SOLUTIONS

AMTA
American Membrane Technology Association

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FROM THE EDITOR

Welcome to the second 2020 edition of *Solutions*, which I hope finds you safe and healthy. In this issue, I'm happy to share three articles highlighting RO membrane technology, from manufacturing and application to separation capabilities. In addition, as water professionals across the globe work hard to keep our water safe and reliable, Ben Movahed provides timely information on the role of membranes and COVID-19 *(pg. 6)*.

In our first article, Jeffrey McCutcheon and his students from the University of Connecticut explore how the RO membrane manufacturing process can be optimized using an additive manufacturing approach via electrospray. With this approach, the membrane water permeability and salt rejection can be easily and accurately controlled and varied per need.

The second article by Stantec's Michael Adelman shows how aggressive RO recovery rates can be achieved by understanding the scaling chemistry and system hydraulics for two different RO configurations.

In the final article, LG Chem's Eugene Rozenbaoum covers the hot topic of removal of contaminants of emerging concern by RO membranes. The study shows how RO membranes provide stable performance in various operating conditions, high rates of CEC removal, including PFAS, and resilience to chemical cleaning. Enjoy!

Where ADDITIVE Manufacturing Meets Membrane Technology:

Opportunities for printing thin film composite membranes

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Nearly all reverse osmosis (RO) membranes used today can be described as thin film composite (TFC), meaning they employ a thin, selective barrier layer that is mechanically supported by a porous, mechanically robust supporting structure. Today's RO membranes employ a variety of aromatic polyamide chemistries as the thin selective layer due to its ability to reject ions and its ability to be formed *in situ* directly onto the supporting material through a process known as interfacial polymerization. The reaction is a relatively well-understood polycondensation reaction between an amine and an acid chloride. A thin film is created by placing these monomers in two separate yet immiscible phases (organic and aqueous). The aqueous phase would contain a diamine, such as m-phenylene diamine (MPD), and be soaked into the porous support layer. The acid chloride (trimesoyl chloride or TMC) would be dissolved into an organic phase (such as hexane or IsoparTM) and then exposed onto one side of the soaked support. The MPD and TMC would react quickly and easily, but since neither phase was miscible in the other, the reaction would occur only at the interface between the two phases. The reaction rate would decrease as the rapid formation of the dense and crosslinked polyamide, stopping the reaction. This self-limiting behavior results in exceedingly thin films being formed directly on top of the supporting layer. The thin nature of these selective layers led to an order of magnitude increase in water permeance compared to cellulose acetate membranes while the extensive crosslinking of the polymer led to an order of magnitude decrease in salt passage. This method

continued on page 4 > > >

By **Christine A. Owen**
Hazen and Sawyer

WELCOME TO SPRING!

It has been an auspicious beginning for 2020 and I am certain that we are all hoping for a more settled second half of the year. First, the AMTA Board and staff sincerely hope that you, your families and co-workers are safe and healthy and continue to be so. We would also like to recognize and thank all the essential workers who have continued to do their jobs in these difficult times, sometimes at personal cost. We are grateful to you, all our members, for your continued support of the AMTA organization and its mission to provide water solutions through the application of membrane technology.

AMTA has experienced several "firsts" since our last edition of *Solutions*. Harold Fravel, our Executive Director for seven years, retired and we welcomed on board a new Executive Director, Deena Reppen. And what a welcome it has been for her! Our annual conference, the Membrane Technology Conference (MTC) was cancelled, and we held our first ever "virtual" Board Meeting. We rescheduled the May 2020 Durham NC workshop to April 2021 and are working on shuffling other events to accommodate travel restrictions and concerns. My professional appreciation and personal thanks to Deena for working through all these challenges in her first few months.

Our May Board meeting was also "virtual". Because MTC was cancelled, we were unable to hold our Annual Members Meeting; however, our annual member event next year will be exciting and will be sure to make up for it! You will find some changes in *Solutions* also. We have opted for an electronic edition this quarter and encourage your feedback on this delivery option, the content and layout. AMTA has taken some steps to enhance its presence in the world of digital media; our Executive Director and Communication Committee Chair have staked a strong lead on developing our digital media presence through regular eblasts and by promoting the importance of water professionals and policy through LinkedIn and Twitter. Please check us out and "like" or "follow" AMTA! We are also making plans to refresh the AMTA Website, so be sure to keep a watchful eye on the site.

For another significant "first", AMTA officially joined forces with the National Association of Clean Water Agencies (NACWA) and other major water organizations to support National Water Week 2020 and Fly In. This annual event is an opportunity for the water profession to meet in Washington D. C. with legislators and regulators to discuss the needs of the water industry and advocate for key legislation and funding. Unfortunately, the Coronavirus Pandemic travel restrictions and "Stay at Home Orders" made face-to-face meetings impossible. However, the Water Week 2020 organizers were able to quickly arrange an online webcast, which included legislators, regulators and water advocates. More than 2,000 people registered for the webinar to hear the latest water policy developments from EPA senior staff, messages from Members of Congress about the value of water sector advocacy, and updates from key Water Week partner organizations. AMTA was recognized as a sponsoring partner for the event and put out a call to our members to submit "Shovel Ready" membrane projects for stimulus investment, which AMTA will compile and share with Congressional staff. Please submit your projects and ideas as soon as possible.

The Coronavirus Pandemic presents all of us with challenges and opportunities. Let's find innovative ways of solving these issues; after all, we are the people who provide water solutions through the application of membranes, a novel and innovative technology. We are re-learning how to wash our hands. In doing so, people are gaining an enhanced appreciation for safe, clean and available water as well as the importance of the essential workforce that provides it. We are learning how to work remotely and "social distance" and finding out how much we miss our face-to-face interactions! We are finding ways to deliver content to our members, customers, and clients in new ways to keep communication open and learning ongoing. It is a new way of doing our business and staying safe. Please be sure to follow the AMTA website for updates on our workshops and opportunities for learning professional credits that you may need. The consequences of the pandemic will continue to present us with challenges and opportunities this coming year, but water professionals and membrane applications will help solve them. ■

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EXECUTIVE DIRECTOR'S MESSAGE

By **Deena Reppen**
American Membrane Technology Association

Across the nation and the globe, the first five months of 2020 are certainly not as anyone would have predicted. We are facing unprecedented times and unique challenges with the onset and progression of the coronavirus pandemic. Certainly, the beginning of my tenure as AMTA's Executive Director was not as I imagined.

While we planned to host a successful annual conference in Phoenix with our partners AWWA, and enjoy networking with hundreds of membrane partners, peers and professionals from all over the world, it was not meant to be. I want to convey our gratitude to you, our members, for your patience and understanding as we navigated through postponement and then cancelation of the conference. With your health and safety in mind, this was our only course of action. I also want to convey sincere thanks to AMTA's Executive Committee and Board of Directors, whose guidance has been invaluable in steering the organization through unpredictable circumstances. AMTA is lucky indeed to have such dedicated, committed and engaged leadership.

Here's the good news: we are already looking ahead to MTC21, which takes place March 22-26 in West Palm Beach, Florida. A call for abstracts will be released in the coming weeks, which will include a 'refresh and resubmit' approach to papers and presentations prepared for MTC20 as well as a call for new content. A robust technical agenda is in design, so please mark your calendars and plan to join us in the Sunshine State for learning, networking and tours! Thank you to those of you that have already transferred your registration from MTC20 to 21!

As travel restrictions, social distancing measures and home-learning continues, AMTA is planning to hold a series of summer webinars designed specifically for membrane professionals. Stay tuned for details and don't forget to explore workshop opportunities for the fall. We hope to be able to move forward with our popular in-person programming towards the end of the year.

Most importantly, stay safe and healthy, and please reach out if there's anything AMTA can do to support you. ■

BOARD OF DIRECTORS UPDATE | *MAY 2020*

With MTC20 canceled, AMTA's Board of Directors convened for the first virtual board meeting in its history on March 20. Members joined by videoconference from across the country to make some important decisions on behalf of the organization. Of note was the election of new board officers for the upcoming year. In light of the pandemic and a strong desire to have continuation in its leadership during the unusual prevailing circumstances, the board elected to have its current officers continue to serve for a second consecutive year with one exception. Long-time AMTA member and dedicated leader, **Lynne Gulizia** announced her retirement, and while she will serve on the Board of Directors through her current term ending in 2021, she stepped down from her role as AMTA Secretary. **Julie Nemeth-Harn** was nominated and unanimously elected to the role. Here are your officers for 2020-21:

- President: Christine Owen, Hazen & Sawyer
- First Vice President: Jill Miller, City of Bozeman Water Treatment Plant
- Second Vice President: Doug Eisberg, Avista Technologies, Inc.
- Treasurer: Russ Swerfderger, DuPont Water Solutions
- Secretary: Julie Nemeth-Harn, Harn R/O Systems, Inc.
- Immediate Past President: Brent Alspach, Arcadis

"I am honored to continue to serve as AMTA's President," said **Chris Owen**. "These are certainly different times for all of us and I cannot think of a better board to guide AMTA through this phase in our long history. I look forward to continuing to work with this experienced and committed Executive Committee and to expanding our services and support for our members in the year ahead."

In addition to electing board officers, the board welcomed **Michael Bourke** to his first meeting as a newly elected board member representing Division 2 (Manufacturers, Suppliers, Consulting) for a term ending in 2022. Mike is the Vice President for Business Development at Wigen Water Technologies, where he has worked for nearly a decade. From water and wastewater treatment projects to water treatment chemical and process manufacturing, R&D management, product development and sales and marketing management, Mike has 28 years of experience in the water industry.

The board also appointed former AMTA Executive Director **Harold Fravel** to the Board as Director Emeritus, recognizing his long service to AMTA and the membrane technology sector. He will join distinguished and respected Directors Emeriti David Brown, Steven Duranceau, Stuart McClellan and Bob Yamada on the board.

"I want to thank Lynne Gulizia for her service as AMTA Secretary," added Owen. "Her leadership has helped make this organization what it is today. I also want to welcome Mike and Harold to the board of directors. I look forward to their insights and leveraging their knowledge, experience and leadership to grow our organization."

For more on the AMTA Board of Directors, visit https://www.amtaorg.com/about-amta/board-of-directors. If you are interested in serving on the board or as a committee member, please email deena@amtaorg.com. ■

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and chemistry would remain the industry standard for decades and remains so today.

In spite of its regular use, the reaction is remarkably uncontrollable. We are unable to control very basic membrane properties such as thickness and roughness. The film properties are also dependent on the substrate properties. Roughness in particular is of concern since it has been linked to membranes with high fouling propensity. Many have tried to make RO membranes better through exploring modification approaches or new materials altogether, but the end result of these efforts has yielded no changes in the ways RO membranes have been made for the past 40 years [1].

We have developed a new approach to making TFC membranes that offers tangible improvements in RO membrane structure and feature control that could represent a step change in RO membrane manufacturing. Using an additive manufacturing approach via electrospray, we deposit monomer solutions in nanoscale droplets directly onto a substrate where they subsequently react to form the crosslinked polyamide film. This can happen on essentially any surface while precisely controlling for thickness. All of this was possible while retaining the same chemistry, allowing for independent variation of selectivity, permeance, and substrate. Such control is impossible with current interfacial polymerization approaches.

We have recently published a paper in *Science* describing a new type of printing approach using electrospray to form smooth polyamide membranes [2]. A rotating drum collector surface is placed below a suspended needle depositing the monomers sequentially. A liquid is pumped out of a nozzle where it is exposed to a powerful electrical potential to form the Taylor cone. The needles raster axially along the rotating drum, enabling the production of a large membrane up to 1 ft^2 in size. More detailed information can be found in our published paper.

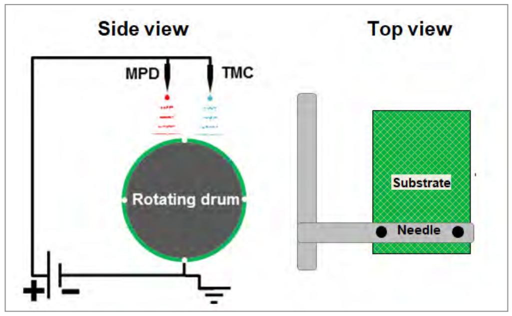

FIGURE 1. Schematic diagram of the electrospray system in the PI's laboratory. The monomers are injected into separate but equally charged needles and each monomer coats the support that is wrapped around a spinning drum collector (indicated by the green on the drum). Taken from [2].

The TFC membranes that we have made have shown the ability to have tunable thickness down to very small increments. You can see that we can make polyamide films from 15 to 160 nm (or more). This enables the control of membrane permeance in ways that are impossible with conventional interfacial polymerization.

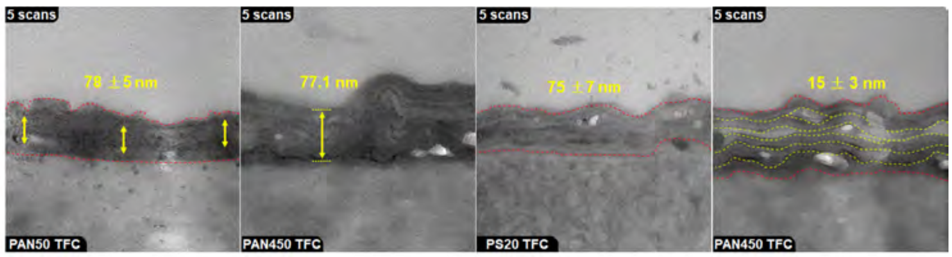

FIGURE 2. TEM cross sections of TFC membranes formed by electrospray printing onto PS20 UF membrane substrates. Taken from [2]. Please note that this figure is best viewed in color.

The TFC membranes are also far smoother than conventionally produced RO membranes. AFM scanning images are shown in Fig. 3 and indicate only modest increases in roughness with increasing thickness of the polyamide. The calculated roughness is 2-10X lower than conventional RO membranes.

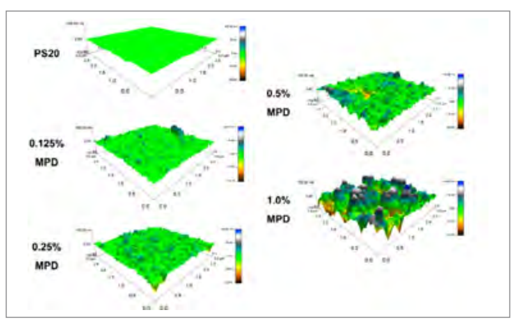

FIGURE 3. (Left) Atomic force microscope mapping of the bare support (PS 20) and 4 films formed at 4 different MPD monomer concentrations in water (TMC held constant at 0.15% in hexane). In part taken from [2] and modified. Please note that this figure is best viewed in color.

These membranes have also demonstrated appropriate permeance and selectivity for a RO membrane. One of our highest performing membranes exhibited a permeance of 15 liters/ m^2.hr.bar (LMH/bar) with a 94% NaCl rejection. A higher rejection membrane (97.5%) still exhibited a reasonable permeance of 5 LMH/bar. These results are reasonable given the novelty of the fabrication method.

Demonstration of the technique with polyamide is important since this material is trusted and reasonably well understood. While there is still much to do with regards to manufacturing research around electrospray and membranes, this work suggests that such research is warranted and should be explored. The potential for impacts beyond polyamide materials should also be considered. ■

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JEFFREY R. MCCUTCHEON, PH.D.

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Executive Director
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Jeffrey McCutcheon *is an Associate Professor in the Chemical & Biomolecular Engineering Department at the University of Connecticut. He received a B.S. in Chemical Engineering from the University of Dayton and his Ph.D. in Chemical Engineering from Yale University. He has authored over 80 refereed publications, served as President of the North American Membrane Society, and is the recipient of numerous awards for his work on membranes, including the 2019 Global Water Summit Water Technology Idol competition for his work on 3D printed membranes.*

>>>Read the full paper.

Xin Qian *is a PhD candidate in the Chemical and Biomolecular Engineering Department of University of Connecticut. He has a Master's degree in Polymer Science from Case Western Reserve University. Xin leads the membrane 3D printing project in Dr. McCutcheon's lab and has produced membranes with a variety of polymeric materials. Xin has successfully developed printing methods for other polymers and is demonstrating the ability to make thin film composite membranes from a variety of materials that have never been processed as ultra-thin films.*

Tulasi Ravindran *graduated from BITS Pilani K.K. Birla, Goa Campus in India with a double major in chemistry and chemical engineering. She works with electrospray printing to deposit polymers to form thin films that can be used for different membrane applications such as reverse osmosis and pervaporation.*

READ THE FULL PAPERS ONLINE: The technical articles appearing in *Solutions* are abbreviated versions of research papers originally submitted for presentation at the 2020 Membrane Technology Conference & Exhibition. The full papers are available to AMTA members online through AMTA's Digital Library and using the links provided in each article.

*By **Ben Movahed**, PE, BCEE*

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ROLE OF Membranes and COVID-19

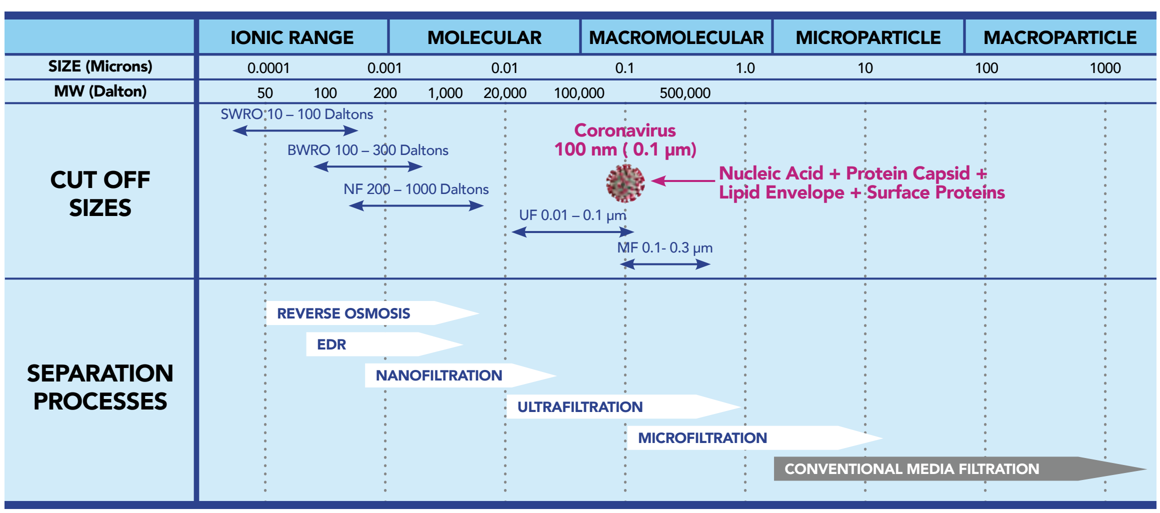
As the entire world is struggling with the anxieties and consequences caused by the Coronavirus disease (COVID-19), water and wastewater treatment professionals are carefully re-evaluating their role and responsibilities towards the protection of public health. The severity and catastrophic magnitude of the impacts of this pandemic clearly demonstrate that we are not prepared for an infectious disease outbreak such as Coronavirus.

The good news is that, fortunately, most current water and wastewater treatment processes are considered effective for the destruction and/or removal of viruses. Disinfection with chlorine, oxidation and ultraviolet disinfection are some examples of technologies that are commonly used and are expected to be effective.

However, the bad news is that some ongoing tests suggest that coronaviruses can remain infectious for many days in both water and wastewater systems. It is important to note that as the World Health Organization (WHO 2020) has indicated, investigations into this pandemic outbreak are ongoing and the information that we currently have may change as we learn more about this pandemic.

At AMTA, we pride ourselves with our knowledge about the reliability and consistency of membranes to effectively remove various contaminants, including viruses, from water and wastewater systems. The chart below shows the nominal size of a Coronavirus in relation to membrane separation pore sizes.

Placement of Coronavirus in a Membrane Separation Chart



Membranes have been proven globally for decades to provide the best protection against pathogens/viruses as a physical separation barrier. These membranes, combined with UV, provide the most reliable treatment technology available.

For wastewater treatment facilities, the use of biological treatment processes combined with the physical separation provided by membrane bioreactors followed by UV can also effectively remove viruses, including Coronavirus, from the wastewater effluent and water reuse applications.

These are challenging times—both scary and exciting at the same time—pushing us forward to expand our global knowledge about the role of membranes for innovative scientific solutions and the protection of public health.

Ongoing research and testing will help the water industry to more confidently answer these critical questions about occurrence and behavior of such contaminants in the months and years to come. However, we do know that we are much better protected with advanced treatment technologies such as membranes.

*By **Jill Miller***
AMTA Technology Transfer Committee Chair

With the onset of the coronavirus pandemic and the health and safety of our members and partners in mind, AMTA made the difficult decision to postpone its in-person technology transfer workshops planned for May and July of this year. In response, the AMTA Technology Transfer Committee has picked up the baton to design and implement online training offerings coming to a desktop near you this summer!

As we build out AMTA's first-ever digital education series, which will be available live and on-demand, pencil in the below dates and membrane topics. CEUs and PDHs will be available for specific states. Check our website and your inbox for announcements in the coming weeks. We look forward to seeing you online!

ONLINE TRAINING COMING THIS SUMMER!

AMTA Technology Transfer On-Line

July 21

- **Membrane Plant Response and Preparedness for Pandemics**
  Continuing to provide clean water during a pandemic is critical to the health of a community. A panel of membrane plant utility managers will discuss the planning process and response to COVID-19, including the impact to operations, staffing, and maintenance activities, along with lessons learned.

August 25 & 27

- **Enhanced Recovery Part I**
  Recognizing the need to build institutional knowledge about the expanding array of options, this unique educational series will focus on enhanced recovery strategies for membrane systems, including technology overviews, applications and implementation.

September 1 & 3

- **Enhanced Recovery Part II**

September 8 & 10

- **Enhanced Recovery Part III**

AMTA/AWWA Membrane Webinar Series

July 30

- **The Role of Membranes in PFAS Removal**

August 6

- **Best Practices for Improving MF/UF Operations**

August 11

- **Membrane Treatment Provides Pathogen Removal Credits**

August 13

- **Concentrate Management**

August 18

- **Ceramic and Polymeric UF Membranes**

August 20

- **Innovative Operations: Reverse Osmosis**

On-line training dates subject to change

Check out pages 18-19 for more on **Technology Transfer Workshops** on offer this fall and in 2021.

Mr. Adelman is a professional environmental engineer with Stantec, working on a variety of water, wastewater, recycled water, site remediation, and waste management projects. He is interested in the intersection of theory and practice, and his process background includes filtration, sedimentation, disinfection, membrane treatment, ion exchange, biological treatment, and municipal waste composting.

>>>Read the full paper.

EXCEEDING 90% Recovery with Conventional and Closed-circuit RO:

Results from Parallel Pilot Systems

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INTRODUCTION

For inland reverse osmosis (RO) systems, there is significant interest in increasing recovery and reducing brine volumes. As recovery increases, fouling and scaling become more acute, and these are key drivers of operating cost (Goosen et al., 2005). Beyond antiscalant addition and chemical pretreatment, scale formation is also affected by local flow conditions. Higher cross-flow velocities play a role in preventing precipitate formation while low cross-flow velocity may exacerbate scaling (Lin et al., 2004), and this is the basis for some proprietary RO systems with novel flow configurations.

The City of Buckeye, AZ is considering future RO treatment of brackish groundwater. Following sampling of a local well (TDS around 2,700 mg/L), desktop modeling with Avista Advisor (Bennet, 2002) predicted that sulfate and silica compounds would govern scaling, and that solubility limits would theoretically allow recoveries >90%. Results of this modeling are shown in **Figure 1**. In this study, a pilot-scale system was used to understand the scaling regime and investigate how flow configuration affected achievable recovery.

MATERIALS AND METHODS

Pilot-Scale RO System Description

The pilot-scale system included two RO trains in parallel. One train was a conventional three-stage array of 6:4:2 pressure vessels with 3 elements each[1]. This system was provided with a booster pump at each stage to overcome increasing osmotic pressure. The other train was a proprietary closed-circuit RO (CCRO) system with a single 3 element stage and a concentrate recirculation loop[2]. The CCRO system operates in two modes: during the closed circuit (CC) cycle, feed comes into the system and an equal amount of flow leaves as permeate, with a constant flow rate recirculated in the concentrate loop. Once the target recovery is achieved, the system switches into plug-flow (PF) mode and the volume of the loop is discharged as brine. A schematic of the pilot system is shown in **Figure 2**.

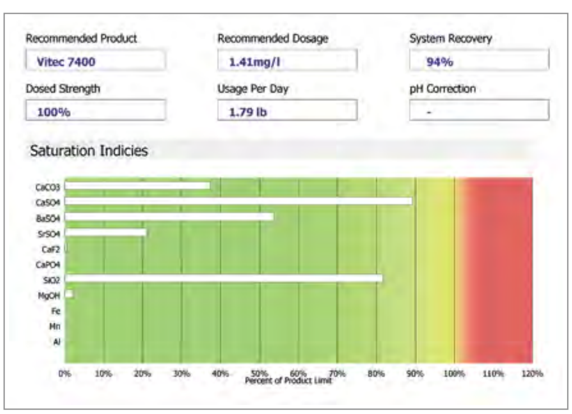

FIGURE 1. Scaling model, 94% recovery with Vitec 7400 at TDS = 2,700 mg/L.

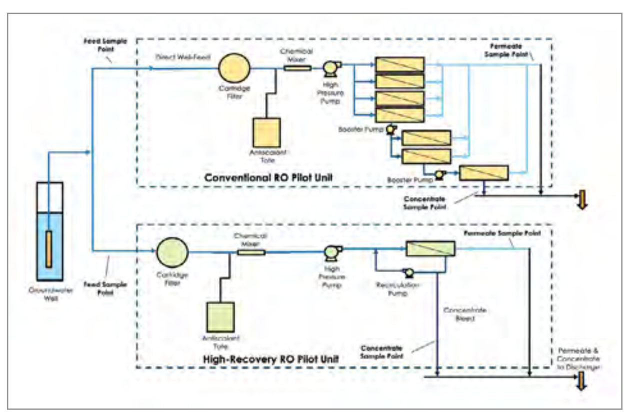

FIGURE 2. Pilot system process flow diagram.

Experimental Procedure

Testing was carried out in three phases:

- **PHASE 1** – sequentially increasing recovery from 80% to 94% for one week each.
- **PHASE 2** – continuous operation over the period of four weeks at constant recovery.
- **PHASE 3** – removal of one membrane element from the tail position of each RO train for off-site autopsy[3] after Phase 1 testing.

The progression of testing along with the operating points of each train in each phase are summarized in **Table 1** *(see paper online)*.

During the 2.5 months of operation, the well water TDS and turbidity were mostly between 2,300 to 3,000 mg/L and 1 to 2.5 NTU, respectively. Scaling projections in Figure 1 were based on this water quality data. Vitec 7400 antiscalant[4] was used without acid addition.

RESULTS AND DISCUSSION

RO Pressure and Normalized Flux

During Phase 1, the normalized specific flux for the conventional RO train was relatively constant at all recoveries, with no perceptible slope that would be indicative of scale formation. During Phase 2 there was a measurable downward slope at 92% recovery, after which recovery was reduced to 91% and normalized flux was relatively consistent (**Figure 3**). For the CCRO train, normalized specific flux, averaged over each cycle, was constant up to 94% recovery in Phase 1 until it trended observably downward at 95% (**Figure 4**). During Phase 2, it was seen to decrease over the several-week run at 94% due to scaling.

PHASE 2, 92% RECOVERY — PHASE 2, 91% RECOVERY

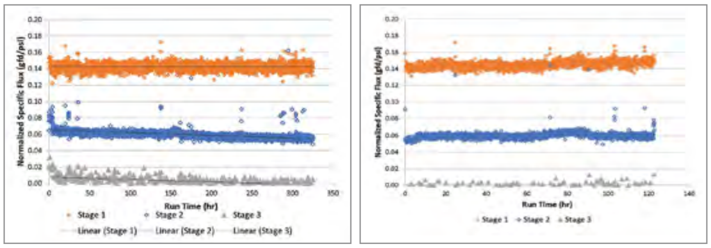

FIGURE 3. Conventional RO train normalized specific flux, Phase 2

PHASE 1, 94% RECOVERY — PHASE 1, 95% RECOVERY

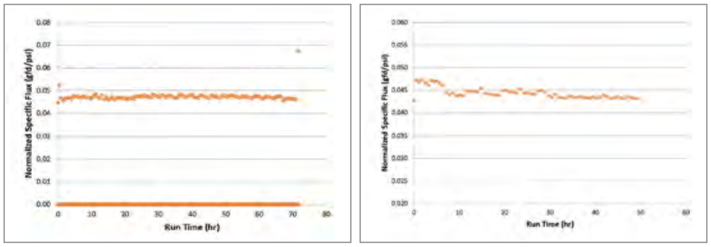

FIGURE 4. High-recovery RO train normalized specific flux, Phase 1.

Effects of Cross-Flow Velocity

For the conventional RO train, cross-flow velocities below the recommended minimum value of 0.08 ft/s occurred at the end of Stage 2 at recoveries of 90% and above, and throughout Stage 3 in Phase 2, as shown in **Figure 5** *(see paper online)*. This appears to have contributed to the observed scaling.

For the CCRO train, the concentrate recirculation loop keeps the cross flow velocities above the minimum cross flow velocity for all recoveries. That appears to have allowed this system to achieve stable recovery closer to the theoretical solubility limit at 94%.

Water Quality

In most cases, the rejection of trace elements arsenic, strontium, selenium, and chromium were better than 99.9% for the conventional RO system. For the CCRO system, rejection decreased at higher recovery for most constituents including arsenic (>99.9% to 75%), strontium (>99.9% to 56%), selenium (>99.9% to 77%), and chromium (>99.9% to 74%). The rejection rate of other major ions including, nitrate and fluoride, were also better with the conventional RO system. The greater observed salt passage in the high-recovery system is a result of every element in the system being exposed to the maximum concentrate strength in the loop at the end of a cycle.

Controlling Constituent for Scaling

In Phase 3, the observed composition of the material on the membranes surface included silicon, sulfur, calcium, iron, and aluminum. Both the RO performance results, where recovery up to 94% was demonstrated, and these autopsy results which identified scaling constituents largely confirm the hypotheses of the initial scaling model.

CONCLUSIONS

This study showed that, through understanding and control of the scaling chemistry as well as the flow conditions in the pressure vessel array, aggressive recovery rates of 90% were achieved in both conventional and closed-circuit systems. Cross-flow velocity exceeding 0.08 ft/s was required to reach theoretical maximum recovery based on solubility. ■

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[3] Avista Technologies, San Marcos, CA
[4] Ibid.

__Eugene Rozenbaoum__ is a Senior Application Engineering Manager at LG Chem in Torrance, California. Eugene has over 10 years of experience in R&D and product development in water separation processes including RO and MF technologies. His expertise includes RO membranes in multiple applications for seawater desalination and potable water treatment.

>>>Read the full paper.

Removal of Contaminants of Emerging Concern

By Thin Film Nanocomposite Reverse Osmosis Membranes

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Contaminants of emerging concern (CECs), including pharmaceuticals and personal care products (PPCPs), disinfectants, pesticides, herbicides, and other chemicals detected at low levels in surface waters, are believed to be detrimental to aquatic wildlife health and pose an unknown human health risk. One of the most notoriously known groups of chemicals that falls in this category and attracted wide publicity over the past years, from the US Senate to a Hollywood movie, are poly- and perfluoroalkyl substances (PFAS). These persistent, bio-accumulative chemical compounds are being detected in water sources all over the world including surface waters, ground waters, tap waters, bottled water, and municipal wastewater influents and effluents. Numerous studies have been conducted to determine the toxicological effects of PFAS and have found correlations between these chemicals and various adverse effects.

One of the most concerning ways the public can be exposed to PFAS is via contaminated tap waters. This results from the inability of conventional water and wastewater treatment systems to remove these chemicals. Therefore, several advanced treatment methods have been proposed for the removal of PFAS, including granular activated carbon (GAC) adsorption, ion exchange (IX), advanced oxidation processes, and membrane technologies.

Reverse osmosis is a membrane process and, besides being the preferred technology in water treatment industry, provides clear advantages in removing CECs compared to other methods. It is arguably the best technology for removing the largest range of contaminants including PFAS and other contaminants at high level of removal (90% or greater). While numerous studies have reported the removal of both inorganic and organic CECs by membrane treatments, systematic field studies understanding effects of operating conditions on the transport of PFAS through RO membranes are lacking. To make things even more complicated, the regulatory environment in the US and worldwide remains uncertain. Combined with the difficulty of monitoring PFAS compounds because of their presence in low concentrations (parts per trillion levels), it becomes extremely difficult to predict the efficiency of RO processes for PFAS removal in the long run.

To bridge this gap, two pilot studies have been conducted recently. Both used brackish water RO membranes produced with Thin-Film Nanocomposite technology. The first trial demonstrates the feasibility of using TFN RO membranes to remove PFAS directly from the well water. To the best of our knowledge, this is the first study that directly evaluated PFAS removal in brackish ground water. It was performed at Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM. The facility has four brackish groundwater wells on-site, each with varying water chemistries that can be delivered to any of the ten test pads at any time.

Over the last few years, PFAS has received a substantial amount of attention in that geographic area. In April 2019, PFOS and PFOA were discovered in Well 2 and Well 4 at elevated concentrations. BGNDRF has taken immediate action to develop and implement PFAS removal technologies. In light of BGNDRF's mission goals and newly found PFAS on-site, a collaboration with LG Chem, the manufacturer of TFN RO membranes, made sense.

The pilot study was conducted on the 4-inch RO pilot system (Figure 1), but for this particular trial, the system was configured in a 2-stage design (3:2). Energy-saving TFN membranes were installed in the pressure vessels of both stages. The system has been in operation for several months. Initially operated at 78% recovery, the operation was adjusted to 73% recovery at a later stage to avoid potential scaling caused by calcium sulfate being near saturation in the raw water. At least one CIP event was performed by this time. During the trial, several sampling events took place to assess the removal rate of two major PFAS components present in the feed water, PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonate). Table 1 summarizes results of PFAS concentrations in the system streams test by present time (the pilot is still in progress). As one can see from the table, the PFAS was not detectable in the final blended product at the method detection limits. The overall rejection for PFOA calculated from the mass balance exceeded 98.7%, which confirms our expectations of high removal rate of PFAS by TFN membranes.

The second study was conducted at Brunswick County's Northwest Water Treatment Plant as a part of its proposed expansion/upgrade. The project consists of expanding the existing 24 MGD (90,840 m^3/d) plant, which treats water from the Cape Fear River, and the addition of 36 MGD (136,260 m^3/d) low-pressure RO system. The RO will polish treated water from the existing plant to reduce PFAS and other CECs, particularly 1,4-dioxane, to acceptable drinking water levels. The test was performed on a standalone pilot system configured as a 2:1 array with eight 4-inch energy-saving TFN membrane elements per pressure vessel. The pilot was operated at the average system flux of 14 gfd and recovery up to 92%. Sampling/analytical events were conducted periodically as well as before and after chemical cleaning.

Overall, the pilot system equipped with the TFN membranes successfully removed CECs such as 1,4-Dioxane, GenX, PFAS, and PFOS to undetectable levels. The system rejection of these contaminants calculated from mass balance exceeded 95%, which safely meets requirements set by the County.

The presented case studies clearly demonstrate advantages of using TFN RO membranes for removal of CECs in various environments. They provide stable performance in various operating conditions, high rates of CEC removal (95% and above) including PFAS removal, and resilience to chemical cleaning. Results of these studies can be leveraged to other locations where the presence of CECs such as PFAS can pose potential environmental or public health risks. ■

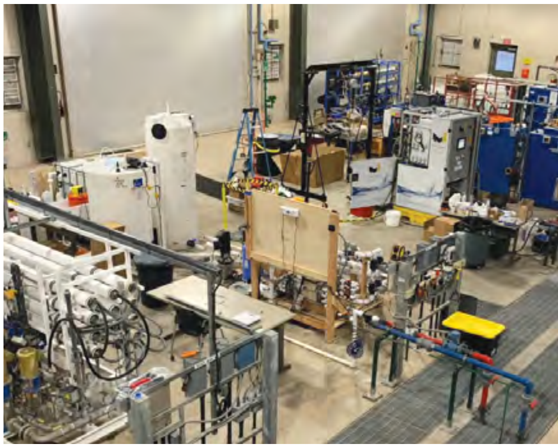
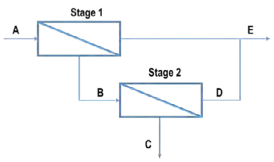


FIGURE 1. BGNDRF Engineering Bay. The 4-inch RO test skid where pilot was performed is in front.

TABLE 1. Table 1. PFAS Concentration in Streams

Sampling Event	Constituent	A, ng/l	B, ng/L	D, ng/L	C, ng/L	E, ng/L
Start-Up Rec. 78%	PFOA	270	400	5.3	1000	ND
	PFOS	33	62	ND	140	ND
Before CIP Rec. 73%	PFOA	180	310	ND	740	ND
	PFOS	22	47	ND	95	ND
After CIP Rec. 73%	PFOA	240	330	ND	840	ND
	PFOS	27	45	ND	100	ND

MDL: PFOA 3.5 ng/L; PFOS 7.6 ng/L



By **Brent Alspach**
AMTA Fellowship Committee Chair

FELLOWSHIPS
for Graduate Students

Each year, AMTA—in partnership with the Bureau of Reclamation and National Water Research Institute—is proud to support Fellowship Awards for Membrane Technology.

As the leading professional association dedicated specifically to membrane treatment technology and research, AMTA administers up to seven awards annually for university students researching the use of membranes for water treatment. With nearly $500,000 awarded since 2007, AMTA's research fellowships lead to cutting-edge innovations in membrane technology and provide career development for some of our brightest young minds.

Applications are open through July 1, 2020 for the following 2020/21 opportunities:

The Ian C. Watson Fellowship for Membrane Advancement is awarded by AMTA to a graduate student with a research focus on innovations in membrane technology for the treatment of water or wastewater in municipal, industrial, or agricultural applications. AMTA established this annual $10,000 award in honor of Watson's distinguished career in membrane technology and his positive influence on both novice and seasoned membrane practitioners. Ian is a modern pioneer of membrane processes and served as AMTA's first Executive Director.

Through a generous five-year grant from the Bureau of Reclamation, AMTA/Reclamation Fellowships for Membrane Technology are available annually to four graduate students researching in membrane-related innovations for water treatment. The $11,750 fellowships are designed to support advancements that will yield new types of membrane systems or optimize existing technology.

In 2007, AMTA and the National Water Research Institute (NWRI) established a partnership to support two graduate students with NWRI-AMTA Fellowships for Membrane Technology. The $10,000 awards support areas of study in the water, wastewater, or water reuse industries, including membrane bioreactors, fouling control, removal efficiency, pretreatment, enhanced recovery, reduced energy consumption, and novel membrane materials.

For more information, or to apply for a fellowship, visit https://www.amtaorg.com/fellowships.

To support the Ian C. Watson Fellowship for Membrane Advancement, visit https://www.amtaorg.com/ian-c-watson-fellowship-for-membrane-advancement

FELLOWSHIP RESEARCH

AMTA Fellowship awardees attend and share their research through podium presentation or poster at the annual Membrane Technology Conference and Exposition.

HANNAH RAY
Arizona State University, Tempe, AZ

2019–20 Ian C. Watson Fellowship

Ray is an environmental engineering PhD candidate with a concentration on wastewater treatment & nutrient recovery. As part of her fellowship research, she is investigating nitrogen recovery from human urine by membrane processes. The novel use of RO, NF, and FO membranes for selective separation of the neutral, nitrogen compounds from the rest of urine and the subsequent use of MD for nitrogen concentration has the potential to produce valuable industry products from the urine waste stream.

MICHAEL GEITNER
The Pennsylvania State University, PA

2018-2020 AMTA-NWRI Fellowship

Geitner is a doctoral student evaluating bioinspired hypochlorite-resistant reverse osmosis membranes under the supervision of Dr. Manish Kumar, Associate Professor, Departments of Chemical Engineering and Environmental Engineering.

CASSANDRA PORTER
Yale University, CT

2018-2020 AMTA-NWRI Fellowship

Porter is a doctoral student developing ion-rejecting membranes with polyelectrolytic layers produced through surface-initiated atom transfer radical polymerization under the supervision of Dr. Menachem Elimelech, who is the Roberto C. Goizueta Professor of Chemical and Environmental Engineering.

MEET THE AMTA FELLOWS

AMTA FELLOWSHIP WINNERS AT THE 2019 MEMBRANE TECHNOLOGY CONFERENCE

Standing (L-R): Kevin Hardy (NWRI Executive Director), Michael Geitner, Allyson McGaughey, Alma Beciragic, Xiaobo Dong, Brent Alspach (AMTA Fellowship Committee Chair and past President), Harold Fravel (former AMTA Executive Director, retired)

Sitting (L-R): Mengyuan Wang, Cassandra Porter, Mackenzie Anderson

MTC20 Joint Awards

MTC20 MEMBRANE FACILITY AWARD:

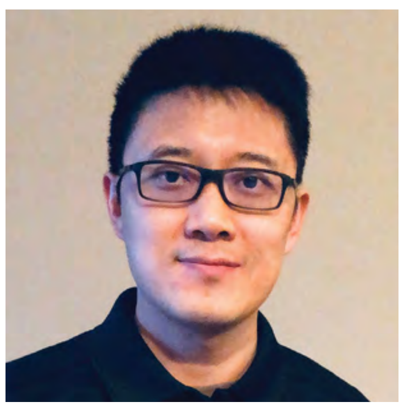
Recognizes an outstanding water/wastewater facility using membrane technology with high efficiency in an environmentally friendly approach.

The Town of Jupiter Utilities Water Treatment Plant, Jupiter, FL as an outstanding municipally-owned drinking water facility serving 87,000 customers. Treatment consists of 13.7 MGD of brackish water Reverse Osmosis, 14.5 MGD of Nanofiltration and 1.8 MGD of ion exchange.

MTC20 ROBERT O. VERNON OPERATOR OF THE YEAR:

Recognizes outstanding contributions to water supply improvement by an individual working at a membrane filtration, desalination and/or water reuse facility.

David Paulson, Irvine Ranch Water District, in recognition of his outstanding service and dedication to membrane operations and for his leadership within the industry.



MTC20 BEST PAPER AWARD:

Recognizes the outstanding preparation of a technical paper.

Max Wang, DuPont Water Solutions, for his outstanding preparation of his technical paper, A Study on Specialty High Temperature Nanofiltration Membrane for Sulfate Removal in Chlor-Alkali Processes.

MTC20 WATER QUALITY PERSON OF THE YEAR:

Recognizes outstanding contributions by an individual in government, academia, research or related field to water supply improvement.

Jonathan Brant, P.E., Ph.D., University of Wyoming, in recognition of his 8 years of service on the MTC Student Awards Committee. As Associate Professor for the College of Engineering and Applied Science at the University of Wyoming, he has devoted his time to research on advanced water and wastewater treatment technologies, RO and Nanofiltration Membranes and Nanostructured Ceramic Membranes.

AMTA AWARDS

AMTA 2020 OUTSTANDING MEMBER AWARD:

Recognizes outstanding contributions to membrane technology by an AMTA member.

David H. Paul received this award posthumously in recognition of his outstanding leadership in advanced water treatment and technical services and more than 20 years of active membership and support of the American Membrane Technology Association.

AMTA PRESIDENTIAL AWARDS:

Presented at the discretion of the AMTA President in recognition of individuals who have made significant contributions to furthering the mission of AMTA:

- **Karen Lindsey** in grateful appreciation of her enduring dedication and commitment to the success of AMTA.
- **Harold Fravel** in appreciation of his outstanding service and dedication to AMTA.
- **Paul Delphos** in appreciation of his dedicated service and leadership.

AMTA SERVICE RECOGNITION AWARDS:

Acknowledging outgoing AMTA Board Members who have made significant contributions to furthering the mission of AMTA:

Mike Snodgrass in recognition of his service and dedication to AMTA.
- AMTA Board of Directors, 2016-2020

Karen Lindsey in recognition of a decade of distinguished service to AMTA.
- AMTA Board of Directors, 2009-2020
- AMTA Executive Committee, 2009-2019

Legislative & Regulatory UPDATE

By Christine Owen
AMTA Legislative & Regulatory Affairs Committee Chair

COVID-19

The U.S. Environmental Protection Agency (EPA) announced a new policy in March to help address water utility trepidation regarding enforcement amid the ongoing COVID-19 public health crisis. The policy applies retroactively to March and provides EPA enforcement discretion for certain noncompliance situations that arise due to the COVID-19 pandemic. Public water systems are specifically singled out as "having a heightened responsibility to protect public health because unsafe drinking water can lead to serious illnesses and access to clean water for drinking and handwashing is critical during the COVID-19 pandemic." The agency will issue citations for violations and those violations will still require public notification. Discretion will only be applied to enforcement actions taken on those citations.

Waters of the United States

The U.S. Army Corps of Engineers' new definition for the Waters of The United States (WOTUS), titled the Navigable Waters Protection Rule, was published in the Federal Register in April. The rule identifies four categories of waters that will be federally regulated as well as what is excluded. Waters included are:

1. The territorial seas and traditional navigable waters;
2. Perennial and intermittent tributaries to those waters;
3. Certain lakes, ponds, and impoundments; and
4. Wetlands adjacent to jurisdictional waters.

Specific exclusions are:

1. Groundwater, including groundwater drained through subsurface drainage systems;
2. Ephemeral features that flow only in direct response to precipitation, including ephemeral streams, swales, gullies, rills, and pools;
3. Diffuse stormwater runoff and directional sheet flow over upland;
4. Ditches that are not traditional navigable waters, tributaries, or that are not constructed in adjacent wetlands, subject to certain limitations;
5. Prior converted cropland;
6. Artificially irrigated areas that would revert to upland if artificial irrigation ceases;
7. Artificial lakes and ponds that are not jurisdictional impoundments and that are constructed or excavated in upland or non-jurisdictional waters;
8. Water-filled depressions constructed or excavated in upland or in non-jurisdictional waters incidental to mining or construction activity, and pits excavated in upland or in non-jurisdictional waters for the purpose of obtaining fill, sand, or gravel;

9. Stormwater control features constructed or excavated in upland or in non-jurisdictional waters to convey, treat, infiltrate, or store stormwater run-off;
10. Groundwater recharge, water reuse, and wastewater recycling structures constructed or excavated in upland or in non-jurisdictional waters; and
11. Waste treatment systems.

USEPA Fourth Regulatory Determination

EPA has extended the opportunity to comment on the Fourth Regulatory Determination until June 10 to provide feedback. The agency intends to regulate both PFOA and PFOS, the most widely studied per-and polyfluoroalkyl substances (PFAS). A positive regulatory determination would kick off a process that would eventually lead to either a maximum contaminant level or treatment technique for each substance. EPA is also asking for data and information to determine the appropriate next steps for other PFAS chemicals.

NPDES and the Supreme Court

In late April, the Supreme Court of the United States (SCOTUS) ruled that Clean Water Act (CWA) permits can be required for some pollutant discharges into groundwater, effectively negating a 2019 EPA guidance which stated that the CWA does not apply to groundwater at all.

The case of County of Maui v. Hawai'i Wildlife Fund involves several environmental groups that sued the County of Maui over whether a discharge from the local wastewater facility must be regulated under the CWA. The facility releases wastewater directly into groundwater which eventually reaches the Pacific Ocean, a regulated waterbody under the CWA. The argument made is that, although the discharge was not directly into a regulated water, because it could be traced via groundwater discharges, it should require federal permits. SCOTUS ruled that CWA permits are required in cases when "there is a discharge from a point source directly into navigable waters or when there is the functional equivalent of a direct discharge," rejecting Maui's contention that permits are not required unless a point source discharges directly to surface waters. The Court also rejected the test adopted by the lower court (the U.S. Court of Appeals for the 9th Circuit), which held that indirect discharges would be covered whenever "fairly traceable" from a point source to a regulated surface water.

The SCOTUS ruling holds that permits are required only if the indirect discharge is the "functional equivalent" of a direct discharge. Whether an indirect discharge is functionally equivalent would be a facts and circumstances test to be applied by permitting authorities and lower courts in future litigation.

California and Microplastics

The California State Water Resources Control Board is proposing to define microplastics in drinking water as "solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least two dimensions that are greater than 1 and less than 5,000 micrometers (µm). Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded." The definition is caveated by the agency because "evidence concerning the toxicity and exposure of humans to microplastics is nascent and rapidly evolving, and the proposed definition of 'Microplastics in Drinking Water' is subject to change in response to new information including advances in analytical techniques and/or the standardization of analytical methods." The measure also requires that the state accredit qualified laboratories to analyze microplastics and to develop, if needed, a guidance to help customers interpret those results.

U.S. Senate Releases Water Infrastructure Legislation

In April, U.S. Senators John Barrasso (R-WY) and Tom Carper (D-DE) released draft water infrastructure legislation, including America's Water Infrastructure Act of 2020 (AWIA 2020) and the Drinking Water Infrastructure Act of 2020. These draft bills are intended to build upon the bipartisan America's Water Infrastructure Act of 2018, which was signed into law in October 2018 and included provisions that increased water storage, authorized federal funding for water projects, reduced flood risks, and improved drinking water systems.

The draft AWIA 2020 legislation includes approximately $17 billion in new federal authorizations to increase water storage, provide flood protection, improve navigation and repair aging wastewater and irrigation systems. The draft Drinking Water Infrastructure Act of 2020 includes approximately $2.5 billion to reauthorize programs under the Safe Drinking Water Act. The Senate Committee on Environment and Public Works began the information gathering process on both pieces of draft legislation on April 22, 2020 and passed the bill out of committee on May 6 with a unanimous vote.

Technology Transfer WORKSHOPS

In partnership with our affiliates across the country, AMTA each year offers a series of Technology Transfer Workshops that provide hundreds of membrane professionals with a unique opportunity to learn about the latest technologies, research and innovations that are solving complex regional water treatment challenges. Hear from industry leaders and practitioners on the cutting-edge of membrane technology.

SAVE THE DATES!

2021 WORKSHOPS

APRIL 27-29
AMTA/SEDA Workshop
Durham, NC

MAY 25-27
AMTA Workshop
Des Moines, IA

JUNE
AMTA 1-Day Workshop
Lancaster, OH

JULY 20-22
AMTA/NWMOA Workshop
Fargo, ND

AUGUST
AMTA 1-Day Workshop
Yankton, SD

OCT. 26-28
AMTA/SCMA Workshop
Houston, TX

**Calendar effective as of May 2020. Check amtaorg.com for the most up-to-date information.*

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Pushing the Envelope: Research, Innovation and New Directions in Desalination

October 20–22 , 2020 I Lowell, MA

- Updates on Cutting-Edge Research from Renowned Research Programs at MIT, Yale, and UConn
- Performance Data on New Technologies from New England Based Companies Driving Change in Our Industry
- Topics include Brine Concentration, 3D Printing of Membranes, Coupling Desalination with Renewable Energy, Forward Osmosis and Membrane Dewatering in Food Processing
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IDA International Desalination Association
NWMOA Northwest Membrane Operator Association
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SWMOA Southwest Membrane Operator Association
MIT | J-WAFS Abdul Latif Jameel Water & Food Systems Lab

Long-Term Membrane Operations

October 27–29, 2020 | Loveland, CO

- Operational Considerations & Lessons Learned
- Membrane Replacement Causes Operational Changes
- Owner, Engineer & Supplier Interaction on Replaced Membranes
- Facility Tour at Local Facility

PFAS and Emerging Contaminant Rejection by Membranes

April 27–29, 2021 | Durham, NC

- "Up to the Minute" Federal and State Regulatory Summary and Background
- Treatability Challenges, Concentrate Management, Approaches to Controlling
- Fouling and Research Results
- Cutting-Edge Research Focused on Treatment Solutions
- Case Studies and Foundational Overviews
- Panel Discussion with Leading Membrane Manufacturers: Challenges in Developing Products to Treat Emerging Contaminants and Meeting the Evolving Contract Expectations of the Industry

Advancing Membranes in the Upper Midwest

July 20–22, 2021 | Fargo, ND

- Brush up on Membrane Math and the Importance of Pre-treatment
- Membrane Case Studies and Retrofits in the Upper Midwest
- Specific Membrane Applications and Advancements

A Note on COVID-19: *The health and welfare of our members and partners is our highest priority. Workshop dates are subject to change. Visit* amtaorg.com *for the latest information.*

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NEW MEMBERS | Since our last newsletter we have welcomed 73 new members!

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Movers & Shakers

AMTA First Vice President **Jill Miller** accepted the permanent position of City of Bozeman Water Treatment Plant Superintendent.

AMTA Board member **Lynne Gulizia** announced her retirement effective June 30 from Toray Membrane after 39 years in the membrane industry. She will fulfill her term on AMTA's Board through MTC21.

Promoting, advocating and advancing the understanding and application of membrane technology to **create safe, affordable** and **reliable water supplies.**

AMTA

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CALENDAR OF EVENTS*

2020 EVENTS

July 24	**AMTA Board Meeting**
Sept. 29	SWMOA Workshop, Irvine, CA
Sept. 30	SWMOA MBR Workshop, Perris, CA
Oct. 1	SWMOA Workshop, Yucaipa, CA
Oct. 20–22	NWMOA MOC-IV, Pierce County, WA
Oct. 20-22	**AMTA Workshop, Lowell, MA**
Oct. 22	**AMTA Board Meeting, Lowell, MA**
Oct. 27-29	**AMTA/SWMOA Joint Workshop, Loveland, CO**
Dec. 8-10	**NWMOA MOC-III, Pasco, WA**
Dec. 8-10	**SWMOA MOC-III, San Diego, CA**

2021 EVENTS

Mar. 15–17	IDA 2020 International Water Reuse and Recycling Conference, Rome, Italy
Mar. 22	**2021 MTC Pre-Conference Workshops, West Palm Beach, FL**
Mar. 22-26	**2021 Membrane Technology Conference & Exposition, West Palm Beach, FL**
Mar. 26	**AMTA Board Meeting, West Palm Beach, FL**
Apr. 27-29	**AMTA/SEDA Joint Workshop, Durham, NC**
May 25-27	**AMTA Workshop, Des Moines, IA**
May 27	**AMTA Board Meeting, Des Moines, IA**
May 30–June 2	SEDA Annual Symposium, Cape Coral, FL
June	**AMTA 1-Day Workshop, Lancaster, OH** *(date tbd)*
June 13-16	**AWWA ACE, San Diego, CA**
July 20-22	**AMTA/NWMOA Workshop, Fargo, ND**
July 22	**AMTA Board Meeting, Fargo, ND**
July	SWMOA Annual Conference, Pico Rivera, CA
August	**AMTA 1-Day Workshop, Yankton, SD** *(date tbd)*
Aug. 25–27	SCMA Annual Conference & Expo, Fort Worth, TX
Oct. 26-28	**AMTA/SCMA Workshop, Houston, TX**
Oct. 28	**AMTA Board Meeting, Houston, TX**
Nov. 7–10	IDA 2021 World Congress, Mombasa, Kenya

**Due to the ongoing pandemic, event dates are subject to change. Check AMTA and Affiliate websites for the most up-to-date information.*

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