National
Water Research
Institute

NWRI FELLOWSHIP PROGRAM

Spring 2012 Fellowship Progress Reports

April 2012

About NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment.

NWRI's member agencies include:

- Inland Empire Utilities Agency (**www.ieua.org**)
- Irvine Ranch Water District (**www.irwd.com**)
- Los Angeles Department of Water and Power (**www.ladwp.com**)
- Orange County Sanitation District (**www.ocsd.com**)
- Orange County Water District (**www.ocwd.com**)
- West Basin Municipal Water District (**www.westbasin.org**)

For more information, please contact:

Jeff Mosher
Executive Director
National Water Research Institute
18700 Ward Street
P.O. Box 8096
Fountain Valley, California 92728-8096 USA
Phone: (714) 378-3278
Fax: (714) 378-3375
jmosher@nwri-usa.org
www.nwri-usa.org

Contents

1. About the NWRI Fellowship Program

For over 16 years, the National Water Research Institute (NWRI) has awarded fellowship funding to graduate students conducting leading-edge research in water science and policy. The purpose of these fellowships is threefold: to 1) support graduate students; 2) highlight talent and innovations at U.S. universities; and 3) encourage students to pursue careers in water.

Our program helps fund an average of 6-10 students a year at universities across the U.S. Fellowships range from $2,500 to $10,000 per student per year. Research areas include, but are not limited to, engineering, physical and chemical sciences, biological sciences, health sciences, political sciences, economics, and planning and public policy that are related to water and/or water resources.

Fellowship recipients are selected based on the strength of the application, which consists of a letter of inquiry, resume, research project proposal, transcripts, and advisor’s recommendation letter.

The NWRI Fellowship Program is funded in part through partnerships with organizations like the American Membrane Technology Association, Southern California Salinity Coalition, and NWRI Corporate Associates. An endowment fund was also established to support the Ronald B. Linsky Fellowship for Outstanding Water Research, which is a special fellowship awarded every 2 years to an innovative, multi-disciplinary research project within the water sciences.

More information about the NWRI Fellowship Program can be found on the NWRI website at www.nwri-usa.org/fellowship.htm.

2. NWRI Fellowship Program Sponsors

The NWRI Fellowship Program is sponsored by the NWRI Corporate Associates, whose membership fees are used to fund NWRI Fellowships. NWRI is thankful for the support of the following NWRI Corporate Associates:

BLACK & VEATCH

Black & Veatch Corporation is a leading global engineering, consulting, and construction company with more than 100 offices worldwide.
www.bv.com

carollo engineers

Carollo Engineers the largest firm in the United States that is solely dedicated to water related engineering.
www.carollo.com

CDM

CDM is a consulting, engineering, construction and operations firm with over 120 offices worldwide.
www.cdm.com

CH2MHILL

CH2M Hill is a global leader in consulting, design, design-build, operations, and program management.
www.ch2m.com

Kennedy/Jenks Consultants provides expertise in water, wastewater, environmental management, industrial facilities, transformational infrastructure, and more.
www.kennedyjenks.com

Malcolm Pirnie, the Water Division of ARCADIS, has more than a century-long history of consulting with a concentration on water and the environment.
www.pirnie.com

MWH is the global leader of the wet infrastructure sector, ranging from water supply and treatment to the design and construction of hydropower and renewable energy facilities.
www.mwhglobal.com

United Water, which is part of the SUEZ ENVIRONNEMENT group, is a leader in the water services industry, operating 226 municipal water systems.
www.unitedwater.com

3. NWRI Fellowship Program Community Partners

Funding for the NWRI Fellowship Program is also provided by water industry organizations, which are involved in selecting and following up with fellowship recipients and their research. NWRI is thankful for the support of the following NWRI Fellowship Program community partners:

AMTA
American Membrane Technology Association

The **American Membrane Technology Association** consists of organizations and individuals from the United States who are interested in solving water supply and quality issues through the widespread application of membrane technology.
www.amtaorg.com

SCSC

The **Southern California Salinity Coalition** was established in 2002 by a group of Southern California water and wastewater agencies to better manage salinity in our water supplies.
www.socalsalinity.org

4. Donors to the Ronald B. Linsky Fellowship Endowment Fund

NWRI established an endowment fund to support the NWRI Ronald B. Linsky Fellowship for Outstanding Water Research. We are thankful for the support of the following donors who have made the Linsky Fellowship possible:

- The Joan Irvine Smith/Athalie R. Clarke Foundation
- Mrs. Patricia Linsky
- Peter and Elsa Ching
- Dr. and Mrs. Harvey Collins
- Dr. William Blomquist
- Mr. Blake Anderson and Rev. Giovanna Piazza
- Dr. Chittaranjan and Sasmita Ray
- Dr. Jack Wang and Family
- Dr. and Mrs. James Moncur
- Dr. and Mrs. Richard Sakaji
- Mrs. Sandy White
- Dr. and Mrs. David Hsu
- Dr. Stephen Lyon
- Dr. and Mrs. H.S. Muralidhara
- Mr. and Mrs. Jeffrey J. Mosher
- Mr. John T. Andrew
- Ms. Dawn Jorgensen
- Ms. Karen Cowan
- Dr. Shahid Chaudhry
- Dr. William Cooper
- Mr. William R. Mills
- Mr. Leonard Dueker
- Dr. Charles P. Gerba
- Ms. Nancy R. Bushnell
- Mr. Terry and Mrs. Jan Debay
- EOA, Inc.
- RBF Consulting
- McCormick, Kidman & Behrens, LLP
- Dr. Kara Nelson
- Mr. and Mrs. Jean Stern
- Miss Kendra Colyar
- Dr. and Mrs. George Tchobanoglous
- Mr. Stewart Suchman
- Mr. and Mrs. John Shearer
- Mr. Michael Wehner
- Mr. Larry McKenney
- Mr. Daniel Cozad
- Dr. Philip Singer
- Dr. Joseph Cotruvo
- Ms. Vicki Elmer
- Mr. Kenneth Ishida
- Mr. and Mrs. Thomas Gielow
- Mr. James Zukin
- Mr. Larry Gallup
- Dr. Menachem Elimelech
- Dr. James Barnard
- Mr. Larry Russell
- Dr. Douglas Call

5. Spring 2012 NWRI Fellowship Progress Reports

Students who receive fellowship funding from NWRI must demonstrate measurable progress in their research. Therefore, they are required to provide short progress reports to NWRI in the fall and spring of each academic year that they are funded.

The following spring progress reports were provided by the five graduate students currently receiving NWRI Fellowship Program funding for academic year 2011-2012.

NATIONAL WATER RESEARCH INSTITUTE
NWRI Fellowship Program

Spring 2012 Progress Report

NWRI Fellowship
(Fall 2010-Present)

Lisa Welsh
Human Dimensions in Ecosystem
Science and Management Major
Utah State University

Graduation Date: 2012
Advisor: Dr. Johanna Endter-Wada

Water Policy Designs to Address Societal Transitions

To examine the foundational rules for allocating scarce water supplies and address current debates on how to meet the challenges of providing water in changing societal contexts efficiently, equitably, and effectively.

Lisa Welsh, Utah State University
NWRI Fellowship Program - Progress Report
April 2012

Policy Designs to Address Water Reallocations During Societal Transitions

Project Overview
My dissertation project explores how new policies that address water reallocation challenges can be designed to work within the context of existing water institutions to meet the parameters of efficiency, equity, and effectiveness. I am using three distinct case studies to illustrate how societal transitions are making people confront the rules by which we allocate and reallocate water. This report outlines the progress that has been made in this research since the last progress report in October 2011.

Progress
Since my last progress report in October, I have completed all of the data collection for my dissertation. My data collection was extensive and consisted of 60 interviews, field observations of water hearings, submitted public comments, and archival records from legislative libraries. In addition, the Nevada State Engineer has made his ruling on the Southern Nevada Water Authority's groundwater applications, and I have the information I need to complete my case study analysis.

Preliminary Research Findings
I am currently focusing on my first case study in my dissertation work, where I am examining human behavioral responses to real-time water meter technologies. Efficiency is commonly seen as a solution to resource scarcity. Increasingly, technology is considered the best way to increase the efficiency of resource use. Human water use in the Bear River Basin, a watershed located at the juncture of Utah, Wyoming, and Idaho, is primarily agricultural with water delivered to irrigation canals and diversions along the Bear River. In the Basin, people have been performing much technical work in metering and monitoring water use in recent years. Streamflow accounting models collect real-time data from various gauging stations that are presented on the internet for all users to examine.

Through interviews, I have found that this technology has led to refined water management, where water managers can more readily make adjustments in water diversions to react to changing conditions. The instrumentation has allowed water managers to regulate water allocations more closely, particularly important in times of drought. Some individual water users have used the real-time data to make more precise plans on how to use their water allocation throughout the irrigation season. The use of information technology in the Basin has shaped human-water interactions by allowing managers and water users to balance water conservation with their water use needs. However, managers and water users of the Bear River Basin do not use the real-time data in a vacuum. Through the creation of the law of the Bear River with compacts and other settlement agreements, water users understand that their water use is interdependent. The real-time data has helped water users develop a continuous dialogue so that they can aim to meet their water needs in ways that are both efficient and equitable.

Future Work
I will be presenting results from my research in the upcoming week at two conferences at Utah State University: the 8th annual Spring Runoff Conference and the Intermountain Graduate Research Symposium. I also plan on attending the annual conference of the American Water Resources Association in November. The support from the NWRI Fellowship has been greatly appreciated, and it has allowed my research to proceed in a timely manner.

NATIONAL WATER RESEARCH INSTITUTE
NWRI Fellowship Program

Spring 2012 Progress Report

NWRI Fellowship
(Fall 2010-Present)

Joshua T. Wray
Molecular and Cellular Biology Major
Arizona State University

Graduation Date: Spring 2013
Advisor: Dr. Milton Sommerfeld

Nitrate and Phosphorous Removal from Waste Streams Using a Microalgae-Based Membrane Bioreactor with Improved Anti-Fouling Design

To examine whether a new microalgae-based membrane bioreactor can be used to remove nitrate and phosphates from waste streams in a cost-effective manner, making nutrient recycling economically viable, as well as reducing impacts on water supplies of communities downstream.

Progress Report (October, 2011—April, 2012)

April 1, 2012

Joshua T. Wray
MCB PhD student
Arizona State University

Project Name: Nitrate and Phosphorous Removal from Waste Streams Using Microalgae-Based Membrane Bioreactor with Improved Anti-Fouling Design

Project Background &Status: Microalgae biotechnology has the potential to revolutionize waste management in industrial and agricultural settings by efficiently utilizing waste nutrient streams and converting them into biomass with valuable co-products, including pigments, oils, starch, and protein. A massive effort is currently underway by private companies and universities alike to capture this potential. The end goal is to create sustainable, profitable businesses that not only remove waste nutrient streams from the environment, but simultaneously create new products and jobs for the economy.

A major barrier to commercialization of many microalgae biotechnologies is the cost-effective production of fit-for-purpose biomass. Many systems require far too much input of energy and resources to make production possible for new algae start-ups trying to enter the market. Of primary concern is the amount of energy required for the cultivation and harvesting of biomass, two critical processes that have to be carried out in a timely manner to ensure quality control. This project has investigated the use of membrane technology to transform the way algae biomass is grown and harvested by using membrane in conjunction with flat panel photobioreactors in such a way that continuous production and harvesting can be achieved. This is expected to lower the overall cost of production for algae biomass as current harvesting systems require a lot of personnel time as well as downtime for the photobioreactor as the vessel must be drained and cleaned each time a harvest occurs.

Figure 1. Algae culture before and after filtration with MF membrane.

Flat panel photobioreactors have been demonstrated to be a highly productive means of biomass production, if properly maintained within acceptable limits in terms of pH, light, cell density, temperature, and auto-inhibitory compound levels (Hu eta al., 1998). Ultra high culture densities up to 10% solids are achievable with maximum productivity in the 1-2% solids range. This is in contrast to the densities maintained by current production technologies where densities are commonly as low as 0.01-0.03% solids. This makes both harvesting and cultivation costly as the labor and energetic cost of dealing with so much water is immense. Although flat panel photobioreactors show such great potential in producing such intense population densities, the cultures will inevitably build auto-inhibitory compounds such as fatty acids that slow growth until the culture media is removed and fresh culture media is added (Richmond et al., 2003). Microfiltration (MF) membrane has tremendous potential to resolve this issue by continuously removing such auto-inhibitory compounds from the culture media to allow continuous production without the need for downtime for harvesting.

The use of MF membranes for mass algae culture is only in its infancy (Castaing et al., 2011), and there are many critical parameters to be considered for a given application. One focus in this project is filter direction. The water can be filtered from the inside of the filter fiber to the outside or outside to inside. Most of the studies to date have focused on inside-out filtering, in which the concentrated algae biomass slurry is held on the inside of the membrane fiber. This will likely increase energy usage for the process because the surface area of the filter is not maximized, and the liquid inside will be more viscous and harder to pump. Outside-in filtration would have a much larger filter surface area than inside-out. While this has not yet been addressed by this project, future work is planned to quantify this affect and determine the optimal parameters for removal of auto-inhibitory compounds, and most importantly, media free of nitrates and phosphates.

After finding the necessary suppliers and procurement of the required materials, the past six months of this project have been devoted to developing a plug and play device that can be utilized inside or next to a flat panel photobioreactor. Figure 1 above demonstrates the effectiveness of the assembled device, which has clearly removed the algae biomass from the culture media leaving relatively clear effluent with a hint smell of algae. This water could be further refined with ultra-filtration (UF) technology or safely discharged to the environment without contributing to eutrophication. Preliminary results were collected showing the energy used for harvesting the biomass and the labor involved with the system. The process is in constant refinement under a continual process improvement approach. As a research associate for Arizona State University's Laboratory for Algae Research and Biotechnology (LARB), there are many times such a device would be utilized, especially as the new Arizona Center for Algae Technology and Innovation (AzCATI) test bed facility comes online. The future of this project will involve securing funding for automating the membrane system to maintain stable culture density overtime and allow addition of nutrients upon harvesting.

Degree Status/Other Projects: I am currently finishing my fourth year as a Molecular and Cellular Biology PhD student at Arizona State University (ASU). My dissertation prospectus is scheduled to be defended soon and will include work on algae auto-inhibitory compounds. This complements the work I am doing on my NWRI project and I am very excited about integrating my membrane photobioreactor into other projects I am involved with as a research associate at ASU's LARB facility, including two carbon capture projects and one wastewater project. One of the projects is concerned with utilizing flue gas from Intel's fabrication plant to grow algae and capture carbon dioxide. This is a wonderful opportunity to test the plug-and-play membrane design and work out automation of the device to make algae culture much more user-friendly and less labor-intense. I am also working on an EPA-sponsored P3 project to create a suitable algal growth media from digested agricultural wastewaters, where the fully automated harvesting device would be invaluable.

Once again, I would like to thank the National Water Research Institute and all sponsors for making this project possible. The knowledge and experience I have gained greatly enhances my dissertation work and I look forward to pushing this technology forward into practical applications.

References:

Castaing JB, Masse A, Sechet V, Sabiri NE, Pontie M, Haure J, Jaouen P. Immersed hollow fibres microfiltration (MF) for removing undesirable micro-algae and protecting semi-closed aquaculture basins. *Desalination* 2011; 276(1-3): 386-396.

Hu Q, Kurano N, Kawachi M, Iwsaki I, Miyachi S. Ultrahigh-cell-density culture of a marine green alga Chlorococcum littorale in a flat-platebioreactor. *Appl. Microb.Biotechnol*. 1998; 49: 655–662.

Richmond A, Zhang CW, Yair Z. Efficient use of strong light for high photosynthetic productivity: interrelationships between the optical path, the optimal populationdensity and cell-growth inhibition. *Biomolecular Engineering* 2003; 20: 229-236.

Su ZF, Li X, Hu HY, Wu YH, Noguchi T. Culture of Scenedesmus sp LX1 in the modified effluent of a wastewater treatment plant of an electric factory by photo-membrane bioreactor. *Bioresource Technology* 2011; 102(17): 7627-7632.

Zhang XZ, Hu Q, Sommerfeld M, Puruhito E, Chen YS. Harvesting algal biomass for biofuels using ultrafiltration membranes. *Bioresource Technology* 2010; 101(14): 5297-5304.

NATIONAL WATER RESEARCH INSTITUTE
NWRI Fellowship Program

Spring 2012 Progress Report

NWRI-AMTA Fellowship for Membrane Technology
(Fall 2010-Present)

Yaolin Liu
Civil and Environmental Engineering Major
University of Maryland

Graduation Date: 2014
Advisor: Dr. Baoxia Mi

Biofouling of Forward Osmosis Membranes: Mechanisms and Fouling Control

To develop a better quantification of concentration polarization in the membrane channel of realistic reverse osmosis processes.

Biofouling in Forward Osmosis: Mechanisms and Fouling Control

3rd Progress Report for NWRI-AMTA Fellowship for Membrane Technology, March 31, 2012

Yaolin Liu
Civil and Environmental Engineering Department,
The University of Maryland

Tasks Completed & Key Results

This report summarized the progress of our work on the proposed project of Biofouling in Forward Osmosis: Mechanisms and Fouling Control. During the past six months, we worked on developing an effective method to directly monitor the forces that govern bacterial-surface interactions in order to better understand the bacterial adhesion to the surfaces. (1) We completed the design and setup of a work station for particle probe preparation and the development of a protocol for making particle probes efficiently; (2) We successfully applied the prepared particle probes in force measurement using atomic force microscopy (AFM) and developed data acquisition/processing procedures; (3) We investigated the effects of solution conditions on particle-membrane interactions. Some preliminary results are presented below.

(1) **Preparation of particle probes.** The particle probe was prepared by attaching a carboxylate-modified particle (5µm, Spherotech Inc. Lake Forest, IL) to a tipless V-shaped cantilever (Bruker, Santa Barbara, CA) by UV-cured glue. Quartz micropipettes controlled by micromanipulator were used for glue and particle transfer. First, a small amount of UV-cure glue was picked up by micro-controlled micropipette and applied on the end of the AFM tip **(Fig 1)**; and then a new micropipette was used to pick up and transfer the particle to the spot of glue (**Fig 2**); the particle probe was then fixed under UV light. The image of the prepared particle probe taken by scanning microscopy (SEM) is shown in **Fig 3**.

Fig 1. Glue transfer.

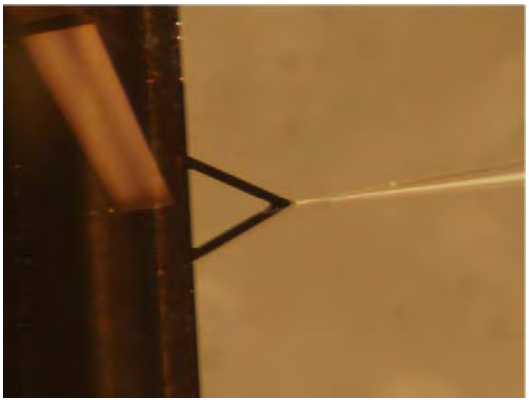


Fig 2. Particle attachment.

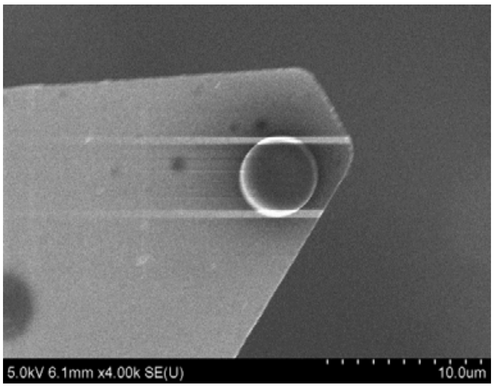
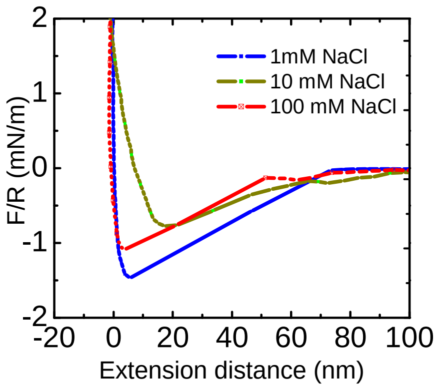
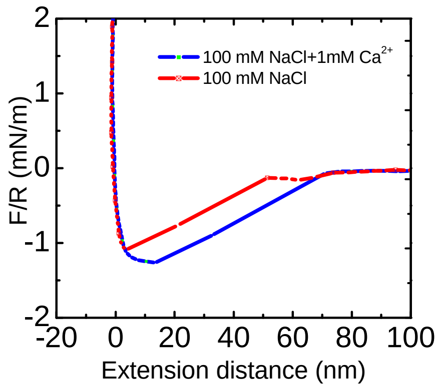


Fig 3. SEM image of the prepared particle probe.

(2) **AFM interaction force measurements.** Force measurements were performed with a Multimode AFM system (Bruker, Santa Barbara, CA) in a fluid cell filled with different test solutions. More than 30 force curves were collected at 6 different locations on the polyamide membrane surfaces under each test condition. The data of cantilever deflection were recorded when particle probe approaches and retracts to/from the surface and converted into force versus distance curves. The adhesion force curves obtained during retraction are shown in **Figs. 4 and 5.** These two figures showed the effects of ionic strength and calcium effects on the adhesion force between carboxylate functional groups and polyamide membrane surface.





.

Fig 4. Effects of ionic strength.

Fig 5. Effects of calcium ions.

Future work

We are planning to perform the following experiments in the next step: (1) to develop a method to prepare single bacteria probe and directly measure the force interactions between a live/dead bacterium and the membrane surface; (2) to investigate the factors (e.g., solution chemistry and exocellular polymeric layers) that affect bacteria-membrane interactions and better understand the mechanisms; (3) to perform long term biofouling experiments to monitor membrane flux decline; (4) to use microscopic techniques, e.g., optical microscopy and confocal microscopy, to characterize biofilm formation in long-term biofouling experiments.

NATIONAL WATER RESEARCH INSTITUTE
NWRI Fellowship Program

Spring 2012 Progress Report

NWRI-AMTA Fellowship for Membrane Technology

(Fall 2010-Present)

Alberto Tiraferri
Environmental Engineering Major
Yale University

Graduation Date: 2014
Advisor: Dr. Menachem Elimelech

Nanocomposite Polymeric Membranes for Enhanced Water and Energy Production in Membrane-Based Separation Processes

To develop robust nanocomposite membranes to enhance the performance and expedite the implementation of advanced membrane-based water and energy production technologies.

NWRI Fellowship Progress Report

Alberto Tiraferri, Yale University:

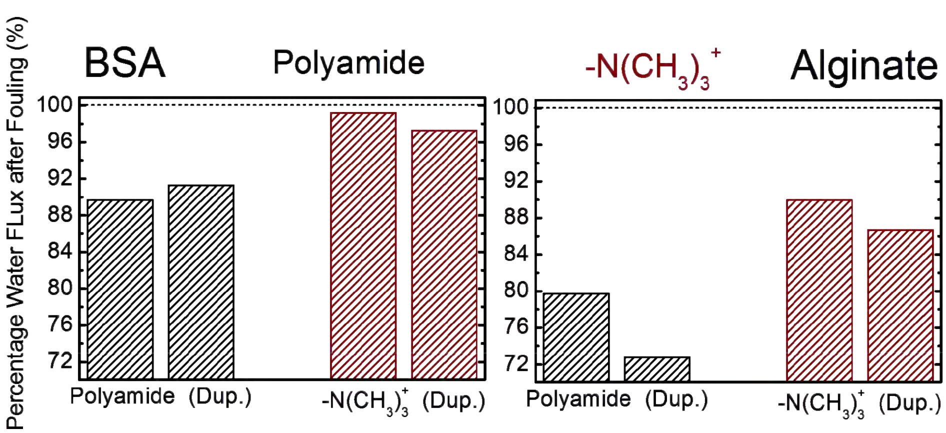
"Nanocomposite Polymeric Membranes for Enhanced Water and Energy Production in Membrane-Based Separation"

alberto.tiraferri@yale.edu

April 1, 2012

The last progress report demonstrated the optimization of forward osmosis membrane properties by surface functionalization with fine-tuned nanoparticles. Silica nanoparticles were coated with superhydrophilic ligands (—$N(CH_3)_3^+$) possessing functional groups that interact with the membrane active layer to produce irreversible bonds. The presence of nanoparticles tailored the chemistry of the membrane surface without altering its morphology or transport properties. Therefore, superhydrophilic and highly wettable surfaces were attained.

The rationale to create superhydrophilic —$N(CH_3)_3^+$ membranes for water separation technologies stems from the point of view of fouling resistance. By maximizing the interfacial acid-base forces between surfaces and the adherent water, we can create a layer of tightly-bonded water molecules that acts as a short-range barrier against the adhesion of foulants.

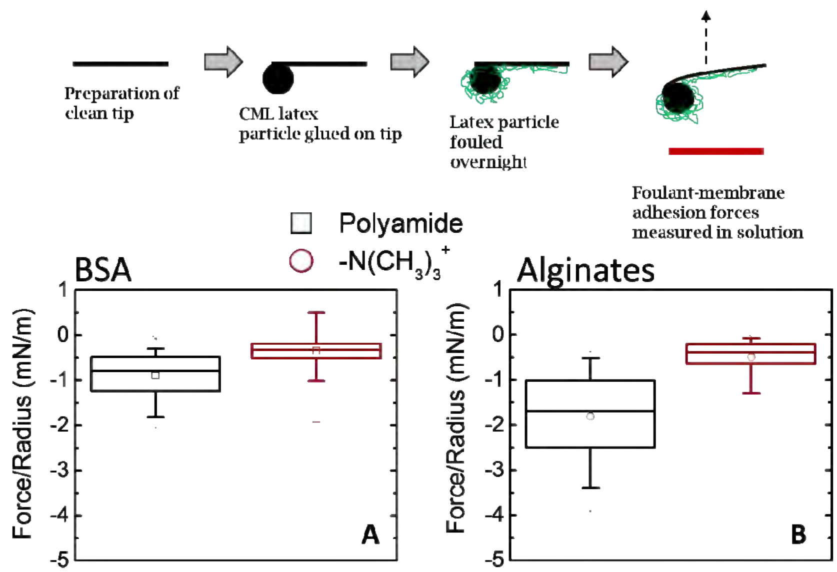


The actual fouling in forward osmosis was studied in the presence of a mixture of mono- and divalent ions and using alginate and BSA. The results of duplicate runs for control and for superhydrophilic membranes are summarized in the figure above.

In all cases, the superhydrophilic —$N(CH_3)_3^+$ membranes experienced a lower overall flux decline compared to control membranes. These results suggest a higher resistance to organic fouling by the functionalized membranes. This effect was very significant for alginate fouling that caused water flux losses of about half the magnitude of those experiences on the control membranes. However, the anti-fouling mechanism of the super-hydrophilic surfaces was especially notable in the case of BSA fouling, which produced only a marginal loss in water flux compared to that observed for control polyamide membranes.

Atomic force microscopy (AFM) has been applied in membrane fouling/cleaning research to quantify intermolecular forces when foulants approach the investigated surface within the contact limit. This technique was found to be successful in predicting and explaining the behavior of membranes challenged by fouling-potential solutions during operation.

Therefore, we have recently investigated the interaction forces between model foulants adsorbed on a colloidal probe, namely alginate and BSA, and control or superhydrophilic $—N(CH_3)_3^+$ membranes, as depicted schematically in the figure on the right. We report the statistics of adhesion forces calculated from a statistically significant number of retracting force-distance curves analyzed in 5 randomly selected spots on each membrane sample. AFM results showed that the attractive energy well between model foulants and control polyamide membranes was generally deeper than that observed using functionalized super-hydrophilic membranes. This mechanism translated in a distribution of foulant-membrane intermolecular forces that are statistically and significantly more attractive, i.e. more negative, on the control polyamide membranes. These results indicate and explain how the superhydrophilic $—N(CH_3)_3^+$ surfaces can potentially reduce and delay fouling during operation.



NATIONAL WATER RESEARCH INSTITUTE
NWRI Fellowship Program

Spring 2012 Progress Report

NWRI-Southern California Salinity Coalition Fellowship

(Fall 2010-Present)

Kari Varin
Chemical Engineering Major
University of California, Los Angeles

Graduation Date: June 2013
Advisor: Dr. Yoram Cohen

Water Desalination by Reverse Osmosis with Nanostructured Polymers

To develop a new class of high-performance reverse osmosis (RO) membranes and conduct a pilot demonstration of advanced surface nano-structured RO membranes to produce water of potable quality.

Water Desalination by Reverse Osmosis with Nanostructured Polymers

Kari Varin
NWRI-SCSC Progress Report
April 1, 2012
Chemical and Biomolecular Engineering Department
University of California, Los Angeles

Broader Impacts

Most of our planet's water is saline (97.2%), while surface water and moisture represent 0.1% of our water, and 2.1% of water is ice caps and glaciers. Saline water (both seawater and inland brackish water) could represent a significant sustainable water resource if upgraded to potable water quality at a reasonable cost. Reverse osmosis (RO) desalination technology is a promising technology for seawater desalination; however, there are crippling problems that include membrane fouling, scaling and high energy cost (due to pressure energy) that now limit the ability to further reduce the cost of water desalination.

Project Summary

Effective use of RO/NF membranes in brackish desalination and water reuse applications requires effective suppression of membrane fouling and mineral scaling. In the present research, a novel atmospheric pressure plasma-induced graft polymerization (APPIGP) method is utilized to generate a high surface density of active surface sites on a polyamide (PA) membrane. This is followed by surface graft polymerization to form a hydrophilic brush layer of polymeric chains that are terminally and covalently attached to the polyamide surface of a thin-film composite (TFC) polyamide (PA) membrane. The physicochemical characteristics (e.g., surface roughness, surface charge and wettability) of the resulting surface nano-structured (SNS)-TFC-PA surface were tailored through the selected vinyl monomer chemistry and the reaction conditions in order to achieve a surface tunable for reducing membrane fouling, while achieving the target membrane performance with respect to permeate flux and salt rejection. The SNS-TFC-PA membrane performance was evaluated with respect to its permeability, salt rejection, and mineral salt scaling and biofouling propensities. The present study demonstrated that it is feasible to synthesize high performance SNS-TFC-PA membranes of reduced mineral scaling and fouling propensities.

Accomplishments

Since the last reporting period (October 2011), I submitted a chapter entitled "Membrane Surface Nano-Structuring with Terminally Anchored Polymer Chains" (Yoram Cohen, Nancy Lin, Kari Varin, Diana Chien, and R. F. Hicks) in November 2011, prepared for Functional Nanostructured Materials and Membranes for Water Treatment, editors M. Duke, D. Zhao and R. Semiat, publisher Wiley-VCH Verlag GmbH & Co. KGaA, in press.

Most recently, in March 2012, I presented a poster for the University of California, Los Angeles Technology Forum entitled "Surface Nanostructuring with Hydrophilic Polymers for Fouling Resistant Membranes" (Kari Varin, Nancy Lin, and Yoram Cohen), which won honorable mention at the poster awards (1 of only 3 awards given).