New Mexico EPSCoR

RESEARCH INFRASTRUCTURE IMPROVEMENT (RII 4)
PROPOSAL DEVELOPMENT PROCESS

SCIENCE WHITE PAPER

FOR DISCUSSION
OCTOBER 21, 2011

TITLE: PRODUCED WATERS IN OIL AND GAS EXPLORATION

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New Mexico EPSCoR Program is funded in part by the National Science Foundation award #0814449 and the State of New Mexico. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Draft White Paper on Produced Waters in Oil and Gas Exploration

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This white paper is still in development. We have established societal arguments to work on produced waters and have are in the process of defining science questions.

First, in meetings with Robert Balch and Frank Huang we explored the three different issues that come first to mind when considering the nexus of energy-water-environment in oil and gas exploration: produced waters, hydraulic fracturing and "pit issues", i.e. how to dispose of waste liquids generated at oil and gas wells. A consensus was reached among us that produced waters seem to hold the most promise for the development of strong science questions. Produced water is water from underground formations that is brought to the surface during oil or gas production. Produced water is the largest waste stream associated with oil and gas production and the cost of managing such a large volume of water is a key consideration to oil and gas producers. Anything that would convert produced water waste into "something useful" would have a positive impact on oil and gas exploration.

The volume of produced waters in the United States is around 21 billion barrels (1 bbl = 42 U.S. gallons) per year or equivalent to about 2.4 billion gallons per day (Clark and Veil, 2009). The latter volume would supply about 14 million people at the level of Albuquerque's per capita water use.

In 2007, Texas contributed 35% of the total volume of produced water generated in the United States followed by California (12%), Wyoming (11%), Oklahoma (11%), Kansas (6%) and Louisiana (5%) (Clark and Veil, 2009). Despite the scarcity of water in many areas of the United States (including Texas, California and Wyoming) more than 98% of all produced water from onshore wells is re-injected underground while the remaining 2% of national produced water volume is managed through evaporation ponds, offsite commercial disposal, beneficial reuse, and other management methods. Therefore, Hendrickx, Balch and Huang first looked for possible science questions in the area of purifying produced waters to alleviate water scarcity. Purification and reuse of produced waters is a great challenge due to the wide variability of Total Dissolved Solids concentrations from several thousand to several hundred thousand mg/L. Attempts have been made to desalinize produced water using membrane processes. However, the cost associated with the treatment is exceedingly high for elevated TDS waters such as in southeastern New Mexico. Transportation cost of the purified water is another major hurdle (Huang, personal communication). In areas with low TDS produced waters such as the Powder River Basin in Wyoming, the beneficial use of produced waters for agriculture is attempted with mixed success due to the problems of water and salinity management (Hendrickx and Buchanan, 2009; Hendrickx et al., 2005). Although many engineering and economic challenges need to be overcome for purification and reuse of produced waters, most of the scientific knowledge is available. Therefore, the topic of "produced water purification" seems not well suited for the NSF EPSCOR proposal.

However, the topic of "energy generation from produced waters" holds much promise for the formulation of exiting science questions. In hydrology, the use of "water power" has been well established from the use of water mills in medieval times (Dooge, 2004) to the generation of electricity by using water elevation differences in mountainous areas today.

Although using produced water as a source of freshwater is often cost prohibitive, the high TDS concentrations actually provide a unique opportunity for power generation with osmotic pressure. Statkraft, a Norwegian utility company, has constructed a pilot plant in 2009 using seawater and freshwater as the source of osmotic pressure. The company has patented osmotic power membranes, which have a thin and open structured support to maximize the trans-membrane salt gradient for higher osmotic pressure. The power density currently achievable is about 3 W/m2 with seawater (3.5% TDS; ~35,000 mg/L) and freshwater. The company believes that the threshold for commercialization of osmotic power is 5 W/m2 but even then, it will need 5 million m2 of membrane for a power plant of 25 MW.

In the southeast New Mexico, the TDS upper limit of 3.5% experienced by Statkraft no longer exists since the produced water in this region can have TDS up to several hundred thousand mg/L. There is also no need for precious freshwater resources as long as produced water with lower TDS can be utilized or non-potable brackish ground water. With the high-TDS produced water in the region, the power generation by osmotic pressure could be increased significantly as shown in the table below.

Source of Osmotic Pressure		ΔP (atm)*	Power density (W/m^2)
Seawater (3.5%)	Freshwater	29	3
Produced water (21%)	Produced water (1.2%)	163	17**

* rough estimation using the Van Hoff's equation
** scaled proportionally using Statkraft's data

The proposed concept extracts clean energy from produced water, currently a waste product of oil production, before it is finally disposed. However, in order to realize the benefit, research in the following areas is needed:

1. New membrane element configurations and perhaps new membrane design
2. High-pressure and corrosion-resistant pressure exchanger and power generator
3. Pretreatment needed to minimize membrane fouling
4. Mitigation of membrane fouling

Advantages:

1. Can only be implemented in certain regions of the country
2. Generate clean energy from a waste product – offset the disposal cost of produced water

3. Freshwater is not used for energy production – lower impact to the surrounding population
4. Facilities can be set up near the injection wells to minimize the cost of transporting produced water from the production wells
5. Disposal of the process brine shouldn't be a problem – using the existing injection wells.

Although existing disposal options can be used, another option is to use the less saline waters that remain after energy generation as a supply for algae ponds. Algae have become a viable option for energy production as is shown by Sapphire Energy that has invested already more than a half-million dollars spent on developing a pilot facility to refine algae into fuel for the U.S. military and it is all happening in southwestern New Mexico. Frank Huang, Snezna Rogelj and Corey Leclerc have worked on different aspects of the use of algae for energy production and are identifying science questions. Researchers at NMSU are also working in this area.

Summary: The topic of energy generation from produced waters is promising since (1) a number of scientific questions need to be resolved and (2) the volume of produced waters is so large that the societal relevance of disposal is significant.

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