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Creative Solutions and Innovative Strategies for Today's Water Challenges: Blue Paper

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Creative Solutions and Innovative Strategies for Today's Water Challenges

Blue Paper

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Connecting People and Ideas to Water Solutions

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INTRODUCTION

The International Desalination Association held an Energy & Environment Forum in Miami, Florida on December 7-8, 2016. The program was chaired by Richard Stover and Leon Awebuch. Attended by invited leaders of the global desalination and water reuse community, the theme of the Forum was "*Creative Solutions and Innovative Strategies to Today's Water Challenges.*"

The Forum addressed three main goals: a) brokering knowledge of the best available and most appropriate technologies and practices for energy efficiency and environmental stewardship in desalination and water reuse; b) raising awareness of the national importance of water as committed to during the 2016 White House Water Summit; and c) identifying and prioritizing solutions that reduce CO2 emissions and promote the use of renewable energy in desalination and water reuse in accordance with the mission of the Global Clean Water Desalination Alliance – H2O minus CO2.

Forum participants contributed information, ideas and practical experiences from around the world. The program included presentations, panels and discussions on topics including:

- The Current State and Future of Water Recovery and Reuse
- One Water: Desalination and Reuse
- Low Carbon Desalination
- Membrane, Thermal and Hybrid Technologies and Use of Clean Energy
- Sustainable and Renewable Desalination and Water Reuse
- Current and Emerging Membrane Technology
- Environmental Issues of Seawater Intakes and Outfalls
- Energy and Efficiency in Desalination
- Progress in Energy Recovery Solutions
- Solar, Nuclear and Geothermal Desalination

Forum participants articulated the state of the art of energy and environmental issues in desalination and water reuse and established guidelines for energy efficiency and environmental stewardship for sustainable water supply for future generations. Forum presentations and discussions documented the breakthroughs and accomplishments that have made desalination and water reuse the reliable and affordable solutions that they are today while reflecting a strong commitment to innovation and improvement. There was clear consensus that seawater, brackish water and wastewater are the only truly sustainable water resources available for drinking water and industrial and agricultural needs. Forum discussions underscored the importance of the water-energy-food nexus and that the continued security, health, economic development and environment stewardship depend on the adoption of sustainable practices.

This IDA Blue Paper report provides a summary of the Forum's proceedings and includes the presentations given and supplemental material submitted by the participants. Rather than distilling the proceedings down to points of consensus, this IDA Blue Paper presents a summary of all the concepts discussed, including, in some cases, diverging views. It is thereby hoped that this IDA Blue Paper will stimulate further discussion and encourage diversity in the global desalination and water reuse community. IDA welcomes your feedback and input via its website: www.idadesal.org.

In addition to the Forum proceedings, the IDA Blue Paper draws upon the work of the Massachusetts Institute of Technology's (MIT) "Low Carbon Desalination - Status and Research, Development, and Demonstration Needs" workshop held in October 2016 [http://web.mit.edu/lowcdesal, Lienhard/Thiel/Warsinger/Banchik].

IDA is grateful to the Forum participants and to the American Water Summit and Global Water Intelligence who hosted a co-located event focused on "Catalyzing Collaboration" with public, private and industrial water sectors. Thanks to all the speakers for contributing to this vital effort, to IDA Headquarters staff for their dedication, and to the members of the Forum's Leadership Club whose financial contribution made the event free of charge to all participants. These contributors include ACWA Power, Consolidated Water/AEREX, Dow, Poseidon Water, IDE Technologies, and the Abdul Latif Jameel World Water and Food Security Lab (J-WAFS).

IDA'S COMMITMENT TO ENERGY EFFICIENCY AND ENVIRONMENTAL STEWARDSHIP

The IDA is the world's leading resource for information for the global desalination and water reuse industry and is dedicated to sustainable and environmentally responsible desalination and water reuse practices. In 2009, IDA convened the Energy and Environment Committee to encourage energy efficiency and environmental stewardship by brokering knowledge of best available and most appropriate technologies and practices. The Energy and Environment Committee draws on experts from the water industry, academia, research and technology institutes, consultancies, regional government water producers, and regulatory bodies.

In 2010, IDA hosted "Desalination and the Gulf: The Relationship between the Environment and Meeting the Region's Water Needs," a conference in Bahrain convened to address environmental issues associated with seawater desalination. In the same year, IDA hosted "Desalination: An Energy Solution," IDA's first conference devoted exclusively to strategies for enhancing energy efficiency in seawater desalination. In 2016, the IDA Energy and Environment Committee convened the Energy and Environment Forum in Miami

as a means to, once again, bring together leaders in the global desalination and water reuse community to explore issues and facilitate discussions that will shape a path to a sustainable water supply for future generations. These events and this report reflect IDA's continued commitment to leadership to energy efficiency and environmental stewardship.

CURRENT DEMAND AND TECHNOLOGIES

Water demand is increasing worldwide as a result of growing populations and rising standards of living. Further, increasing climate variability is disrupting historical patterns of precipitation and water storage. By 2020, 35% of the global population will live in water-stressed regions. By 2030, increases in both domestic water and energy demand of 50% are expected. By 2050, industrial water demand will have increased by 400% compared to 2016 requirements [Desai/Barclay, Sharma].

While conservation and reuse efforts have helped to moderate demand for new freshwater resources in some locations, desalination and water reuse are increasingly being used to meet demand worldwide. Current installed capacity (as of 2016) is almost 90 million m^3/day (23.8 billion gallons per day) of desalinated water, a value that has been growing rapidly, with continued growth projected at 12% in the next five years. A 50% increase in annual contracted desalination capacity from 2016 to 2020 is forecast. By far, the greatest spending will be in Oman, Egypt, Iran and Saudi Arabia – $28B between – followed by China and Taiwan at $10B and Chile and North America at $5B (Figure 1) [Gasson].

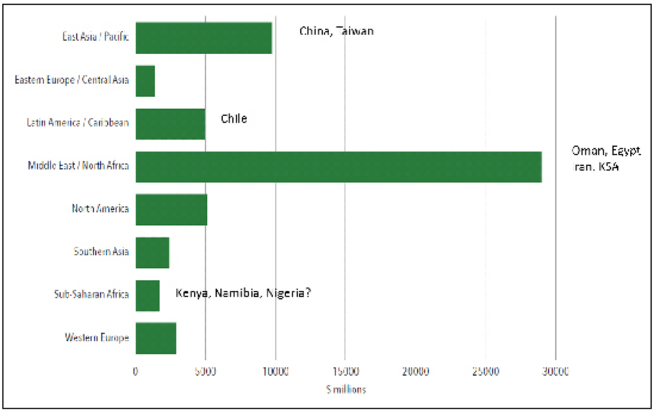


Figure 1 - Anticipated Cumulative Spending on Desalination by Region, 2016-2021 [Gasson]

Desalinated water represents a unique form of water, embodying value in many different

forms: as a source of supply with locational value; as an essential form of insurance; and as a source of optionality – a tool that lets utilities operate their systems more flexibly and efficiently. Although desalination may not play a major role in some region's water utilities' portfolios in the near future, strategically it may emerge as a vital option to help utilities and communities plan for the future with confidence [Riva].

Desalination technologies can be categorized into non-phase change, phase change and hybrid processes. Phase change processes, including multi-stage flashing (MSF) and multi-effect distillation (MED), require heat and electricity. They involve heating the feed, flashing or evaporating it under vacuum, and condensing the vapor formed into fresh water. The greatest advantages of these thermal processes are their proven long-term reliability, the large scale possible, the high purity of the product, the ability to be implemented as dual purpose power and water plants, and the ability to be powered by any type of thermal source including renewable resources.

Non-phase processes include reverse osmosis (RO) and electrodialysis (ED). These techniques involve the use of mechanical and electrical power to separate the salt from the feed.

Hybrid processes combine the best features of non-phase change and phase change processes such as reverse osmosis coupled with MSF or membrane distillation [Hasan]. Often, several technologies are combined to achieve treatment goals such as minimum liquid discharge (MLD) or zero liquid discharge (ZLD), limiting water consumption or handling complex waters reliably [Desai/Barclay, Sharma].

In seawater desalination, energy consumption is the most significant economic issue, accounting for more than 1/3 of the cost of water in modern plants and 50% of ongoing operating costs (Figure 2) [Lienhard, Tonner]. Energy use also represents the major environmental impact of desalination, with top-down estimates at around 23 GWe, corresponding to a carbon footprint of approximately 120 million metric tons of CO_2 per year emitted to power desalination processes worldwide [Lienhard].

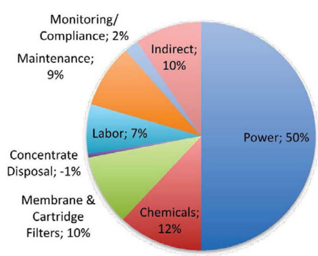


Figure 2 - Typical seawater RO operating costs [Tonner]

With respect to electrical energy, seawater RO plants are the most efficient (Figure 3), consuming about 3 kWh per cubic meter (11.4 kWh per 1000 gallons) of pure water produced [Gasson, Felber]. However, because of the inefficiency of electricity generation, thermal desalination technologies operate with the greatest overall energy efficiency, especially MED due to low temperature operation and the use of heat cascading/recycling. State-of-the-art MED plants consume as little as 0.9 kWh of electric energy per cubic meter (3.4 kWh per 1000 gallons) of pure water produced [Awerbuch/Canton/Van der Mast] plus thermal energy, or about 4 kWh per cubic meter (15 kWh per 1000 gallons) total equivalent power [Lienhard].

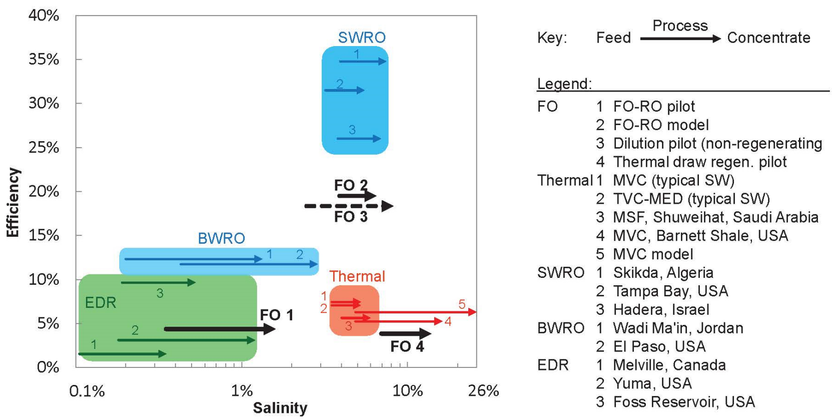


Figure 3 - Efficiency for Various Systems and Salinities [Lienhard]

In terms of cost, large-scale seawater RO plants have achieved economies enabling production of drinking water at a cost as low as $0.50 per m^3 ($1.89 per 1000 gallons) [Kim]. A more typical example is the cost of water production at the Carlsbad seawater RO plant which is $1.40 per cubic meter ($5.3 per 1000 gallons) plus a delivery cost of $0.34 per cubic meter ($1.29 per 1000 gallons) [MacLaggan].

Globally, over 90% of new desalination capacity uses membrane technologies as opposed to thermal technologies [Gasson]. Membranes are increasingly being used to treat brackish and surface water, in industrial concentration and purification processes, in membrane bio-reactors instead of traditional aeration digestion, and in decentralized point of use/point of discharge applications [Fravel].

Figure 4 - Brackish Water Reverse Osmosis System [Fravel]

Membrane technologies have also been developed to displace older, more chemically-intensive techniques and improve the performance of desalination processes. For example, nanofiltration (NF) can often replace lime softening to allow thermal desalination to operate at higher temperatures and higher efficiencies or to allow membrane desalination processes to operate at higher recovery rates [Desai/Barclay, Awerbuch/Canton/Van der Mast]. Integrated water solutions are significant drivers for the water purification industry [Desai/Barclay].

Environmental issues are impossible to avoid, but technologies and approaches exist to minimize impacts [Hogan]. For example, the Carlsbad Desalination Plant is the first large-scale water treatment plant in California to achieve net-carbon-neutrality. Because the plant is located in the population center it serves, a key energy savings feature is the elimination of the need to transport up to 68.9 million m^3/year (18.2 billion gallons/year) from northern California to the San Diego region. This offsets 190,000 megawatt-hours of electricity and 68,000 tons of carbon emissions each year. The high efficiency process design and energy recovery devices in the plant reduce its energy consumption by 150,000

megawatt-hours and carbon emissions by 43,000 metric tons year. Other features of the greenhouse gas reduction plan include sequestering 2,100 metric tons of carbon each year through the use recycled CO_2 in the water treatment process, sequestering carbon through reforestation of a fire-damaged state park, and purchase of carbon offsets for the residual portion of plant energy not supplied by renewable sources [MacLaggan].

Concentrate management is of key importance for the viability of seawater desalination projects. At present, ocean outfalls are the most widely used means of concentrate management [Voutchkov]. Returning to the Carlsbad example, the desalination plant receives seawater for processing and brine dilution from the Encina Power Station cooling water discharge. Under co-located operation, impingement and entrainment impacts have been eliminated with 1.0 mm fish-friendly traveling screens, 0.15 meter per second (0.5 ft/s) through-screen velocities, a fish return system and fish-friendly brine dilution pumps. Brine salinity is reduced to an acceptable level by mixing it with power plant discharge before release to the ocean [MacLaggan]. The result at Carlsbad and at most desalination facilities around the world has been no evidence of marine impact [Riva].

Although the implementation of direct potable reuse faces regulatory, utility and community concerns, onsite industrial reuse and direct use between facilities with decentralized treatment are applied around the world. For example, the Monterey Regional Water Pollution Control Agency operates one of the world's largest water recycling facilities, producing 112,000 m^3/d (30 million gallons per day) for irrigation of food crops [Carpenter]. The Pohang, South Korea hosts another of the world's largest municipal wastewater reuse facilities, producing 132,000 m^3/d (35 MGD) for industrial use (Figure 5) [Kim].

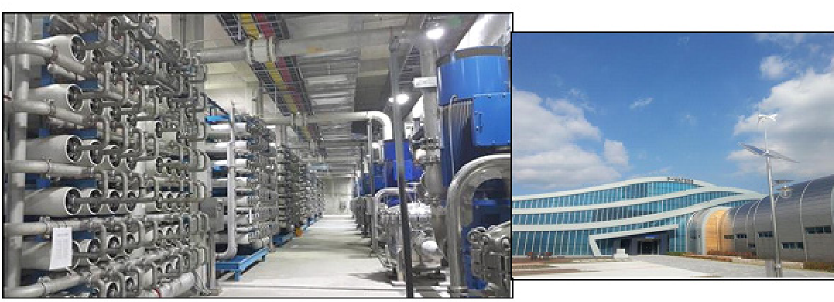


Figure 5 - 132,000 m^3/d (35 MGD) Pohang Reuse Plant, South Korea [Kim]

EMERGING TRENDS AND TECHNOLOGIES

New water systems must be as efficient, low-cost and environmentally-benign as is feasibly possible. At the same time, water utilities have an obligation to meet their customers' needs with a bedrock level of assured reliability.

Taking the case of California, a major drought extended to six years, generating worrisome signs that the region may experience, on average, a much drier "new normal" across the 21st century. Given the region's growing population, such a climate shift would be expected to put huge pressure on a water delivery system designed for the cooler and wetter conditions of the early to mid-20th century. Other coastal regions across the United States face their own challenges due to a variety of factors including coastal population growth, climate change and salt water intrusion driven by rising sea levels. In light of all these concerns, it is more important than ever to address head-on some of the outdated myths and misconceptions that have deterred consideration of desalination and water reuse as modest but critical parts of balanced water portfolios [Riva].

Significant research and development effort is being applied to desalination and water reuse systems and technologies to improve operational reliability, reduce energy consumption, increase product water recovery and purity, and drive down costs [Desai/Barclay]. The relative importance of these issues depends upon the composition of the water being treated and costs and conditions at the specific location.

Developers continue to reduce the energy requirements for desalination and water reuse with best available technologies. It is anticipated that a 3% reduction in SWRO energy requirements could be achieved with near-term membrane improvements [Stover] including membrane chemistry and surface structure enhancements [Kim]. An additional 4% reduction can likely be achieved with energy recovery device improvements [Stover].

There is a trade-off between the cost of additional or enhanced equipment required to increase efficiency and the cost of the energy saved. For example, lower recovery approaches have been very successful for lowering energy in seawater desalination plants with deep wells intakes and minimal pretreatment needs. However, with typical pretreatment requirements, lower recovery operation requires additional pretreatment equipment. Total cost of ownership analyses and peak efficiency envelope(s) should be assessed during plant design and operation [Tonner].

Prefabricated modular RO units are being deployed, even for large projects, as a means to accelerate project implementation and drive down costs. In mega-plants, optimized process designs reduce plant footprint and environmental impact, including pressure centers, 16" vertical membranes and chemical-free desalination [Felber].

In brackish and industrial desalination, water reuse and water treatment applications, maximizing recovery is important both as a means to maximize utilization of source water and to minimize waste reject. However, dissolved salts can limit recovery in desalination applications if their osmotic pressures exceed the capacities or corrosion resistance of equipment. Also, foulants and sparingly soluble salts can limit achievable recovery rates by contaminating membrane or heat transfer surfaces.

Storing water can reduce total cost by up to 40% with storage of about 8% of production capacity being typically economical [Tonner]. Hybrid membrane inter-stage designs combine membranes of different nominal flux and salt rejection in the same pressure vessel to achieve higher average permeate flux, better permeate quality and lower energy consumption [Kim]. Self-regulating RO process schemes to maximize flexibility and minimize instrumentation and intervention can provide savings over the life of an operation [Oklejas].

Conventional brine concentrators use evaporators, seeded slurry precipitators and mechanical vapor compressors to achieve dissolved salt concentrations that approach saturation – up to 250,000 mg/l. However, membrane processes are being used to reduce the size and energy consumption of conventional brine concentrators required or replace them altogether.

Today it is possible to concentrate salts to over 100,000 mg/l = 10% salt with pressure-driven membrane technology [Fabig]. Forward osmosis has shown the potential to achieve salt concentrations in excess of 250,000 mg/l in oil & gas, power generation and chemical manufacturing applications [Pendergast]. Membrane distillation has also achieved concentration levels approaching saturation in test applications. This means that in the future it will likely be possible to achieve MLD/ZLD with only membrane processes feeding a crystallizer [Fabig].

Those working to advance the use of direct potable reuse are addressing regulatory, utility and community concerns in the effort to gain public acceptance. There is a clear need to establish treatment requirements and criteria for pathogen and chemical control, define reliability, and implement on-line performance monitoring with minimal response time to upsets and off-spec water [Carpenter]. Potential contaminants of concern include pharmaceuticals, personal care products, hormonal products and pesticides [Kim]. It is likely that contaminants will need to be controlled at their sources throughout the collection system [Carpenter].

Co-sited desalination and reuse plants are gaining popularity because they provide opportunities to reduce energy consumption, increase fresh water production and



diminish the environmental impacts of plant discharge and intake operations [Voutchkov].

Increasingly, public-private partnerships or P3 models are being used to implement new water supply projects. They enable water utilities to meet their needs while retaining public oversight and avoiding costly debt obligations. The pay-for-performance framework provides clear, contractually-defined relationships, brings market rigor, cost control and predictability of results [Riva].

Regardless of the type of water treated or the process used, some environmental issues are impossible to avoid. The goal is to develop alternative water supply technologies and approaches that minimize impacts [Hogan].

INNOVATIONS

Innovation was a theme addressed by many Forum participants, with contributions ranging from improvements of existing desalination and water reuse methods to research and development of novel technologies.

Batch and semi-batch RO processes have demonstrated increased recovery rates in single-stage systems, reduced fouling and scaling, and lower power consumption compared to conventional continuous RO processes [Stover]. Modeling of batch and semi-batch versus continuous SWRO indicate that up to a 10% thermodynamic efficiency increase is possible with semi-batch RO and an additional 10% with batch RO at 45% recovery. For SWRO at higher recovery rates, the savings potential can be 4 times as much. For brackish RO, semi-batch processes can increase thermodynamic efficiency by 25% while batch RO can double efficiency compared to continuous RO (Figure 6) [Warsinger].

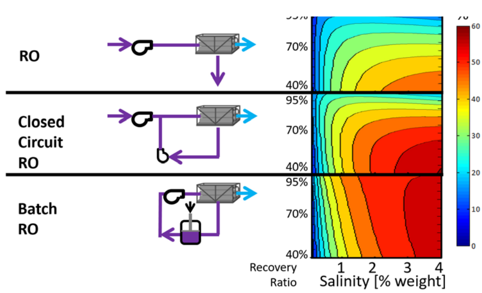


Figure 6 - 2nd Law energy efficiency of single stage RO, batch RO and semi-batch RO (single stage RO modeling includes a pressure recovery device not shown in diagram) [Warsinger]

Dead end operation of RO membranes with pulsed brine release have demonstrated some of the same advantages as batch and semi-batch RO, with increased recovery rates, higher brine concentrations and power consumption reductions of up to 20% compared to conventional multi-stage RO systems [Liberman].

For inland desalination plants, discharge of RO reject can be a major concern because long lines to the ocean, deep well injection or vehicular transportation can be expensive or impractical. Squeezing more product from the raw water and thereby reducing the flow of the reject stream seems the most logical. Minimal liquid discharge (MLD) is significantly more practical than zero liquid discharge (ZLD), which can be prohibitively expensive. However, recovery rates in brackish and industrial water treatment can be limited by membrane fouling or scaling. Novel operating techniques in which the membranes are vibrated or oscillated have demonstrated improved fouling and scaling resistance, lowering pretreatment requirements and allowing for operation at higher recovery rates. Alternately, pulse flow reverse osmosis (PFRO) can be used to shorten brine concentration cycles to less than scale nucleation times, allowing operation at extremely high recovery rates with reduced risk of scaling [Liberman].

The configuration of RO modules can produce energy savings. Hybrid membrane inter-stage design (HID) combine membranes of different nominal flux and salt rejection performance in the same pressure vessel to achieve higher average permeate flux, better permeate quality and lower energy consumption [Kim].

For thermal brine concentration for oil and gas wastewater and RO concentrate, advances have been made that can decouple heat transfer and scaling surfaces. Novel carrier gas extraction (CGE) through a packed bed humidifier and multi-stage bubble column dehumidifier enables use of lower-cost materials and reduces pretreatment requirements compared to traditional evaporation techniques (Figure 7). In addition, thermodynamic balancing has been used to optimize and minimize energy consumption [Govindan].

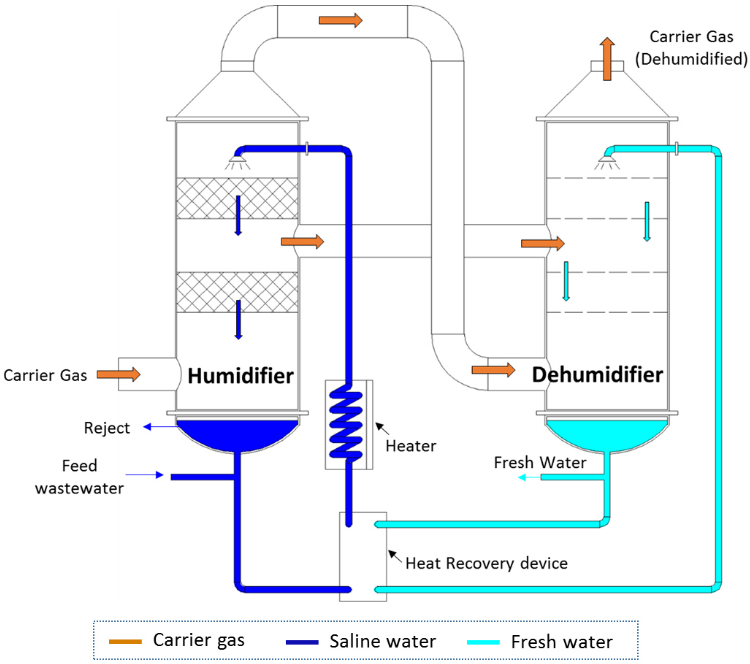


Figure 7 - Carrier Gas Extraction Process [Govindan]

A number of Forum participants proposed combining different membrane processes or membrane and thermal processes to achieve overall performance and cost benefits. MED feed can be softened with nanofiltration (NF) membranes to reduce MED operating temperatures. Seawater can be preheated in an MED reject section, then softened with NF prior to SWRO desalination, and the SWRO reject brine with reduced sulfate, calcium and magnesium can be the feed for the distillation plant [Awerbuch/Canton/Van der Mast]. Several novel membrane processes including membrane distillation and FO can utilize waste heat [Hong, Yong, Delagah].

RO feed can be diluted with a low salinity source such as wastewater treatment plant effluent across an FO membrane to reduce desalination energy requirements [Kim, Yong, Hong] or RO brine can be used as a draw solution for pressure retarded osmosis or reverse electrodialysis to recover energy [Voutchkov]. Pressure-assisted forward osmosis (PAFO) has potential for reducing CAPEX by reducing SWRO plant footprint while reducing energy requirements and improving RO permeate quality [Kim].

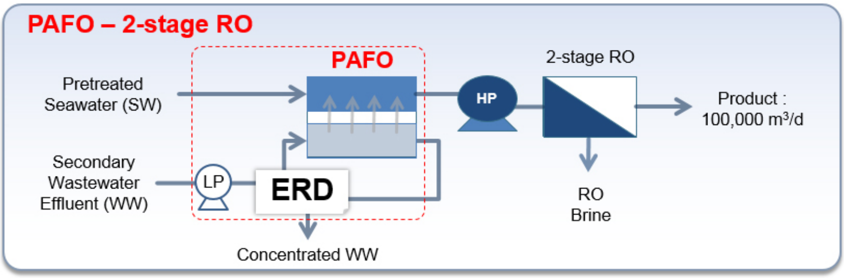
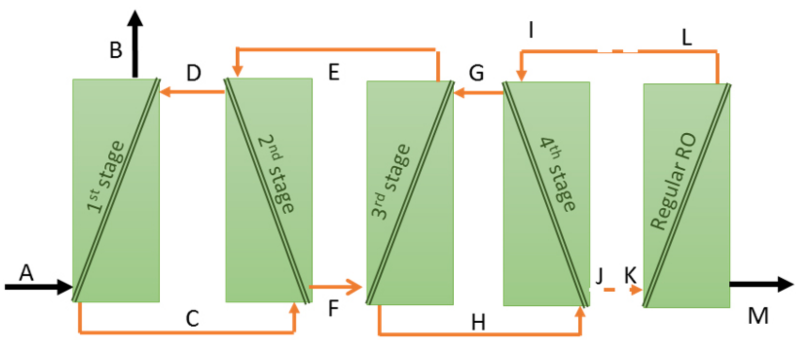


Figure 8 - Pressure-Assisted Forward Osmosis [Kim]

Crossflow RO has been demonstrated as a means to produces brine salt concentrations of up to >20% salt with standard RO membranes and pumps [Govindan].



Stream	A	B	C	D	E	F	G	H	I	J	K	L	M
Salinity [%]	5	17	4.5	15.3	13.6	4	11.9	3.5	10.2	3	2	6.8	0

Figure 9 - Crossflow Reverse Osmosis [Govindan]

Improvements to electrodeionization membranes are being researched to improve their performance. Pervaporation membranes, photoelectrochemical ZLD and IX membranes are being evaluated for concentrate minimization [Delagah].

Challenges faced by new water technologies include funding for access to "real world" installations, without which test results can lack credibility with the broad range of stakeholders that must be onboard for a water technology to be adopted [Yong].

SUSTAINABLE DESALINATION AND REUSE WITH RENEWABLE ENERGY

Because energy consumption is the greatest cost and environmental impact of desalination, there is broad interest in low-cost energy sources that have low greenhouse gas emissions. A sustainability index was proposed for straightforward objective appraisal and comparison of planning alternatives. It is obvious that the necessary sustainability criteria should best be implemented into the planning and design stages rather than after the project is already under construction or in operation. In view of the higher investments required for sustainability-based development, uncertainties about the future and some possible delays in project completion, society will have to be convinced that the most reliable, or perhaps the only, path to a satisfactory future for humanity is by sustainable development, and that time is running out; such conviction should also be effective for creating political leaderships that would be willing to invest in the needed efforts and see them realized [Lior].

Renewable energy is an environmentally friendly option that decreases the stress on fossil fuels. With the growing demand for desalination technologies to provide potable water, it is expected that renewable energies will have a flourishing future and a dominant role in many developing countries [Hasan].

Of particular interest is solar energy, the cost of which has dropped from 20-30 cents/kWh in 2008 to less than 5 cents/kWh in 2016, making it cost-competitive with fossil fuel energy sources in high irradiation regions. By 2050, renewable energy will supply 69% of electricity and 35% of total energy needs in the US. For low-density population areas that lack fresh water and electrical grid connections, the use of solar panels, wind turbines, and geothermal energy can be the only option [Fthenakis].

Several Forum attendees had participated in Massachusetts Institute of Technology's (MIT) "Low Carbon Desalination - Status and Research, Development, and Demonstration Needs" workshop held in October 2016 (http://web.mit.edu/lowcdesal). The workshop addressed reducing the carbon footprint of desalination systems. The workshop was organized at the request of the Global Clean Water Desalination Alliance (GCWDA) and sponsored by the MIT Abdul Latif Jameel World Water and Food Security Laboratory. The GCWDA established a goal that at least 80% of new desalination plants and at least 10% of existing plants be powered by clean energy by 2035. Given the average lifespan of desalination plants, achievement of the GCWDA's goal will mean that, by 2035, the majority of desalination plants will produce minimal greenhouse gas emissions. The workshop addressed two ways to decarbonize desalination: use of low-carbon energy sources such as solar, wind, geothermal or nuclear, and improvement of the energy

efficiency of existing technologies with new process configurations, improved membranes, improved components and control of fouling [Lienhard].

Integrated renewable energy water solutions include variable load operation, intermittent operation, continuous operation with water or power storage, continuous operation with a mixture of renewable energy and grid services, or a combination of these approaches. Examples include photovoltaic + solar thermal and photovoltaic-RO + MED-absorption-desorption. A 19% cost reduction is possible, with the potential to increase the reliability and longevity of systems [Fthenakis].

Examples of solar-, wind-, fuel cell-powered grids with variable load operation RO units and water storage controlled with decentralized energy management systems exist in Greece. These include energy storage with capacitor panels [Papadakis]. Alternatively, rather than storing energy, water can be pumped to a higher elevation when energy is available and then released through a turbine energy recovery device when power is not available [Oklejas].

Several evaluations of the economic feasibility of wind-powered RO plants were carried out, taking into account the intermittence, feed pressure, wind availability and speed, proving to be a successful technique. Considering wind energy coupled with solar energy, a known example of such a system is wind generator/photovoltaic energy combination implemented to run desalination plants with the presence of a battery bank system [Hasan].

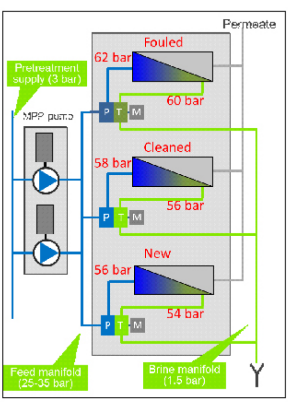


Figure 10 - Pressure Center RO Process Design [Oklejas]

One means to utilize intermittent renewable energy for desalination is with multi-train semi-pressure-center RO designs equipped with different pump and train capacities to allow matching of capacity with power availability (Figure 10) [Oklejas, Felber].

Powering desalination plants with geothermal energy is also highly feasible without the intermittent supply challenges of solar energy. The global installed base of geothermal energy facilities is about 13.3 GW as of January 2016, spread across 24 countries. Hot water from a geothermal source can be transferred over great distances economically and used to power MED systems [Awerbuch/Canton/Van der Mast]. Geothermal energy is renewable, abundant, and comparatively clean and sustainable, with a long-term potential estimated to be more than 200,000-fold of current world energy demand [Lior]. Binary-type geothermal power can be used to extract thermal energy from low and moderate grade geothermal resources (usually below 150 °C or 302 °F) when direct flashing the geofluid is undesired [Lior].

Interest in using nuclear energy for producing desalinated water is growing and has been considered as an option by several countries around the world, as well as countries with existing operating nuclear power plants. As of November 2016, 450 nuclear power plant units with an installed electric net capacity of about 392 GW were in operation in 31 countries, and 60 plants with an installed capacity of 60 GW were under construction in 16 countries. In USA, 99 nuclear reactors were in operation producing 98.9 MWe, and 4 reactors were under construction that will generate an additional 4.5 MWe. Combining thermal and membrane desalination processes with nuclear power can reduce desalinated water costs, add flexibility and better match the demand to the combined water and power production, and minimize environmental impact. The optimum desalination technology for nuclear desalination was considered a hybrid of Multi-Effect Distillation (MED) with Reverse Osmosis (RO) [Awerbuch/Khamis].

One of the constraints on the availability of renewable energy is that existing power companies often hold monopoly control over regions and use it to prevent to inhibit implementation of distributed solar power. An example is Florida where a narrowly defeated 2016 amendment would have made it illegal or prohibitively expensive for anyone except the monopoly area provider to operate solar units for third parties [Meyer-Steele].

CONCLUSION

The Forum and this Blue Paper represent another step by the IDA in the ongoing and critically important effort to bring understanding and specific actions to desalination and water reuse applications to achieve energy efficiency, minimize environment impact, and find innovative solutions to today's and tomorrow's water challenges. As water demand continues to grow around the world, it is critical that desalination and water reuse plants be constructed and operated in an energy-efficient, environmentally-friendly manner. Facilities around the world today have proven this can be achieved.



NEXT STEPS

- IDA will work closely with Global Clean Water Desalination Alliance – H_2O minus CO_2 – of which IDA is the founding member, in identifying and prioritizing desalination and water reuse solutions that reduce CO_2 emissions and promote the use of renewable energy in accordance with the Alliance's mission, especially the Alliance's stream 1 goal: clean energy supply for desalination plants.
- This report will be presented at in a special workshop at the IDA 2017 World Congress on Water Reuse and Desalination, taking place October 15-20, 2017 in São Paulo, Brazil.
- IDA will encourage the inclusion of mandatory energy and environment assessments in requests for proposals and project specifications for new and retrofit desalination and water reuse projects.
- Through its publications, meetings and conferences, IDA will continue to educate and advocate the critical importance of energy efficiency, the use of renewable energy and consideration of environmental impact.
- The IDA Energy and Environment Committee in partnership with IDA Technical Programs Committee will organize a follow up Forum/Conference in 2019 to assess the progress that has been achieved since the Miami Forum and to continue to encourage energy efficiency and environmental stewardship in desalination and water reuse projects by brokering knowledge of best available and most appropriate technologies and practices.

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Vasilis Fthenakis, *Views and Modelling Renewable Desalination*

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In S. Kim, *Emerging Technologies in Desalination and Water Reuse*

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Peter MacLaggan, *Energy and Environment Issues in Desalination*

Shawn Meyer-Steele, *Government, Utilities and Power Company Regulation and Impedance of Renewable Energy Implementation*

Eli Oklejas, Progress in Energy Recovery Solutions: *Five Hacks to Reduce Energy Consumption of Mid to Mega Scale SWRO Facilities*

George Papadakis, *Aspects of Variable Operation of Autonomous and Island Grid Connected RO Desalination Systems*

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Mr. Greg Wetterau, Co-Chair, United States
Mr. Gary Crisp, Australia
Dr. Masura Kurihara, Japan
Mr. Shawn Meyer-Steele, United States
Mr. Juan Miguel Pinto, United States

Richard L. Stover, PhD, has over 25 years of professional experience, specializing in water technologies. His work included serving as Chief Technical Officer and Senior Vice President of Marketing for Energy Recovery, Inc., the leading supplier of energy recovery devices for seawater reverse osmosis. There he directed the technical/commercial effort that took the company from startup through a very successful global launch and IPO in 2008. He held responsibility for engineering, research and development in addition to product strategy and pricing, technical support and field service. His technical competencies include chemical and mechanical engineering, systems and process engineering, electrochemistry, and membrane science. His commercial experience includes sales and marketing of products, systems and services.

Having had a major impact on seawater desalination for municipal water supply, Dr. Stover has turned his attention to increasing the efficiency of industrial water, brackish water and waste water treatment. His work with Desalitech focused on reducing waste, reducing energy consumption and increasing reliability with Desalitech's high recovery water purification and effluent treatment products. Dr. Stover also served as Vice President of Engineering for Oasys Water where he developed forward osmosis processes for desalination, water reuse and osmotic power. Earlier positions included consumer product development and manufacturing engineering for IBM and 3M.

Dr. Stover has been granted numerous patents for desalination methods and devices. He was co-recipient of the European Desalination Society's Sidney Loeb award for outstanding innovation.

Dr. Stover obtained a doctorate degree in Chemical Engineering from the University of California at Berkeley and a Bachelor's degree in Chemical Engineering from the University of Texas at Austin.

Mr. Greg Wetterau is a Vice President with CDM Smith in Rancho Cucamonga, California, where he works with the planning and design of membrane filtration, potable reuse, and desalination projects around the globe. He has been involved with membrane technologies since 1992, completing his Master's thesis at the University of Illinois Urbana-Champaign modeling fouling and hydraulics in an ultrafiltration system.

Before joining CDM Smith, Mr. Wetterau worked at Economic and Engineering Services (now part of HDR), where he designed and permitted the first municipal membrane plant in the Pacific Northwest in Aberdeen Washington. He joined CDM in 1999 and has worked on over 60 membrane treatment facilities, ranging in size from the 375,000 m3/d Sulaibiya Advanced Water Treatment Facility in Kuwait to the award winning 3,000 m3/d Emergency Water Supply in Cambria, California. Mr. Wetterau serves as Treasurer of the American Membrane Technology Association Board of Directors and is past Chair of the American Waterworks Association Water Desalting Committee, where he led the development of the first edition Manual of Practice on Desalination of Seawater (M61).

Mr. Wetterau holds a Masters and a Bachelor of Science from the University of Illinois, and a Bachelor of Arts from Wheaton College.

Mr. Gary Crisp graduated from University of Pretoria as a Civil Engineer and has 36 years of water experience, 18 of which is in desalination. He recently joined John Holland Group as Engineering Manager and is based in Perth.
Gary was an integral member of all Water Corporation desalination projects, including the Perth Seawater Desalination, Southern Seawater Desalination, Burrup Fertilizers, and Kwinana Water Reuse plants. He was Chief Technical Officer for the construction and commissioning of the Gold Coast Desalination Plant over a period of three years. Gary has worked on five desalination projects that have won GWI Desalination Plant of the Year titles. He has been involved with a number of North American desalination and reuse projects, most notably Carlsbad Desalination Plant, Huntington Beach Desalination Plant, Camp Pendleton Desalination Plant, BP Mad Dog II EOR and Rosarito Desalination Plant.

Gary is a director of the International Desalination Association. He was awarded Western Australian Professional Engineer of the Year 2007, by Engineers Australia for his contribution to desalination in Australia.

Gary has prepared and presented many papers related to desalination.

Dr. Masaru Kurihara is Senior Scientific Director of "Mega-ton Water System", Funding Program for World Leading Innovation R&D on Science & Technology, Japan, and Fellow of Toray Industries, Inc.
He graduated from Gunma University, Technical Department, Applied Chemistry in 1963 and completed his doctoral dissertation at the University of Tokyo in 1970. He joined Toray Industries, Inc. in 1963, working in polymers research at Basic Research Laboratory. Since then, he has held several positions in research and water treatment technology within the company.

Dr. Kurihara is a member of numerous organizations, including the American Chemical Society, Japan Chemical Society, Japan Polymers Society and Japan Membrane Society. He is President of the Asia Pacific Desalination Association (APDA) and Vice President of the Japanese Desalination Association (JDA). He has received numerous awards in recognition of his work including a Lifetime Achievement Award from IDA, presented in 2011.

Mr. Shawn Meyer-Steele is founder and Managing Director of H2O PROFESSIONALS, a consulting group to equipment manufacturers, service providers, municipalities and end-users of water treatment equipment and services worldwide.

From Jan 2008 to June 2013 he was Sr. Vice President – Director of Business Development for Seven Seas Water Corporation, a leading service provider in the Americas of sustainable desalination and water reuse. From Jan 2003 through May 2007 he was Sr. Vice President of Marketing & Sales for Energy Recovery Inc., the world's leading energy recovery device manufacturer.

Mr. Meyer-Steele enjoyed a 12 year career at Ionics Incorporated (now part of GE) from 1990 to 2002, From 1998 to 2002 he was General Sales Manager for the Southern US and the Caribbean and Manager of International Operations from 1994 to1998. From 1990 to 1994 he enjoyed positions as Product Manager, Process Design and Development Engineer and in R&D.
Shawn has served on the board of directors of the International Desalination Association since 2011 and the Caribbean Desalination Association since 2009. He has also held chairs, served on panels, as well as written and presented numerous papers in other industry conferences as well as published in leading industry publications. Shawn has literally worked throughout the world and is conversant in Spanish, speaks some German, Dutch, Papiamento and Portuguese.

Shawn has a Bachelor of Science in Chemical Engineering from Northeastern University in Boston

Mr. Juan Miguel Pinto currently holds the position of Sales Manager, Desalination Americas for Energy Recovery Inc (ERI). He has been involved in the water industry for more than 10 years. He joined ERI on 2004 and he played key roles through various Departments such as R/D, Engineering, Project Management and Sales. He has authored and co-authored over 9 international publications.

Mr. Pinto serves on the Board of Directors of the International Desalination Association (IDA), as well as La Association Latino Americana de Desalacion y Reuso (ALADYR). Additionally, He served on the Board of Directors of the Caribbean Desalination Association (CARIBDA) on 2012.

Mr. Pinto received an Industrial Engineering Degree from Universidad Catolica Andres Bello in Caracas, Venezuela. He also received a Certification in Master in Business Administration (MBA) and Project Management from the University of California at Berkeley.

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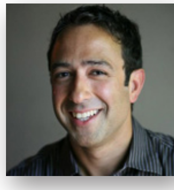

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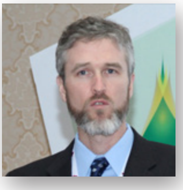

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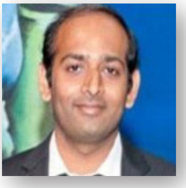

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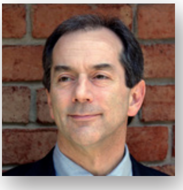

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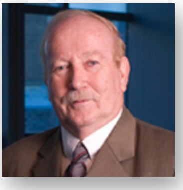

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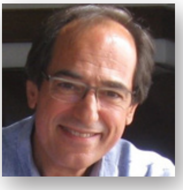

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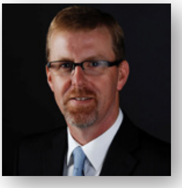

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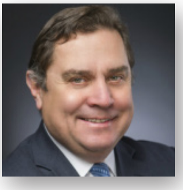

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APPENDIX



ABOUT IDA

The International Desalination Association (IDA) is the leading global organization dedicated to the advancement of desalination, desalination technology and water reuse. A non-profit organization and NGO of the United Nations, it is the global hub of expertise, news and information, and professional development for the worldwide desalination and water reuse industry. In addition to its industry-leading events held around the world and its comprehensive print, online and multimedia resources, IDA also provides educational opportunities and information about desalination and water reuse to a variety of constituents, from industry professionals in the public and private sectors to students and the general public.

IDA serves more than 2,600 members in 60 countries and reaches an additional 4,000 affiliate members that represent scientists, end-users, manufacturers and suppliers, engineers, consultants, developers, financiers and researchers, representing governments, corporations and academia. Its growing network of regional and association affiliates located around the world covers North America, Latin America and the Caribbean, the Middle East and Africa, Europe, Asia, the Pacific and Australia.



ENERGY & ENVIRONMENT CONNECTIONS

In 2016 IDA expanded its energy and environment initiatives by co-founding the Global Clean Desalination Water Alliance: "H_2O minus CO_2". Formed by the United Arab Emirates (UAE), France and IDA during the 2015 Paris Climate Conference, also called COP21, the Alliance brings together leading water desalination and clean energy stakeholders with the goal to reduce the CO_2 emissions of the world's water desalination operations. Organizations from 23 countries are members of the Alliance, including the USA, China, Japan and several European countries.

To limit and reduce CO_2 emissions from the currently-forecasted exponential increase in the production of desalinated water, the Alliance is developing an integrated strategy with the goals that at least 80% of new desalination plants and at least 10% of existing plants to be powered by clean energy by 2035. Given the average lifespan of desalination plants, achievement of the Alliance's goal will mean that, by 2035, the majority of desalination plants will produce minimal greenhouse gas emissions. The Alliance's strategic plan also aims to increase the energy efficiency of desalination processes, reinforce research, applied research and development capacities, promote innovative technologies to address environmental issues such as brine management, and analyze policies and regulatory frameworks.

IDA GOVERNANCE

IDA is governed by a 40-member Board of Directors. To assure that the global water reuse and desalination community is properly represented within the Association's leadership, 21 elected directorships are apportioned between the five regions (Europe, Latin America and the Caribbean, Middle East and Africa, North America, Pacific and Asia) in proportion to the number of Class I and Class II members in good standing in each region. The other eight voting Directors are appointed by IDA's Regional Affiliates. In addition, eight non-voting directors are appointed by IDA's Association Affiliates. Three other officers are also included in the 40 members of IDA's Board.

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IDA MEMBERSHIP BENEFITS

Categories

The IDA membership year runs from July 1 – June 30 and is not pro-rated. The membership categories are as follows:

Corporate Membership: IDA offers two categories of Corporate Membership, one for the corporations or utilities, and one for smaller companies with 10 employees or less, universities or NGOs.

Individual Membership: IDA offers two types of Individual Memberships, one for professionals covered under a corporate membership, and one for those who join IDA on their own.

Full-time students and individuals from least developed countries (LDCs).
Non-profit libraries (Class III-B).

Benefits

- Discounted registration rates for IDA events
- Eligibility for career development programs
- Access to Publications relevant to the industry
- Networking opportunities with industry experts
- Complimentary Conference Proceedings on IDA website
- Complimentary on-line Membership Directory
- Annual subscription to IDA Newsletter
- Access to Complimentary copy of the IDA Desalination Yearbook
- Eligible for education benefits such as Fellowship

For a more detailed listing of benefits and pricing visit: www.idadesal.org/membership.
General inquiries should be sent to: membership@idadesal.org.

IDA AFFILIATES

The Forum is supported by IDA's North American affiliate, the American Membrane Technology Association (AMTA), a leading advocate of membrane applications in the United States, Canada, Mexico and Central America for the creation of safe, affordable and reliable water supplies as well as the treatment of municipal, industrial, agricultural and waste water for beneficial use. AMTA is a strong voice for regulatory and legislative reforms essential to the understanding, acceptance and utilization of membrane processes. AMTA provides broad opportunities for the exchange of technical, operational and financial information among individuals and organizations interested in membrane technologies via its annual Conference, Technology Transfer workshops, Quarterly Newsletter, Tech Fact Sheets and website www.amtaorg.com.

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American Membrane Technology Association (AMTA)
Australian Water Association (AWA)
Caribbean Desalination Association (CaribDA)
European Desalination Society (EDS)
Japan Desalination Association (JDA)
Levant Desalination Association (LDA)
The Membrane Industry Association of China (MIAC)
Water Desalination Engineering Chapter (WDEC)

ASSOCIATION AFFILIATE MEMBERS

Asia Pacific Desalination Association (APDA)
Asociación Latinoamericana de Desalación y Reúso del Agua (ALADYR)
Indian Desalination Association (InDA)
Korea Desalination Plant Association (KDPA)
Pakistan Desalination Association (PakDA)
Singapore Water Association (SWA)
Water Science and Technology Association (WSTA)

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