Desalination Research at Texas Universities —A Brief Overview

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Introduction

Since 2002, the Texas Governor's Office and the Texas Water Development Board (TWDB) have led efforts to promote desalination in Texas. Several agencies and organizations have suggested that desalination—both of coastal and inland waters—may help water-short regions of Texas meet their water needs.

For desalination to succeed in Texas, reliable, cost-effective, and adoptable technologies are needed. This will require scientific advances in pretreatment, characteristics of different sources of saline water, methods of salt separation, disposal of brine, effects of byproducts on the environment, and management of desalination facilities. Scientists at universities across Texas are investigating these high priority issues.

This paper presents an overview of recent desalination research in Texas. The paper includes a list of additional readings that provide technical information and the email addresses for each author cited in the paper.

Recent Efforts to Support Desalination Research in Texas

In April 2002, Texas Governor Rick Perry announced an initiative to develop a demonstration project to desalinate waters from the Texas Gulf Coast. Later that year, TWDB —the State's water planning agency—worked with the Governor's office and regional planning groups to develop a process to screen and prioritize proposed demonstration projects. TWDB presented information on desalination to regional water planning groups who were in the process of developing strategies to meet future water needs in their area. In December 2002, TWDB submitted a report to the Governor's Office that recommended desalination demonstration projects.

In April of 2003, TWDB staff worked with the Texas Water Resources Institute (TWRI) at Texas A&M University, and the Center for Research in Water Resources (CRWR) at the University of Texas at Austin to conduct a workshop to raise awareness and interest in desalination research. The goal was to ensure that people engaged in desalination activities were aware of research being carried out throughout Texas. Several of the research projects mentioned in this paper were discussed at the workshop. Presentations made at the workshop can be viewed on the TWDB website, http://www.twdb.state.tx.us.

Since that time, interest in desalination has increased substantially in Texas. TWDB published a report describing the volume of brackish and saline groundwater in Texas aquifers and developed a competitive grants program to support desalination research projects at universities

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in Texas. Several grant awards have been made by TWDB for desalination research and those studies are presented in this paper.

The National Research Agenda

Several federal agencies are involved in developing national research goals for desalination, including the U.S. Bureau of Reclamation (USBR), the U.S. Environmental Protection Agency, the U.S. Department of Energy (DOE), the Bureau of Land Management, and Sandia National Laboratories. State agencies that are supporting desalination research include TWDB, the Texas Railroad Commission, the Texas Commission on Environmental Quality, the Texas Higher Education Coordinating Board (THECB), and the Houston Advanced Research Center.

The "desalination roadmap" was published in 2003 as a joint effort of USBR and Sandia National Laboratories, and describes a vision for a national desalination research agenda. It states, "By 2020, desalination and water purification technologies will contribute significantly to ensuring a safe, sustainable, affordable and adequate water supply for the United States."

According to the report, some of the factors that are driving the heightened emphasis in desalination include the following:

- The potential to treat saline groundwater,
- The need to reduce the cost of water produced through desalination,
- Technologies created through research must be transferred to users.

The Roadmap identifies research challenges that need to be addressed, including:

- Reducing the cost and energy requirements to dispose of concentrates,
- Lowering the total cost for desalination processes,
- Developing beneficial uses for reject waters.
- Minimizing the impacts of the disposal of reject water on receiving ecosystems (i.e., bays, estuaries, and other habitats).

Over the short-term, the report suggests that the cost of waters reclaimed through desalination can be reduced by 25% and that 5% of reject waters can be beneficially reused. Over the long-term, the aim is to lessen the cost of desalination by 80% and to beneficially use 15% of reject waters.

Aspects of desalination research now emphasized by USBR include the following:

- The creation of smart membranes that sense changes in water quality in real time,
- The use of sensors to rapidly detect the formation of biofilms that increase fouling,
- Thermal technologies,
- Recycling and reuse strategies,
- Methods to manage concentrate and reject waters,
- New approaches to membrane design to increase permeability,
- Developing ways to reduce energy costs.

In 2004, the National Research Council published a review of the desalination roadmap. The review suggested that future research needs should address energy efficiency and air emissions associated with large-scale desalination plants, the development of membranes and related technologies that are resistant to fouling, improving pretreatment methods, and developing alternative technologies that would reduce costs and be more environmentally sustainable. The review recommends that more emphasis be placed on the reuse, recycling, and management of concentrates and reject waters. Charles Turner of the Civil Engineering Department at the University of Texas at El Paso was a member of the review team that developed the report.

DOE researches issues associated with oilfield-produced water through its National Energy Technology Laboratory. DOE efforts focus on understanding the chemical constituents in produced waters; the volume of waters that are generated; how produced waters are managed; and related economic and environmental challenges. In 2004, DOE worked with the Argonne National Laboratory to develop a white paper that describes issues associated with the desalination, treatment, reuse and disposal of produced waters. The white paper discusses water quality concerns associated with produced waters, the potential effects of discharging produced water to terrestrial and coastal environments, and regulatory issues.

Research in Pre-Treatment

Researchers from the University of Texas at Austin, Texas A&M University, Rice University, the University of Houston, Lamar University, Texas Tech University, and Texas A&M University—Kingsville are engaged in research about pretreatment to improve desalination performance.

At the University of Texas at Austin, researchers are working to characterize the traits of "ideal" membranes, to develop a "total recycle" membrane system, and to evaluate pretreatment methods to optimize membrane performance. Benny Freeman of the Chemical Engineering Department is working to develop membranes that can deal with high water fluxes and high rejection rates. The goal is to create membranes that are inexpensive, mechanically strong, chemically stable, resistant to fouling, and able to withstand high temperatures. Desmond Lawler of the Civil Engineering Department is carrying out studies to determine how particle size, precipitation, and water softening prior to the use of ultrafiltration and reverse osmosis affect the ability of membranes to achieve drinking water quality. Lawler is studying how removal of natural organic matter by conventional water treatment processes (i.e., coagulation and softening) can reduce organic fouling. Gerald Speitel of in the Civil Engineering Department is investigating how the removal of organic compounds through adsorption, oxidation, and biodegradation can inhibit fouling and improve membrane performance. He is evaluating such pretreatment methods as advanced oxidation using a combination of ultraviolet light, hydrogen peroxide oxidation, and granular activated carbon for adsorption.

At Texas A&M University, studies are under way to model pretreatment processes that influence the performance of desalination processes, to develop processes that restrict membrane fouling, and to design pretreatment strategies based on the traits of the waters to be treated. Bill Batchelor of the Civil Engineering Department is engaged in research to model how chemical processes such as equilibrium, precipitation, and leaching affect membranes used for desalination. Batchelor is also investigating how the use of high doses of lime combined with aluminum can improve softening pretreatment by removing scale-forming compounds such as silica and sulfate. Tim Kramer of the Civil Engineering Department is investigating physical and chemical processes including coagulation and particle motion that influence membrane performance. Kramer is researching how nanofiltration pretreatment affects absorption and coagulation and how membrane fouling can be better understood by monitoring biological, chemical, and colloid parameters. Mahmoud El-Hawagi of the Chemical Engineering Department is designing sitespecific pretreatment strategies based on the characteristics of incoming feed streams and the traits and intended uses of treatment byproducts. He is also working to optimize the performance of desalination plants by incorporating processes that reduce energy needs, conserve water use, and reduce waste streams.

At Rice University, researchers are evaluating parameters that optimize pretreatment processes used in association with desalination. Mark Wiesner of the Civil and Environmental Engineering Department is studying coagulation, membrane rejection, and the use of nanofiltration, ultrafiltration, and granulated activated carbon for pretreatment. He is also researching how colloids and organic matter influence membrane fouling, and is designing and testing modular membrane systems that may lessen the initial investment cost and optimize operating costs.

At the University of Houston, studies are underway to evaluate the effects of pretreatment and operating conditions on membrane performance. and to develop and test bench-scale and pilot-scale membrane systems. Shankar Chellam, in the Civil and Environmental Engineering Department, has investigated how membrane filtration performs in removing sediments in waters from Lake Houston. Chellam and Dennis Clifford of the Civil and Environmental Engineering Department are also investigating if pretreatment methods that use iron and aluminum compounds can reduce membrane fouling and enhance the removal of contaminants.

At Lamar University, studies are being conducted to characterize the rate of inorganic fouling, and the mechanisms that cause fouling, in nanofiltration and reverse osmosis membranes used for desalination. Jerry Lin of the Civil Engineering Department is assessing the extent to which fouling occurs, both under typical desalination operating conditions as well as in cases with varying concentrations of saline water. One goal of these studies is to compare the performance of various conventional pretreatment methods used in desalination with membrane filtration. Lin is refining and testing an experimental membrane system with a Proportional, Integral and Derivative (PID) control system that precisely monitors the results of the treatment process in real-time. Lin and Thomas Ho of the Chemical Engineering Department recently completed a study funded by the Texas Hazardous Waste Research Center to characterize and model inorganic scaling caused by soluble salts.

At Texas Tech University, researchers are developing “closed loop” pretreatment systems that can improve membrane treatment for space travel. Andrew Jackson of the Civil Engineering Department is conducting research for the National Aeronautic and Space Administration to develop pretreatment applications for closed-loop systems used for spacecraft. Jackson and Audra Morse recently completed a project funded by TWRI that assessed how remnants of antibiotics may survive after treatment by membranes and other technologies.

At Texas A&M University – Kingsville, researchers are studying issues related to biological and chemical fouling of gas-permeable membranes. Lee Clapp of the Environmental and Civil Engineering Department is evaluating the effects of biofilm formation and iron sulfide precipitation on membrane gas transfer characteristics under anaerobic conditions. Results may provide insights into how to minimize biofouling and scaling problems in reverse osmosis applications.

Developing Advanced and Improved Membranes

Researchers from the University of Texas at Austin, Rice University, Lamar University, the University of Houston, and Texas A&M University are developing methods to improve the capability of membranes to be used in desalination operations.

At the University of Texas at Austin, researchers are investigating how polymers can be modified to improve membrane performance, and are carrying out evaluations of the use of membranes in treatment processes. Benny Freeman of the Chemical Engineering Department is examining how characteristics of the feed water and flux influence the likelihood that fouling may occur. Freeman is also engaged in efforts to modify polymers through the use of inorganic hybrid materials to optimize desalination performance. The goal is to create coatings for ultrafiltration that can limit the adverse effects of membrane fouling. Douglas Lloyd of the Chemical Engineering Department is investigating ways of forming and modifying membranes to improve performance, including the development of flat sheet and hollow-fiber advanced membranes. Lloyd is now leading studies to investigate ways of controlling pore size and pore size distribution in the formation of flat sheet and hollow fiber membranes. Lloyd is also investigating ways of modifying membranes through a unique stretching processes designed to improve performance and is developing membranes that can be disposed of and biologically degraded after use. Lloyd and Roger Bonnecaze of the Chemical Engineering Department developed computer models that foster the development and manufacture of hollow fiber membranes created through spinning processes. This research was funded by THECB.

At Rice University, researchers are evaluating new methods to develop membranes, including the use of nanostructures, ceramic materials, polymers, reactive and smart membranes, rotating disks, and the creation of membranes with different geometric patterns. Mark Wiesner of the Civil and Environmental Engineering Department, Andrew R. Barron and Vicki Colvin of the Chemistry Department, and Michael Wong of the Chemical Engineering Department are engaged in new technologies to create advanced membranes. They are developing models to project the initial investments needed to start up and operate desalination treatment plants as well as the cost associated with concentrate disposal. In studies funded by THECB, Wiesner evaluated the use of ceramic membranes to treat waters with high levels of dissolved organic matter and suspended solids. The study assessed the use of these membranes in microfiltration and ultrafiltration to produce drinking water, and compared the performance of membrane treatment to conventional systems.

At Lamar University, research is developing new techniques to detect membrane fouling using micro-sensor and micro-fluid technologies, and creating membranes that are resistant to inorganic scaling. Jerry Lin of the Civil Engineering Department is evaluating the use of deoxygenation methods to control corrosion in desalination processes as well as methods to provide direct in-situ measurement of membrane fouling. Lin is collaborating with Sun Yat-Sen University in Taiwan to explore the feasibility of using an imprinted micro-fluid system on membrane surfaces coupled with electronic measurements to directly detect and quantify inorganic scaling. Rafael Tadmor of the Chemical Engineering Department is developing methods to measure how the interfacial tensions, surface roughness, and composition of membranes relate to the wetting properties and affect membrane performance. Tadmor is investigating how membrane surfaces can be modified using surfactants and polymer coatings.

At the University of Houston, researchers are developing complex computer software systems to monitor and predict membrane performance and are comparing the performance of membranes with other technologies in desalination processes. Shankar Chellam of the Civil and Environmental Engineering Department is working to develop neural computer networks that can predict membrane fouling. Results may play a role in developing full-scale membrane treatment systems. Dennis Clifford of the Civil and Environmental Engineering Department is carrying out investigations to compare the performance of such desalination technologies as reverse osmosis and electrodialysis to processes that remove single contaminants, such as ion exchange and adsorption. In studies funded by THECB, Chellam and Paul Ruchhoeft of the Electrical and Computer Engineering Department are developing new processes to fabricate membranes that have a uniform size and few imperfections. The goal is to create membranes with exact standards that have a consistent pore size to ensure specific contaminants are filtered out and removed.

At Texas A&M University, researchers are developing and testing advanced membrane technologies. Tim Phillips of the College of Veterinary Medicine is developing porous filtration materials with composite organic clay materials that may improve treatment capabilities. Tim Kramer of the Texas A&M University Civil Engineering Department is evaluating a capacitive deionization technology that may provide low-energy and low cost desalination.

At the Houston Advanced Research Center, Richard Haut of the Sustainable Technologies Group is cooperating with the U.S. Navy Surface Warfare Center (NAVSEA) in Maryland to evaluate the performance of reverse osmosis systems used for desalination. NAVSEA supports the testing of components and systems of advanced concepts for desalination, and replicates the new generation of desalination technologies used in ships now being constructed. Filtration and high pressure pumps are tested at NAVSEA.

Desalination of Brackish Groundwater and Oilfield Produced Waters

Although much of the focus of desalination research focuses on recovering drinking water from the Gulf of Mexico and other coastal waters, researchers at Texas A&M University, Rice University, the University of Texas at Austin, Texas Tech University, the University of Texas at El Paso, and the University of Houston are investigating the treatment of saline and brackish groundwater, as well as produced waters generated by oil and gas exploration processes.

At Texas A&M University, researchers are developing innovative methods to desalinate brackish and saline groundwaters and treat oilfield-produced waters. In 2000, a comprehensive program was initiated by TWRI and the Department of Petroleum Engineering to study desalination and its role in becoming a sustainable source of fresh water supplies. David Burnett of the Petroleum Engineering Department has used the experience of the oil and gas industry to design special pretreatment practices to treat oily wastes from brine water and make them amenable to membrane desalination. A special joint venture, led by Burnett, was established in 2002 by the Global Petroleum Engineering Research Institute (GPRI) to investigate the desalination of oilfield brines to recover fresh water for beneficial use. In June 2004, Burnett established a program to develop new types of membrane cleaning agents to be used in water treatment facilities. Burnett was awarded a DOE grant in August 2004 to develop new practices to restore membranes used in microfilter and reverse osmosis technologies used for desalination. This project also involves developing cleaning agents and evaluating strategies to remove plugging materials. In 2003, Burnett worked with Carl Vavra of the Texas A&M University Separation Sciences Program to construct a mobile, portable, treatment unit that can be operated at remote test sites. Burnett also worked with Maria Barrufet and graduate student Mustafa Siddiqui of the Petroleum Engineering Department to develop extensive data about the specific contaminants that must be removed if oilfield-produced waters can be treated, desalinated, and reused. By learning more about the components of waste streams, the most appropriate desalination methods can be selected on a case-by-case basis. Burnett and Bill Fox of TWRI are developing research and demonstration projects that will treat produced waters onsite with a mobile unit that uses membranes, reverse osmosis, and related technologies. The research will include evaluating potential uses for reclaimed water (i.e., landscape irrigation, habitat restoration, and streamflow augmentation) as well as monitoring how reuse and land application affect ecological conditions. Burnett, Fox, and Gene Theodori of Texas Cooperative Extension are examining community attitudes about whether residents want to accept treated produced water and the ways they prefer to use this resource. In all these projects, researchers are examining ways to reduce the cost of treatment in order to make reuse more economically attractive than current practices to dispose of produced waters.

Texas A&M University faculty are investigating how water chemistry affects the stability of high salinity waters and are developing brine diffusion systems. Bill Batchelor of the Civil Engineering Department is assessing the chemical stability of high-salinity reject waters produced in association with desalination. Roy Hann of the Texas A&M Civil Engineering Department is designing brine disposal systems for the United States Strategic Petroleum Reserve that may have minimal negative environmental impacts.

At Rice University, Mark Wiesner of the Civil and Environmental Engineering Department has developed data from 120 wells in 11 states about the water quality parameters associated with oilfield brines that may influence the needed level of treatment before these waters can be disposed of or reused. The research involved matching desalination treatment processes to water quality challenges, and estimating the costs associated with treatment, reuse, and disposal.

At the University of Texas at Austin, researchers are examining how water treatment processes can be optimized for saline waters, how desalination byproducts can be used to enhance oil production, and finding the most ecologically sound sites to dispose of these resources. In 2002, Lynn Katz and Kerry Kinney of the Civil Engineering Department were awarded a DOE grant to provide new alternatives to purify water produced during oil and gas exploration. Katz and Kinney were subsequently awarded another DOE grant in 2004 to conduct long-term field testing of a treatment system that uses surfactant-modified zeolite to remove dissolved organics from produced water. Gary Pope of the Petroleum Engineering Department is examining how reject waters and brines can be reused to maintain and enhance formation pressures for secondary oil recovery. Jean-Philippe Nicot, and Sigrid Clift of the University of Texas at Austin Bureau of Economic Geology are exploring the use of abandoned oil and gas well fields as disposal sites for reject waters resulting from desalination in research supported by TWDB and USBR. The goal is to demonstrate that disposal of desalination reject water in oil and gas fields is safe and reliable. The project involves modeling the physical and chemical characteristics of oil fields in the Permian Basin, East Texas, the Gulf Coast, the Dallas-Fort Worth area, and other sites. Nicot is also leading a TWDB-funded project to develop an inventory and database of municipal and industrial desalinization facilities in Texas.

At Texas Tech University, researchers are developing innovative methods to reuse desalination byproducts. Andrew Jackson, Clifford Fedler, and Priyantha Jayawickrama of the Texas Tech University Civil Engineering Department are developing desalination technologies that can use brines various components of road construction projects.

At the University of Texas at El Paso (UTEP), research has evaluated the use of desalination technologies to treat impaired waters and saline groundwater. Anthony Tarquin of the Civil Engineering Department has tested methods to remove silica compounds and salts from groundwater. UTEP researchers have conducted several studies for USBR to develop desalination methods that can treat impaired waters while generating electricity.

At the University of Houston, Shankar Chellam of the Civil and Engineering Department is developing methods to treat saline groundwaters. Chellam and graduate students recently completed studies to delineate the effects of temperature on how water, salts, and organic compounds are transported across membranes used for nanofiltration and reverse osmosis. Chellam is testing membrane systems that can operate at a wide range of temperature fluxes that have the potential to recover up to 85% of feed water volumes, thus decreasing the amount of wastes that have to be disposed.

Environmental Issues Associated with Coastal Desalination Projects

One of the major issues that must be overcome if the desalination of coastal waters is to become a reality involves evaluating the extent to which coastal ecosystems may be affected by the discharge of reject waters from these plants. Scientists from Texas A&M University—Corpus Christi, the University of Texas at Austin, and Texas A&M University—Kingsville are studying these concerns.

At Texas A&M University—Corpus Christi, James Bonner of the Conrad Blucher Institute for Surveying and Science is conducting studies to establish ambient conditions in near-shore Texas waters, focusing on the Corpus Christi Bay region. Information gained through such monitoring activities provides an environmental baseline for a variety of water quality parameters, including salinity. Bonner and graduate student Temitope Ojo are developing a modeling method which could be used to detect environmental changes due to the discharge of brine. Modeling results are being confirmed by high frequency radar and remote sensing data. The studies have the potential to provide new insights about the dispersal of brines in near-shore waters. Joanna Mott is part of a team studying populations of marine bacteria that are present in various stages of desalination processes, including intake waters, produced water, and reject waters. The research, funded by USBR, was conducted at a treatment plant near Corpus Christi Bay and provides insights into the extent that desalination can remove bacteriological organisms.

At the University of Texas at Austin, investigations have examined such issues as the ecological impacts of disposing of brines in coastal waters, and modeling how saline and fresh waters mix in bays and estuaries. Ben Hodges and graduate student Paula Kulis of the Civil Engineering Department are carrying out computer modeling studies funded by THECB to predict how brine reject waters will mix with surface waters once they are discharged to bays and estuaries, as well as the effects of brine disposal on dissolved oxygen levels other environmental parameters. Results of the project will be useful in identifying sites for brine discharges that are environmentally benign and economically feasible. George Ward of CRWR is investigating the use of hydrologic models that predict how the mixing of waters in bays and estuaries affects salinity concentrations. The research, funded by THECB, can be used to assess the impacts of the disposal of brines from desalination plants.

At Texas A&M University—Kingsville, Ni-Bin Chang of the Environmental and Civil Engineering Department is using advanced computer models to simulate how the operations of a proposed desalination plant in Oso Bay near Corpus Christi may affect salinity concentrations in coastal waters. The research is using two- and three-dimensional hydrodynamic models to predict how water quality and fisheries harvests may be affected by brine discharges from desalination plants.

Operations of Desalination Plants

Researchers at the University of Texas at El Paso (UTEP), Texas A&M University, and the University of Texas at Austin, the University of Houston, and Midwestern State University are evaluating engineering, mechanical, and operational issues associated with desalination facilities.

At UTEP, several research projects have been undertaken to develop desalination technologies and management strategies. In 2004, Charles Turner of the Civil Engineering Department worked with Ed Hamlyn of the Center for Environmental Resources Management (CERM) and Alfredo Olivas of the University of Ciudad Juarez in Mexico to examine if desalination may extend the usable life of the region's aquifers. The study uses the MODFLOW model and geographic information systems to examine the feasibility of underground storage of desalination concentrates for future use, as well as more conventional techniques to manage desalination reject waters. Turner and Jesus Moncada are now conducting research into the use of concentrates for electrokinetic soil sealing to replace geomembranes in evaporative ponds. A 2003 study by Turner and John Walton of the Civil Engineering Department evaluated the performance of a desalination project that incorporates membrane distillation and is powered by thermal energy supplied by a salt-gradient solar pond. That study was funded by USBR. Anthony Tarquin of the Civil Engineering Department carried out a study for USBR to evaluate treatment methods to remove silica compounds from reject waters that are created when reverse osmosis is used for desalination. The research was conducted at a plant operated by El Paso Water Utilities and compared treating reject waters with nanofiltration or lime, followed by reverse osmosis. A 2002 USBR-funded investigation led by Huanmin Lu, Herbert Hein, and John Walton developed and field-tested a thermal desalination system that uses multi-effect and multi-stage flash desalination with salinity-gradient solar pond technology. In 2002, UTEP researcher Huanmin Lu of CERM developed a "zero discharge" waste brine management system for desalination plants. This project was also funded by USBR.

At Texas A&M University, researchers are developing new desalination technologies, evaluating operational issues related to proposed desalination plants, and developing public-private sector strategies to design, build, and manage desalination facilities. Mark Holtzapple and graduate student Jorge Lara of the Chemical Engineering Department are evaluating the economics of a novel patent-pending vapor-compression desalination approach which has the potential to substantially reduce capital and maintenance requirements while achieving greater energy efficiency. Much of Holtzapple's research is conducted in a pilot-scale plant at Texas A&M University. Although vapor-compression desalination is a well-known technology, it has not been commercialized on a large scale compared to reverse osmosis and multi-stage flash evaporation. To improve the economics of vapor-compression evaporation, Holtzapple and Lara are developing low-cost, high efficiency, evaporators, compressors, and engines. Holtzapple and graduate students Manohar Vishwanathappa and Somsak Watanawanavet are investigating the use of jet ejectors for desalination operations. The research includes the development and testing of more efficient jet ejectors and compressors, as well as advanced heat exchangers and optimal system configurations. The Texas A&M University Separation Sciences Group coordinates workshops and training associated with membrane technologies used in desalination. This training, coordinated by Carl Vavra, offers hands-on training about the use of membranes for desalination to professionals in the oil production industry and can develop customized solutions to match treatment processes to specific water quality concerns. In Far West Texas, a desalination research and education consortium was recently formed involving the Texas A&M University Agricultural Research and Extension Center at El Paso, UTEP, New Mexico State University, El Paso Water Utilities and the Alamogordo National Laboratory. The Consortium for High Technology Investigations in Water and Wastewater will foster collaboration among researchers at these institutions. James Smith, a researcher in the Construction Sciences Department, is evaluating global trends in desalination (including operations and economic issues) and is developing strategies to more fully engage the private sector in the design, construction, and operations of desalination plants. Smith has identified several alternative methods in which private sector corporations can best work with the private sector while simultaneously mitigating risks and reducing the likelihood of lawsuits.

At the University of Texas at Austin, George Ward of CRWR participated in a 2000 study to evaluate the potential environmental effects of discharging reject waters from a proposed desalination plant to Lavaca Bay. The project assessed how plant operations might affect temperature and salinity regimes in the bay and whether aquatic organisms might be harmed by such mechanical processes as pumping and recirculation. The study also compared the environmental merits of alternative methods to dispose of concentrates and reject waters that would be generated by the plant.

At the University of Houston, Dennis Clifford and Shankar Chellam of the Civil and Environmental Engineering Department are developing integrated portable membrane systems that can be used in remote locations without ready access to electricity. The concept is to avoid the use of chemicals for coagulation and disinfection by using iron electrocoagulation ahead of membrane filtration

At Midwestern State University in Wichita Falls, John Rhoads of the Physics Department and Jerry Faulk of the Mechanical Engineering Department are evaluating the potential to recover and reuse water from oilfield brines not amenable to reverse osmosis. The project, now underway, integrates the use of condensers and related technologies.

Computer Modeling of Watersheds and Coastal Basins

Several studies have been undertaken by researchers at Texas A&M University, Texas A&M University-Corpus Christi, Texas A&M University—Kingsville, and the University of Texas at Austin to utilize computer models to predict how reducing concentrations of saline water may affect river systems and coastal waters.

At Texas A&M University, Ralph Wurbs of the Civil Engineering Department at Texas A&M University has carried out several studies to model how salinity constraints affect the usable yield of waters in river and reservoir systems. These studies, which were funded by THECB and TWRI, were used to assess how removing salts from portions of the Brazos River can increase water yields. Wurbs has also led research projects to investigate the extent to which diverting water from saline streams and preventing it from flowing into river systems may lessen salinity concentrations in the Brazos River watershed.

Researchers at Texas A&M University—Corpus Christi, the University of Texas at Austin, and Texas A&M University—Kingsville are also using computer models to simulate how discharges of saline water may affect coastal environments. These studies are noted previously in this paper.

Social Sciences Research

Even though most aspects of desalination research have emphasized technical issues, scientists at Texas universities are also examining the politics, economics, and social sciences aspects associated with desalination technologies.

At Texas A&M University, Gene Theodori of Texas Cooperative Extension is examining public attitudes towards desalination projects and the conditions under which communities may choose to accept desalination reject waters.

At Texas State University, Walter Rast of the Geography Department has carried out international analyses about how the use desalination may lead to more sustainable use of water resources.

At Rice University, Dagobert Brito of the Economics Department has studied whether providing additional water via desalination may improve the chances for long-term peace between Israel and the Gaza Strip. His studies point out that desalination may provide enough water to alleviate water shortages in the region. A scarcity of water is one of the root sources of political tension in the region.

It also needs to be noted that several engineering and technology development studies of desalination have included economic components, even though little research has been conducted that focuses on a comprehensive economic analyses of issues pertaining to desalination.

Summary and Conclusions

Regional water planning activities have identified the water supply challenges facing many Texas communities. Desalination—of seawater, brackish ground and surface waters, and oilfield-produced waters—is expected to provide an increasing percentage of future water supplies.

Research at Texas universities is contributing to the knowledge base required to implement reliable, cost-effective desalination technologies. This paper summarizes these efforts and identifies additional resources and contacts. However, more research and development will be needed to realize the potential for desalination to contribute meaningfully to community water challenges.

In order to meet the water needs of Texas, the following principles should be incorporated into an action plan:

- State and local agencies must work together with universities to obtain federal funds for research and development,
- Local, regional, state, and federal agencies must work together to help communities evaluate opportunities to meet pending water shortages through the use of desalination and other non-conventional methods (i.e., water conservation, wastewater reuse, rainfall harvesting, brush control to improve streamflows, and water marketing).
- Under the continued leadership of TWDB, universities, agencies, and communities should continue to meet together to discuss strategies to meet water challenges.

In addition, the following high priority technical issues must be addressed through research, outreach, and education:

- Perfecting pretreatment and anti-fouling technologies,
- Developing new membrane materials that work efficiently at high temperatures,
- Recovering energy from reverse osmosis processes used for desalination,
- Perfecting promising low-energy technologies (i.e., capacitive deionization) and alternative energy sources (i.e., wind and solar),
- Injecting reject waters into depleted oil and gas fields,
- Evaluating the effects of the operation of desalination plants on the environment,
- Teaching water resources managers about best management practices.

With leadership from TWDB and other state and federal agencies, Texas universities can make a significant contribution to desalination technologies and management systems. The greatest potential lies in developing a coordinated network of university researchers and agency specialists to quickly and effectively mobilize needed research and development in support of communities throughout Texas.

Additional Readings

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