Office of Fossil Energy

eye on environment

**Produced Water Issue**
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This Edition of Eye on Environment features Produced Water filtration technologies.

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# Technology to Clean Produced Water for Beneficial Use

There is tremendous appeal in turning wastewater from oil and gas operations into an economic asset. Large volumes are produced in the arid western United States in association with oil and gas activities, particularly coalbed natural gas development. The concept of finding beneficial uses for produced water could result in converting a high-cost liability into an asset.

Statistically, 98% of all waste generated by petroleum exploration and production activities is produced water. Current regulations and practices cause most of this produced water to be reinjected in disposal wells, a costly and wasteful practice, particularly in areas where the water could be used for agricultural or municipal needs.

DOE's Oil and Gas Environmental Program places a major emphasis on developing new technologies to clean produced water for beneficial use. The results of several recent and ongoing projects illustrate the new directions in produced water management. Improved membrane filtration systems are the focus of research at Texas A&M University (**Figure 1**), the Petroleum Recovery Research Center (PRRC) at New Mexico Tech, and the University of Texas. Projects at Texas A&M and New Mexico Tech focused on removing salts from brackish and produced waters, while the new research at UT focuses on removal of organics and oil particles.

**Figure 1.** *Mobile Desalination Unit. The trailer can process up to 10,000 gallons per day of water suitable for local ranching and small communities' water use.*

## ADVANCED MEMBRANE TECHNOLOGY

Texas A&M's Dr. David Burnett has worked on two DOE-funded research projects to develop advanced membrane technology for desalination of oil field brine and new cleaning agents for membrane filters used to treat oil field produced water for beneficial purposes. The research has produced a mobile testing and treatment laboratory (**Figure 1**) that can be taken to the field to process produced water onsite. The trailer uses membrane filtration technology applied to reverse osmosis (RO) systems for desalination of brackish waters and brines.

RO has been used for decades for desalination of seawater, primarily in arid, coastal countries where fresh water for human consumption is scarce. The process works extremely well but is expensive and requires a disposal site for the concentrated brine produced. Desalination projects located on seacoasts traditionally dispose of the concentrated brine into the ocean.

Development of cost-effective desalination technology that can be used inland and applied to oil and gas field produced waters opens up tremendous potential for beneficial use of the produced water in arid parts of the western U.S. Texas is a prime state to test the membrane filtration technology because of its extensive oil and gas production, the need for large volumes of water for agriculture and human use, and the diminishing water supply from the major aquifers supplying water to Texas citizens. In Texas there are over 300,000 operating wells producing over 500 million gallons of water a day. Other western states also produce large volumes of water. The increase in coalbed natural gas (CBNG) production in the Rocky Mountain states has greatly increased the volume of produced water, as water production is particularly high in the initial phases of CBNG development.

Work with the Texas Water Resources Institute has shown that brackish produced water with moderate salinity (less than 40,000 parts per million [ppm]total dissolved salts, or TDS) can be desalinated using the advanced membrane filtration RO system (**Figure 2**). The key to cost-effective RO desalination is the pre-treatment of the water to remove particular matter and heavy minerals and to reduce the saline content. The process relies on improved filters and new methods to clean the filters on a daily basis. The concentrated brine produced by the filtration system has been classified as hazardous waste requiring special precautions for disposal. Texas A&M recently has received permission for a pilot test of the mobile processing system to treat produced water and reinject it into deeper formations onsite. This would significantly reduce the cost of disposal of the concentrated brine and make the cleaning of produced water for beneficial applications affordable for agricultural and human use.

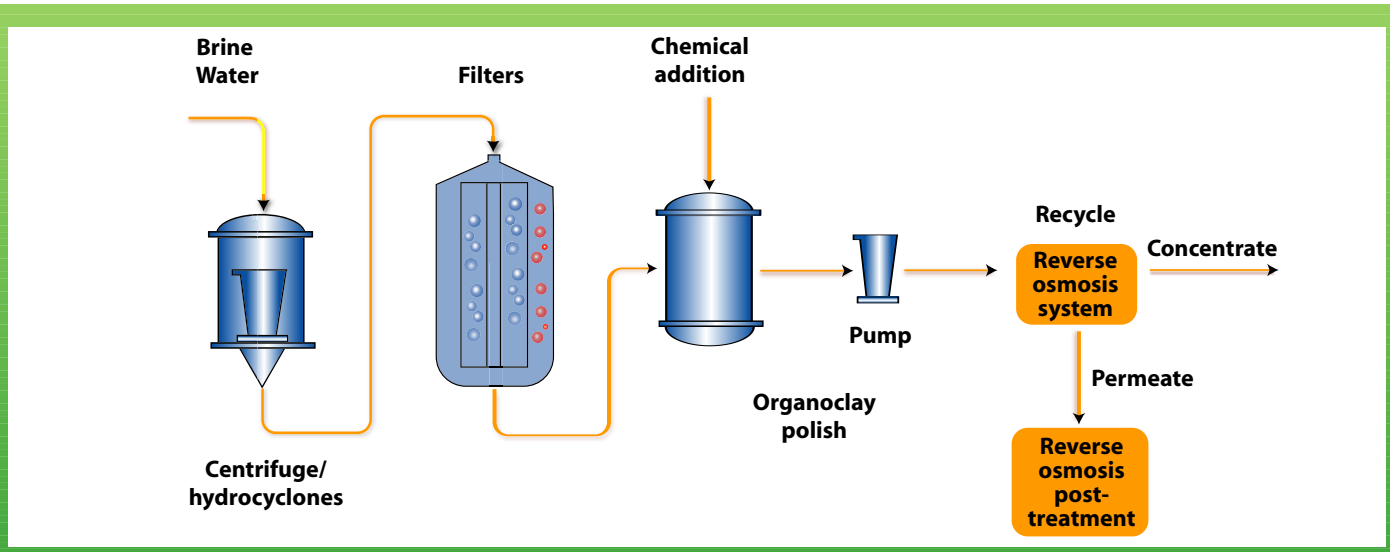



**Figure 2.** *The produced water pre-treatment and reverse osmosis system process.*

## Cost-effective filtration

Currently, the membrane filtration system is capable of treating 2 gallons per minute or roughly 6,000-10,000 gallons per day. Brackish water is cleaned to a quality level of 100 ppm TDS. The trailer includes pre-treatment filtration, reverse osmosis, and a cleaning unit for the filters. The unit can clean the produced water for 50-98 cents per gallon depending on the salinity of the water treated. Use of variable frequency pumps for power generation and refinements of the filter cleaning system are expected to lower the costs to 2 cents per gallon. Field tests of the new pumps and cleaning system are being conducted in South Texas in the spring and summer of 2005.

Pilot studies using the mobile advanced membrane filtration system in the Barnett Shale play in North Texas found that proper pre-treatment of water used to hydraulically fracture new gas wells could save an average of $8,000 per completion or $40,000 per well. Operators in the active Barnett Shale play are drilling 5 new wells a day, with each well using 10,000-15,000 bbl of fresh water per frac treatment. Savings for one company operating in the Barnett Shale that cooperated in the pilot were estimated at $250,000 per month. Addtional tests of the membrane filtration system (**Figure 3**) were conducted at the Texas A&M firefighter and hazardous substance training facility.

## Filter cleaning technology

The emphasis of the DOE-funded project on cleaning agents for the membrane filters is to reduce the time and labor costs in cleaning filters and maintaining production volumes. Membranes function like injection well surfaces and can't be flushed or backwashed. A special chemical system currently being tested reduced the cleaning time from all night to less than 3 hours. The goal is to cut down the amount of time and water need to clean the membrane using micellar solutions.

## Benefits to the operators

The reduction in cost of water disposal could save operators thousands of dollars per well over disposal by reinjection, including trucking produced water to EPA-specified sites. Cost reduction is estimated at 10% of the operating budget. If the pilot onsite brine reinjection is successful and EPA approves this method, the savings in disposal costs would be significant. In addition, operators would have large volumes of marketable fresh water. For hydraulic fracturing and waterflooding projects membrane filtration of produced water would reduce the cost of water needed for these oil and gas field operations by allowing recycling of produced water.

**Figure 3.** *The water used at Texas A&M's firefighter and hazardous substance training facility contains chemicals and oily wastes produced by fires in realistic domestic field situations. The mobile desalination unit recycles the water for continuous reuse.*

## Benefits to the community

Low-cost clean produced water could provide much-needed water for crops, livestock, and human consumption in Texas and other western states. In Texas the depleted aquifers are a growing problem with the inability to provide adequate water supplies to a number of communities looming in the near future, suggesting the prospect of long-term water rationing. Many of these small communities are in the Permian Basin and South Texas where oil production is high. In the Permian Basin 8 barrels of water are produced for each barrel of oil. In many areas produced water could become a valuable asset to the producers and the communities.

***Produced Water*** *feature continued on page 8*

special section

# DOE's Alaska Office Promotes Environmentally Friendly Energy Development

Alaska is a unique collection of sensitive ecosystems, home to awe-inspiring natural beauty and innumerable wondrous fauna and flora. For many Americans it is the crown jewel of the Nation's natural endowment.

An equally impressive part of the state's natural endowment is its status as the Nation's largest repository of energy resources. Alaska holds about half of America's remaining proved oil reserves, almost a quarter of its proved natural gas reserves, and over half of its coal resources. When nonconventional oil and gas resources such as viscous oil, coalbed natural gas, and methane hydrates are factored in, the potential energy resources of the Last Frontier state dwarf the combined resources of its Lower 48 brethren.

Alaska's vast natural endowment thus makes it not only a microcosm of many of the energy and environmental challenges facing the nation but also a lightning rod for the conflicts between those two critical values.

Mindful of this challenge, Alaskan North Slope oil and gas operators today continue a long-standing tradition of safeguarding environmental values. Extensive research has been conducted and millions of dollars spent to protect the slope's flora and fauna. Just a few examples of these efforts include the following:

- Special care to preserve caribou calving grounds means that the population of the Central Arctic caribou herd near Prudhoe Bay oil field is at its highest level in 25 years, having grown more than sevenfold since Prudhoe Bay development started in the 1970s.
- Careful monitoring by scientists has shown no species population has ever declined in the region due to oil industry activity.
- The first field development offshore the North Slope, Point McIntyre, even included a multimillion-dollar "fish-funnel" breach in the causeway to the Beaufort Sea gravel island production site that allowed arctic char and other fish to pass through unharmed rather than disrupt their migration.
- Drilling operations on the slope occur only during a limited winter weather window when the ground is snow-covered and hard. Special fat-tired rolligon vehicles are used to transport rigs and other equipment and to conduct seismic exploration during this weather window to avoid damaging the delicate tundra.
- The "footprint" and impacts of oil operations today have been greatly reduced in recent years. Alpine, the latest major development on the slope—and a likely prototype for future developments—was developed on just 0.2% of the field area. Alpine discharges almost no wastes, focusing on recycling or reuse. Ice roads that melt and disappear in the spring provide the only ground access to the field, and then only in winter.

*The Alaskan North Slope Porcupine caribou herd has grown sevenfold since Prudhoe Bay development started in the 1970s.*

### Arctic Energy Office

The Department of Energy's Arctic Energy Office (AEO) was established in 2001 to address Alaska's unique energy needs and potential.

AEO, a partnership between DOE's National Energy Technology Laboratory and the University of Alaska-Fairbanks (UAF), works in collaboration with state agencies, the energy industry, and public stakeholders. The office's mission is to facilitate arctic energy research and development in two areas: Fossil Energy and Remote Electrical Power Generation.

The Fossil Energy R&D mandate is a given for Alaska: It has perhaps the largest remaining undiscovered oil and natural gas potential of any state in the U.S. and yet the biggest technical, economic, and environmental hurdles to exploration and production. Access issues stemming from environmental concerns remain the most contentious of these hurdles.

AEO's R&D mission demonstrates NETL's commitment to ensure environmentally responsible development of Alaska's hydrocarbon resources.

*Alpine oil field facilities. The North Slope field development footprint has shrunk by over 77% since the 1970s.*

That's an especially crucial mandate for the North Slope, where in-place and yet-to-find petroleum resources are estimated at more than 100 billion barrels of oil. Without timely development of these resources, America's most important pipeline, the Trans-Alaska Pipeline System (TAPS), would be shut down. TAPS ships some 18% of U.S. oil production to market, but North Slope output is in decline. Failing to replace that declining production in a timely way would render TAPS uneconomic and cripple America's ability to recover the slope's remaining oil resources.

Some of the environmental barriers to E&P that AEO is working to address in the Arctic include:

- Transportation issues, such as moving heavy equipment in arctic regions within acceptable limits of tundra disturbance.
- Issues related to the building of pipelines where permafrost is present.
- Restricted access to the North Slope.
- Limited technology for dismantlement and removal of idled infrastructure and restoration of the landscape.
- Fragile ecosystems.

AEO works with UAF, industry, and state agencies to identify research priorities to address these barriers and R&D needs and to improve technology transfer to Alaska operators.

## Arctic program projects

AEO-managed projects are designed to bolster U.S. energy security by leveraging Alaska's uniquely large hydrocarbon potential and to provide energy solutions for isolated Alaskan residents. About 15 projects are active. A sampling of the key NETL program activities in Alaska in 2005 appears on the following two pages.

DOE is conducting a detailed analysis of Alaska North Slope oil and gas resources and interrelated technical, economic, and environmental factors that control the development of these resources. This assessment, to be completed in 2005, would project where future development might occur in order to assist regulatory agencies with planning, predict future oil production under three assumptions about the anticipated North Slope natural gas pipeline, and estimate when Prudhoe Bay oil field may no longer be economic to operate.

Development is continuing of a Tundra Pond Pumping and Watershed Model that would allow for more effective, efficient, and economic development of ice roads for low-impact North Slope oil and gas development. Ice roads are the preferred method for providing access to drilling sites on the North Slope of Alaska. Water supplies also are needed to support facility operations. There is little precipitation and little water flow except during snow melt in the spring. Generally, the State limits pumping of arctic lakes to 15% of volume but does not know whether that is a safe limit. In fall 2002, the University of Alaska-Fairbanks, together with other project cooperators, initiated a study to obtain baseline information about the physical, biological, and chemical characteristics of North Slope lakes in order to help assess some of the major questions related to lake water use. The study found that there were no measurable impacts in the Kuparuk River field area at pumped levels (which were lower than the 15% permitted volumes); data collected could enable development of lake recharge models to estimate maximum quantity of water available without adverse environmental impact; ice-chipping could be removed from permit-volume restrictions at selected lakes, resulting in increased water availability; and the state and BLM are considering use of watershed and recharge estimates when issuing water withdrawal permits models. This project will help ensure continued access to water for building ice roads and for facility operations while maintaining or enhancing current levels of environmental protection.

*Winter ice roads are critical to North Slope operators' efforts to minimize damage to the fragile arctic tundra.*

Further validation is expected of the Tundra Travel Model, which already has enabled North Slope operators to significantly expand a once-shrinking window of opportunity for drilling. Generally, drilling and other industry operations such as seismic surveying are allowed on the slope when the snow over the tundra is six inches deep and the ground is frozen solid to a depth of 12 inches. But changing weather patterns reduced this window by half over the last 30 years. Reducing the drilling window could mean stretching out a well over several seasons, crippling an exploration or development project's economics. The DOE-funded Tundra Travel Model project studied the possibility of developing a new standard based on scientific data and found the tundra to be much more resistant throughout the season than previously thought. Armed with better data, Alaska's Department of Natural Resources (DNR) was able to advance the opening date for tundra access and still maintain—and in some cases enhance—current levels of protection. Most recently, DNR opened the eastern coastal area of the slope on Dec. 10, 2004, the earliest opening since 1995 and two weeks earlier than the prior season.

DOE, with BLM and Alaska's Division of Geological and Geophysical Survey (DGGS) and others, is co-funding a project to evaluate the potential of coalbed natural gas (CBNG) as a remote

power fuel in rural Alaska. DGGS studied CBNG potential in rural Alaska and identified 38 rural villages on or near coal resources. Exploiting nearby CBNG resources could provide a long-term source of low-cost, clean energy to rural Alaskans, who usually must rely on diesel-fueled generators for heat and power. The logistics of supplying liquid fuels to these remote locations drive rural Alaskans' energy costs to more than fivefold those in Fairbanks and Anchorage. The project recently completed drilling into low-rank coals at Fort Yukon, AK, using slimhole drilling technology that sharply reduces mobilization and drilling costs, and is analyzing the results. Separately, DOE also is funding review of CBNG produced water disposal methods in Alaska, also a critical issue for resource development amid environmental concerns in the Lower 48.

In a continuing effort to strive for a "zero-footprint" drilling operation on the North Slope, DOE in 2003 announced the successful start-up of Anadarko Petroleum Corp.'s Arctic Platform. This lightweight, 100-by-100-foot aluminum drilling platform stands 12 feet above the frozen tundra on specially designed steel legs. Modeled after offshore drilling platforms, the rig is compact and modular, allowing it to be transported with negligible surface impact. It could some day eliminate the need for ice roads and gravel and ice pads that often are needed on the slope.

*Anadarko Petroleum Corp.'s Arctic Platform is part of DOE's efforts to create a "zero-footprint" drilling operation on the North Slope.*

A consortium led by Petro Star Inc., Anchorage, AK, is developing a microbial biocatalyst to remove sulfur from diesel with funding from DOE. Once the biocatalyst has been developed, Petro Star will use biocatalyst desulfurization in tandem with hydrotreating to achieve the EPA-mandated future diesel sulfur level of 15 parts per million. Plans call for building a demonstration unit at Petro Star's Valdez, AK, refinery. Petro Star also will demonstrate feasibility of chemical extraction desulfurization in producing an ultra-clean diesel, engine-test the diesel, and design a pilot plant with an eye toward future commercial demonstration.

Further testing of ultra-clean diesel fuel derived from natural gas continued this year in Alaska following successful tests of the fuel last summer. Tulsa, OK-based Syntroleum Corp. developed a proprietary process based on Fischer-Tropsch technology that yields ultra-clean transportation fuels from natural gas. That shows promising potential for monetizing huge reserves of stranded natural gas on the North Slope. The DOE-funded Syntroleum project logged a major milestone in March when its gas-to-liquids (GTL) demonstration plant at Catoosa, OK, achieved a cumulative production level of 200,000 gallons of ultra-clean fuels. The lead partner with Syntroleum is Integrated Concepts & Research Corp., a subsidiary of Koniag Inc., an Alaskan Regional Native Corporation. The Catoosa GTL plant's output underwent real-world testing in bus fleets in Alaska's Denali National Park. The Denali National Park summer testing was so successful that park officials asked to continue use of the fuel into the winter months. Early results showed significantly reduced emissions and improved vehicle performance. The GTL diesel burns with much less of the soot commonly seen in diesel exhaust and surpasses not only current but pending federal and state air quality standards for ultra-low levels of sulfur in fuels.■

### Benefits to the environment

Approval of the EPA for onsite reinjection of the concentrated brine from membrane filtration treatment will have a valuable environment impact. It will reduce the operations footprint by eliminating the need to truck brine to EPA Class II disposal wells. Mobile membrane filtration systems can be deployed in many small communities to handle wastewater and recycle the water for beneficial use. The membrane filtration trailer (**Figure 3**) set-up has been demonstrated for recycling water at the firefighter and hazardous substance training facility at Texas A&M.

## ZEOLITE MEMBRANES

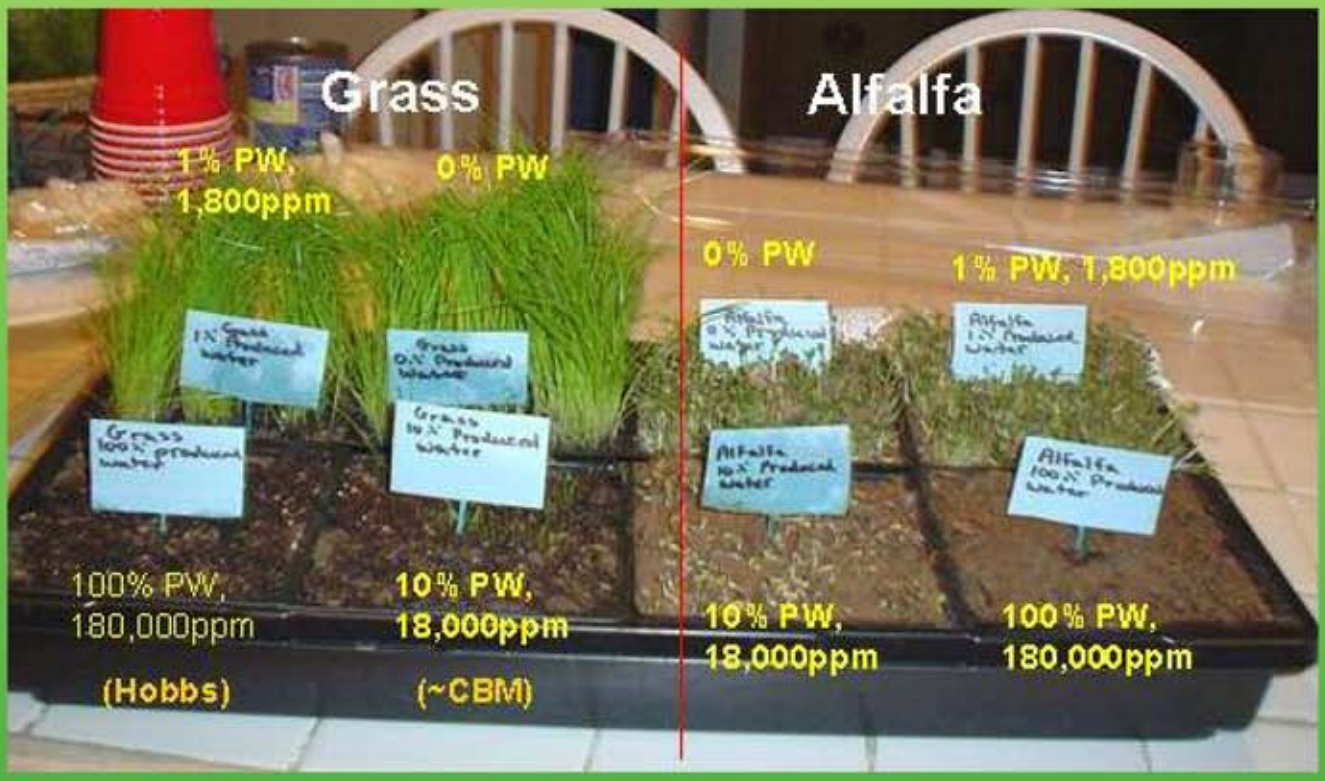
Research conducted at PRRC by Drs. Junhang Dong and Robert Lee and their associates has resulted in development of new zeolite membranes to treat CBNG produced water for beneficial use. Salinities for CBNG produced waters from New Mexico are high at about 170,000 ppm TDS. Most of this produced water is disposed of in deep injection wells, which is a costly process and inherently wasteful in an arid state where water supply is crucial.

The current project's objectives include improving operating conditions to optimize water flow, evaluating the technical and economic feasibility of scaling zeolite membranes from laboratory to field use, and achieving a better understanding of the RO process and membrane performance. The data presented in **Figure 4** demonstrate the challenge. The zeolite membrane has excellent performance factors for water separation, but the low volume of water flow and high cost of the membrane make it uneconomic at present. Improving methods to synthesize the zeolite membranes and to optimize operating conditions for water and ion exchange are expected to provide a long-term, cost-effective membrane.

Previously, DOE-funded projects at PRRC have shown the technical superiority of zeolite membranes and RO purification techniques for processing CBNG produced water. Laboratory-tested produced water samples from CBNG and oil field development can be cleaned sufficiently to provide irrigation water. A New Mexico State Science Fair project in 2005 used water provided by PRRC to demonstrate the effects of typical produced water vs. produced water processed through the zeolite membrane. Species of native grasses and alfalfa were monitored as shown in **Figure 5**.

| Properties | Polymer membrane | Zeolite membrane |
|---|---|---|
| Organic resistance | Poor | Excellent |
| Organic rejection | Incapable of | Very good |
| Ion rejection | Good | Good |
| Applicable TDS level | Low (<4%) | High (to saturation) |
| Membrane regeneration | Difficult | Simple |
| Lifetime | Short (< 3 mon) | Long (> 5 yr) |
| Chemical stability | Unstable in low pH | Stable: acidic to basic |
| Operating pressure | >800 Psi | <450 Psi |
| Thermal stability | Poor | Outstanding |
| Water flux | >5 kg/h.m$^2$ | ~0.5 kg/h.m$^2$ |
| Membrane cost | Low | High |

**Figure 4.** *A comparison of the properties exhibited by traditional polymer membranes and zeolite membranes.*




Hobbs oil field PW 180,000 ppm; Farmington CBNG PW 18,000 ppm

***Figure 5. A New Mexico State Science Fair project by Brittni Romero using produced water and zeolite membrane filtered water to irrigate grasses and crops. Four levels of salt concentration were used to analyze the effects of produced water on plant growth. The first plot in each sample used produced water from oil fields near Hobbs, NM, at original concentrations of 180,000 TDS. Additional plots used produced water that had been treated through the zeolite membrane filtration system developed by PRRC, at levels of 10% (18,000 ppm TDS) and 1% (1,800 ppm TDS). The final comparison test used pure distilled water. In the samples where the produced water was cleaned to 1% of the original salt concentration, seed germination and growth was significantly improved. Photo courtesy of Brittni Romero.***

## Synthesized Zeolite Membranes

The improved zeolite membranes developed at PRRC are in-situ synthetically grown membranes of a type termed Modified Fouling Index (MFI) membranes. They have been shown to be thinner membranes with better ion exchange capabilities than previously available synthetic membranes. The intercrystalline pore space of the MFI zeolite membrane is significantly smaller at 0.55 nanometers (nm) than that of the FAU type zeolite membrane (0.74 nm), providing superior filtration of salts from the produced water.

The zeolite membrane develops by geothermal formation into a very strong organic material. The zeolite membrane is highly porous, allowing small water molecules to pass through but preventing larger organic constituents and salts from passing through the membrane. Zeolite membrane surfaces are illustrated in schematic diagrams and SEM (scanning electronic microscopy) photographs (**Figure 6**).

## Sensor Development

In conjunction with the zeolite membrane project, research is being conducted on a robust sensor for in-situ detection and monitoring of various chemicals. An innovative material has been developed that enables optical chemical sensors to produce a response. One process to be evaluated is the

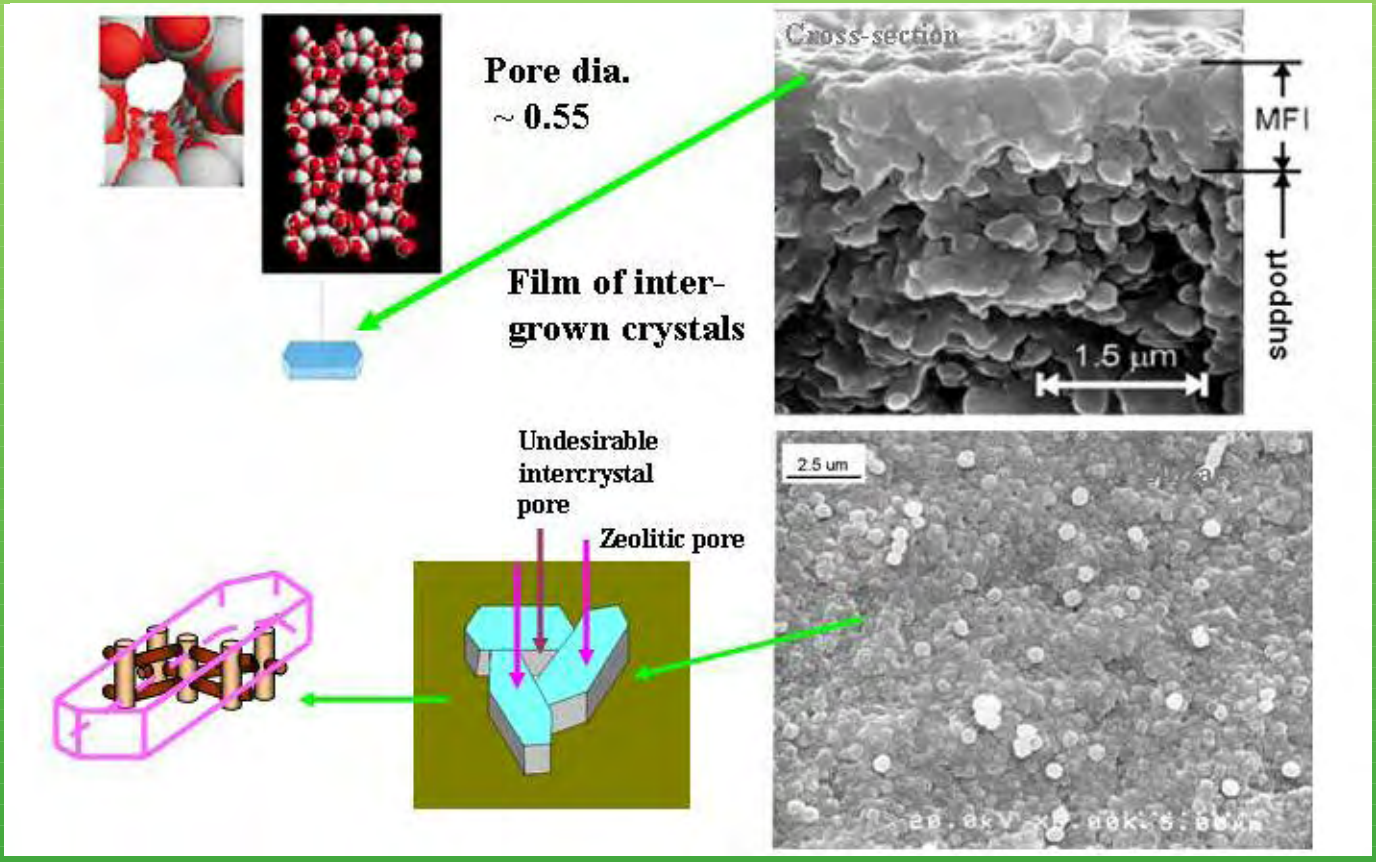



**Figure 6.** *Close-up microphotographs of the zeolite membrane and diagrams of the crystal growth system that allows water to pass through but prevents salts from passing through the membrane.*

growth of zeolite crystals, which are very porous, on a surface optical fiber. The optic properties of this membrane enables use of a light index to identify the chemicals in the produced water. This holds potential for in-situ monitoring produced water during the filtration process. It would avoid having to take samples and the preparation and analysis time for the samples as well as provide real-time data on organic and salt content of the produced water. These zeolite optical sensors can be developed for environmental monitoring in addition to use in membrane filtration systems.

### Benefits of Zeolite Membranes

The synthetic zeolite membranes are easy to clean, have a longer life, and are chemically more stable that other in-situ synthetic membranes. The membrane can resist acid corrosion and operate under low-pressure conditions. Performance of the modified zeolite membrane is better than traditional polymer membranes for separation of produced water. The goal of the project is to provide an economic membrane system that can reduce oil field produced water salinity to less than 10% of normal levels and make the water available for beneficial use, particularly in agriculture. In-situ monitoring of produced water using zeolite-impregnated optical fibers could result in significant cost savings in CBNG produced water monitoring.

## NOVEL CLEANUP AGENTS FOR MEMBRANE FILTERS

A newly funded project at UT conducted by Dr. Benny Freeman is starting to look at removal of emulsified oil, particulates, and dissolved solids from produced water. The focus of the research is on alternatives to dramatically improve the fouling resistance of polymer membranes used in mem-

brane filtration RO processes. New chemical fouling-reducing membrane coatings will be developed and applied to commercially available RO and other membrane systems currently in use.

Polymer membranes are potentially the most flexible and viable long-term strategy for treatment of produced water. The mixture of impurities in produced water including salt, emulsified oil, and particulate matter dramatically decreased the membrane life through irreversible fouling. Organic constituents in particular are difficult to remove and cause damage and rapid depletion of filtration membranes used in the RO process. Because membranes are porous the fouling penetrates the membranes as well as coating the surface.

Copolymer-based membranes formed from polyethylene glycol compositions will be used as the basis of the chemical tests. Several formulas will be tested for their ability to provide optimum separation of organic constituents and water. A series of chemical coatings will be tested on the membranes. An important aspect of the copolymers is that they are able to maintain the flexible rubbery nature and strength of the original membrane without damage by the cleaning agents applied and without reduction in water separation ability.

The novel approach of the project is to develop techniques to apply the new coatings directly on the RO membranes, which then would be capable of removing fouling by particulates, salts and emulsified oil in a single step. Direct chemical modification work will include preparation and testing of the RO membranes grafted with molecules that provide a strong double polymer bond. The goal is to find the optimal materials for water flow and reduction of fouling.

Initial laboratory results with water emulsions of oil and organic materials show the coated polymer filters can produce high-quality water. In comparison tests against pure water the time required for filtration of water and oil mixtures and mixtures with surfactants added is longer than for pure water (**Figure 7**).

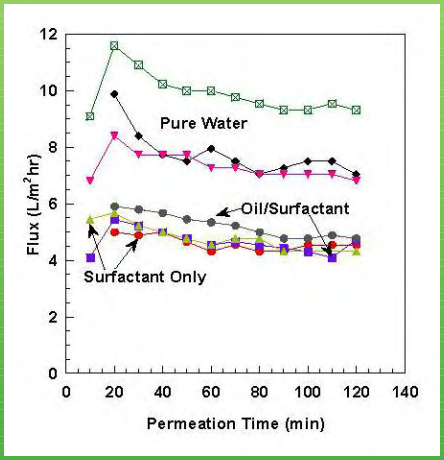



**Figure 7.** ***Comparison tests of time and penetration for pure water and oil/ water mixtures through the newly developed coated filters.***

## Summary

Because of the great need for water in the western U. S. and the high costs of produced water disposal, the interest in developing efficient, cost-effective methods of cleaning produced water for beneficial use has become a high priority for the Department of Energy. Clean, usable produced water will provide independent operators an alternative to high-cost disposal methods for large volumes of water and at the same time provide them a high-demand, saleable commodity. Farmers, ranchers, and communities in the West need high-quality water for agriculture, and basic water supplies, particularly areas such as West Texas where the aquifers are rapidly being depleted. The three projects in Texas and New Mexico are employing different approaches to the search for technologies to improve existing distillation and filtration methods. Research to provide low-cost, high volumes of reduced-TDS produced water ultimately will help fill the water needs of the arid western states.

# Upcoming Events/Meetings

**May 15-17, IOGCC,** *2005 Midyear Meeting,* Anchorage, AK
Contact: **www.iogcc.state.ok.us**

**May 24-25, Alaska Clean Energy Symposium,** Anchorage, AK
Contact: **www.weststart.org**

**May 24-25, IADC,** *Drilling Engineering Association Workshop,* Galveston, TX
Contact: **www.iadc.org**

**June 12-14, Western Governors' Association,** *Western Leadership in the Global Economy,* Breckenridge, CO
Contact: **www.westgov.org**

**June 15-17, IPAA,** *2005 Midyear Meeting,* San Francisco, CA
Contact: **www.ipaa.org**

**August 1-3, Colorado Oil & Gas Association** *Rocky Mountain Natural Gas Strategy Conference & Investment Forum,* Denver, CO
Contact: **www.coga.org**

**September 18-20, IOGCC**, *2005 Annual Meeting,* Jackson Hole, WY
Contact: **www.iogcc.state.ok.us**

**October 24-26, IPAA,** *2005 Annual Meeting,* Houston, TX
Contact: **www.ipaa.org**

**November 8-11, International Petroleum Environmental Conference (IPEC),** Houston, TX
Contact: **http://ipec.utulsa.edu**

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