues identified during review

^{5a} Burnett, D. 2007, “Recovery of fresh water resources from desalination of brine produced during oil and gas production operations,” Global Petroleum Research Institute report prepared for the United States Department of Energy. College Station, Texas: Harold Vance Department of Petroleum Engineering, Texas A&M University.

^{5b} Highway Research Board, NAS, 1962.

Disposal by Desalination and Re-injection

Alternative to disposal by hauling, water produced by drilling for crude oil and gas could be treated for reuse and the remaining volume disposed of by re-injection into an underground aquifer. Historically however, there have been environmental concerns associated with produced water re-injection practices. Produced groundwater contains elevated concentrations of dissolved solids and minerals.

The World Health Organization recommends the dissolved solids concentration (or salinity) of drinking water should be less than 500 parts per million (milligrams per liter). Less than 3% of the world's water has a salinity low enough for human consumption, and it is estimated that less than one-half of 1% of the world's water is safe for human consumption and is easily accessible (Desalination.com, "An Environmental Primer," by Tom Pankratz and John Tonner). Disposal of desalination concentrate in an environmentally acceptable method often has been difficult, and the practicality and cost associated with desalination is directly proportional to the concentration of dissolved solids and the availability of alternative water sources. According to Pankratz and Tonner, as concentrations of dissolved solids increase, so does cost associated with desalination. Indeed, in some cases it can be more costly to desalinate brackish groundwater than to produce fresh groundwater supplies.

Contemporary pre-treatment and desalination technologies however, can offer means to recover fresh water resources from brine produced during oil and gas production operations.⁶ Desalination refers to any of several processes that remove excess dissolved solids (salts and other minerals) from water. The public's perception of desalination can mean different things to different people. Most people associate the term "desalination" solely with seawater desalination and are unfamiliar with its application to remove dissolved solids and minerals from subsurface groundwater, to polish or purify non-potable water for potable or beneficial reuse, and to reclaim and reuse domestic wastewater. Produced water recovery technology can include pretreatment followed by membrane filtration (a combination of micro-, ultra- and/or reverse osmosis). This produced water recovery treatment method is similar in process and technology to that being used in brackish groundwater and seawater desalination. Produced water can be treated and used as an alternative to fresh water supplies in appropriate applications.

Commercial systems currently marketed to treat wastewater produced during oil and gas operations include improved reverse osmosis membrane filtration technology preceded by innovative pretreatment. The pretreatment stage is very important to the efficient utilization of the reverse osmosis filtration technology. The pretreatment approach incorporates combinations of liquid-liquid centrifuges, organoclay absorbents, micro filtration, ultra-filtration and other treatment methodologies.

Preliminary Data/ Studies

Water Conservation and Beneficial Reuse

Many parts of the United States are facing, or in the future could be facing, water shortages. According to the 2002 Texas State Water Plan, if a drought occurs in 2050, almost half (43%) of the municipal water demand in Texas will not be satisfied by current sources. The best response to this situation is a thoughtful, feasible, and long-term plan for acquiring new water supplies and reducing demand.⁷

⁶ Burnett, D. 2007. Recovery of fresh water resources from desalination of brine produced during oil and gas production operations. Global Petroleum Research Institute report prepared for the United States Department of Energy. College Station, Texas: Harold Vance Department of Petroleum Engineering, Texas A&M University.

⁷ Texas Water Development Board, The Future of Desalination in Texas Volume 1, Biennial Report on Seawater Desalination, December 2004.

Continued improvements in desalination technologies and the associated decrease in costs have made desalination a practical and cost-effective alternative source of water supply in Texas. In 2002, during the first round of water planning, only five regional water planning groups recommended desalination as a water management strategy. This number has since risen to 10 in the current (2006) round of water planning within Texas (Texas Water Development Board: Desalination FAQs).

GWCD and PGMA

The formation of the Upper Trinity Groundwater Conservation District (GWCD) set precedence for potential regulation of water used during oil and gas operations. Prior to the formation of the Upper Trinity Groundwater Conservation District, the oil and gas industry was not regulated regarding their use of water in their operations by Ground Water Conservation Districts in Texas. The Upper Trinity Groundwater Conservation District will be responsible for the conservation, preservation, and protection of groundwater within Parker, Wise, Montague, and Hood counties.

The Texas Commission on Environmental Quality (TCEQ) completed a report in June, 2007 presenting data pertaining to an updated priority groundwater management area (PGMA) study for North Central Texas. This study addresses the Trinity and Woodbine Aquifer area included in Collin, Cooke, Dallas, Delta, Denton, Ellis, Fannin, Grayson, Hood, Hunt, Johnson, Kaufman, Lamar, Montague, Navarro, Parker, Red River, Rockwall, Tarrant and Wise Counties. The study suggests that there is not enough groundwater to meet the needs of future population growth in these counties. Beneficial reuse of an alternative supply (produced water) and conservation of an existing supply (conservation of potable water sources during fracturing operations) would offset to the extent practical the need for increased water supplies to make up the shortage in water demand in the future for these counties outlined in the TCEQ June, 2007 PGMA study.⁸

Barnett Shale

The Barnett Shale is a large extensive gas reserve in North Texas. The Barnett Shale fracturing operations utilize massive hydraulic fracturing stages in horizontal wells. Wells in Johnson County in the spring of 2006 were being fractured with more than 5 million gallons of water. This water for the most part was coming from surface water supplies and other municipal sources in the area. This was considered by some citizens as unrestrictive use of large amounts of potable water during what some considered to have been a drought situation.⁹ Railroad Commission of Texas staff estimate there could be over 50,000 wells in the Barnett Shale before the field is fully developed.¹⁰ Beneficial reuse of any viable portion of produced water and practical conservation of fresh water during well fracturing operations would be of benefit to the local communities of North Central Texas.

⁸ June 2007 Priority Groundwater Management Area File Report –Updated Evaluation for the North-Central Texas – Trinity and Woodbine Aquifers –Priority Groundwater Management Study Area, Water Supply Division of Texas Commission on Environmental Quality.

⁹ Burnett, D. 2007. Recovery of fresh water resources from desalination of brine produced during oil and gas production operations. Global Petroleum Research Institute report prepared for the United States Department of Energy. College Station, Texas: Harold Vance Department of Petroleum Engineering, Texas A&M University.

¹⁰ June 2007 Priority Groundwater Management Area File Report –Updated Evaluation for the North-Central Texas – Trinity and Woodbine Aquifers –Priority Groundwater Management Study Area, Water Supply Division of Texas Commission on Environmental Quality.

Conclusion

Pre-treatment practices followed by membrane filtration can reduce disposal costs associated with the hauling and injection of produced water. Treated, produced water can become an economically viable alternative water supply, helping to offset future water shortages in high growth areas having, or that will have, limited access to fresh water resources.

Proper treatment and reuse can decrease the amount of produced water(s) that will require disposal in an environmentally acceptable manner, and can:

- Reduce oil and gas producers' costs associated with disposal of produced water
- Allow produced water byproducts from oil and gas operations to be re-injected in an environmentally acceptable manner.
- Provide an alternative source of treated water for beneficial reuse in a manner considered appropriate by the local community
- Provide an alternative source of treated water for reuse by oil and gas producers
- Reduce the need for oil and gas producers to consume potable water during well fracturing operations and/or well stimulation procedures
- Reduce the number and frequency of truck hauling operations associated with produced water disposal
- Reduce the number and frequency of truck hauling operations associated and well fracturing operations
- Reduce road repair and maintenance costs associated with damage caused during oil and gas water hauling activities.
- Reduce vehicle emissions (increased air quality) due to reduction in truck hauling operations

The old adage that oil and water do not mix might not apply any more. Contemporary advances in treatment technologies can allow for the treatment (pre-treatment and membrane filtration) of oil and gas produced water so that a portion of what once would have been considered wastewater can be reused to benefit our communities.

Treatment Approach & Design: Oil and Water DO Mix After All

1. Hypothesis and Long-Term Objective

Reclaimed produced water from crude oil and gas production operations can serve as a beneficial water supply.

2. Proposed Approach: Pre-Treatment and Membrane Filtration

A challenge of utilizing membrane filtration is to protect the process from produced water constituents that can damage the surface of the membranes. Any and/or all the following considerations should be addressed prior to membrane filtration:

- a. Flow equalization
- b. De-oiling
- c. Suspended solids removal
- d. Soluble organics to control biological growth

Pretreatment can reduce membrane fouling, thus optimizing the membrane efficiency and extending the time frame between element cleaning cycles. Membrane filtration preceded by pretreatment reduces the costs of reverse osmosis in the treatment of oil and gas produced water and increases overall effectiveness.

3. Use Benefit of Treated Produced Water

3.1 Agricultural Use - According to estimates by the U.S. Geological Survey (Hutson et al. 2004),¹¹ the U.S. agricultural community withdrew more than 140 billion gallons per day (more than 3 billion bbl/d) of fresh water for irrigation, livestock, and aquacultural use in 2000.

- a. Irrigation of crops
- b. Livestock watering
- c. Wildlife watering and habitat
- d. Managed wetlands
- e. Aquaculture and hydroponics vegetable culture

3.2 Domestic Use - Treated to potable water quality

- a. Surface water discharge – released to a surface water source
- b. Groundwater discharge – injected to be stored for future use
 - Recharge for a water bearing aquifer
 - Aquifer Storage and Recovery (ASR)
In 1999 the EPA identified at least 130 ASR wells in use throughout the country;¹² however, at the time none were injecting produced water.

¹¹ Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, "Estimated Use of Water in the United States in 2000," U.S. Geological Survey Circular 1268, 46 pp. Available at <http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf>.

¹² EPA, 1999, "The Class V Underground Injection Control Study, Volume 21, Aquifer Recharge and Aquifer Storage and Recovery Wells," EPA/816-R-99-014u, U.S. Environmental Protection Agency, Sept. Available at <http://www.epa.gov/safewater/uic/classv/pdfs/volume21.pdf>.

- c. Pipeline transfer – piped for direct use, to surface water and/or groundwater storage

3.3 Industrial Use

- a. Cooling water and other power production uses – Another potential use of produced water is cooling water. According to the U.S. Geological Survey (Hutson, et al. 2004), the U.S. power industry withdrew about 136 billion gallons per day (more than 3 billion bbl/d) of fresh water for power plant cooling.
- b. Oil Field Use
 - Fracturing operations – In areas where natural gas fields are expanding rapidly (e.g., the Barnett Shale in Texas and the Fayetteville Shale in Arkansas), local water supplies may not be adequate to meet the demand for frac water. Produced water or "flow-back water"—the water returning from the formation following a frac job—can be treated and reused for new frac jobs.
- c. Dust Control – Most unpaved roads can create substantial dust. Some oil and gas regulatory agencies allow operators to spray produced water or treated produced water on dirt roads to control the dust.
- d. Fire Control – Fires can exist anytime, but often occur during the driest seasons of the year. Areas experiencing drought conditions are particularly vulnerable. In many cases, only limited surface and ground water resources are available for firefighting. During drought conditions there may only be limited surface and/or groundwater resources available for firefighting. Produced water may in some cases be used for firefighting applications; although, application of large volumes of saline produced water can adversely impact soils. The impact to soils may be far less devastating however, than a large fire.
- e. Underground Injection for enhanced oil recovery – oil and gas producers already are capable of doing this as applicable.

4. Current Methodologies Oil and Gas Producers Use to Address Produced Water Concerns

- 4.1 Offsite Commercial Disposal – Some operators prefer to send their produced water offsite to a commercial disposal facility. This is typically accomplished by having a truck periodically visit the well locations, remove the accumulated water, and haul it away to the destination facilities for processing and disposal.
- 4.2 Underground Injection for Disposal – Injection into underground formations is the most common approach for onshore produced water management. These injection wells are designated as Class II wells and are further subdivided into the following:
 - a. Class II-R – enhanced recovery
 - b. Class II-D – disposal
 - c. Class II –H – hydrocarbon storage
- 4.3 The produced water may need treatment (to control excessive solids, dissolved oil, corrosion, chemical reactions, or growth of microbes) prior to being injected into the formation to prevent plugging of the formation or damage to equipment.

Appendix: Outline of Review Process

References and Additional Publications