Spurning the downturn: worldwide trends in desalination

Despite the decrease in growth in other areas, desalination has continued to develop with regards to energy savings and sustainable water management. **LIS STEDMAN** discusses the advances in desalination, and projects across the world that are using this technology.

One market that seems to be bucking the negative or stagnant trend of general construction is desalination. With demand sparked by drought and intriguing energy developments fuelled by soaring energy prices, desalination is still very much an area of constant development.

Atkins group desalination expert Ian Stout notes that even in the Middle East reverse osmosis (RO) is becoming increasingly popular: 'Historically, thermal distillation has been an extremely low tech, extremely green and viable technology.' The emergence of these technologies in the Middle East was predicated on sustainable and reliable energy sources, optimising the waste heat from the associated power plants to heat the water for the distillation process, he notes.

'The focus has moved away towards RO technologies because in the Middle East new areas are being developed that do not have large power plants, hence the heavy research and development to reduce the amount of power required, and under the green remit, the amount of carbon generated. These systems have historically been very energy intensive and quite expensive to operate,' he adds.

With developments such as the Masdar 'green' city in Abu Dhabi, the focus is 'to challenge the norm,' he says. 'It is a refreshing change,' he adds. 'When you look at the global energy crisis and the population crisis, we need to look at new technologies to produce water.'

Sustainable power

Those on offer include Reverse Electrodialysis (RED) and concentrated solar energy (see box). Atkins' Middle East offices are advising clients on how to maintain environmentally sustainable power sources, linking through its knowledge network with staff working on power generation. 'The best solution is not just a process unit, but will consider how to get power to it and reduce carbon consumption for clients,' Mr Stout says.

Mr Stout touches on 'seawater greenhouses', which couple low and high tech solutions. The Seawater Greenhouse uses seawater to cool and humidify the air ventilating it, and water is condensed from this water vapour. An early example of this technology in use is the Sahara Forest project, which combines the seawater greenhouse principle with concentrating solar power (CSP), which is seen as a promising form of renewable energy.

In an Australian project, a large bank of solar panels is being used to provide the energy for an RO system, and the salts produced are being sold. Atkins is also involved in the UK's Beckton project, Thames Water's first, ambitious desalination plant.

Strain on water reserves

CDM Vice President Ken Klinko envisages that the market for

T-Rack reference with 416 dizzer modules. Credit: inge watertechnologies AG

desalination will continue to grow 'as the planet gets more crowded'. 'It depends on how you define desal; many just think of ocean desalination but CDM and others consider it a term used with brackish water as well,' he adds. This is more common in the US than seawater desalination, although California, Texas and Florida are all looking at this more thoughtfully, he notes.

The key question is priority, Mr Klinko explains. 'Texas is a large state and right now is undergoing a drought. The question is will they start to look at it again if it starts to rain?' he adds. 'A lot of western states are driven by how thick the snowpack is and how much rain they get, and whether it can sustain them for the next year or more. The planning for desalination that is going on in water agencies is more or less emphasised depending on the depth of the snowpack in the Sierra Nevada and other demands and priorities. Many water agencies are constantly trying to balance their budget to get fiduciary responsibility. It is extremely difficult to talk about ocean desalination when you have got to fix the pipes.'

CDM has been involved in a project recently to create a reference plant for a small town in the Monterrey Bay area of California, where the sensitive ecosystem has placed stringent requirements on the plant's operation.

'Sand City is one of those desalination plants on the cusp between brackish and seawater,' Mr Klinko explains. 'Seawater is around 3.5% salt, and Sand City is between 1.7% and 2.8% salt by weight. They are treating water pumped out of the aquifer, which is close to the ocean. Monterrey Bay may have some influence on it and certainly there are times of the year when there's not a lot of replenishment from rainwater runoff and the salinity goes up, so the plant has to be able to desalt water of a wide range of salinity, from 17 to 28,000mg.'

In order to gain a permit the concentrated brine stream residual had to be diluted such that it matched the background salinity in the bay. The residual is then discharged under the bay and percolates up through the sand, further mitigating any impact. CDM designed the building and treatment facilities, and provided solutions to the challenges of meeting the regulatory discharge requirements and the variable feedwater salinity.

To achieve this the plant has been designed for low water recovery, he explains, for several reasons. 'It is economically beneficial – the lower the water recovery, the wider the range of feedwater the plant could accept and still produce a brine residual that met the permit requirements and would not have to be diluted. We thought this was a benefit to the environment and to the aquifer.'

Lower recovery also meant lower operating pressures, and lower energy costs. The permeate plant was also required to have energy recovery turbines, which recover more energy if more flow passes through them – another argument for the lower recovery system.

There are several more seawater desalination projects under consideration around the bay, with Californian American looking into one, and the Santa Cruz Water District and Sotel Creek Water District also involved, with CDM operating a pilot for these agencies in the University of California Santa Cruz. This pilot is studying many different types of pre-treatment and desalination options to determine the optimum configuration.

CDM is also involved with a significant number of aquifer replenishment and storage (ASR) projects, for instance for Orange County in California, which has a huge $3 million-plus system providing 75MGD of recharge. The company is involved in a similar project designing and engineering a recharge system in Miami-Dade county, Florida.

Environmental impact

Mr Klinko says there are a number of issues surrounding desalination, depending on the part of the world or even the region. 'In a coastal state like California there is always a public perception issue and the necessity to protect the coastal environment. Anything we do with a desalination project the developers, engineers and other stakeholders need to understand thoroughly and we need to explain thoroughly to the public the potential coastal and environmental impact. It is an issue. You can't just build a plant; you have to be aware of its impacts.'

California is on the leading edge of the move, he notes. In the Middle East too environmental issues have arisen, such as the potential impacts on coral reefs in the Gulf of Arabia. 'These, and various coastal aquatic zones, need to

Pretreatment advances

Inge's Executive Vice President, Business Development and Marketing, Bruno Steis, explains that the company supplies components for products based on its ultrafiltration (UF) technology, and that the specially-structured membranes resemble a honeycomb of seven capillaries in one fibre, rather than the standard one to one capillary to fibre ratio. 'Based on this structure, the membranes have very special mechanical strength and because of the materials, special chemical strength.' The resistance to breakage is unique, he claims.

UF is used for general water treatment and increasingly in tandem with RO as a pre-treatment system, Mr Steis says: 'The new technology is a combination of UF and RO. UF is a porous membrane, in which the size of the holes determines what passes through. You can hold back all larger particles and all kinds of bacteria and viruses. RO is a very sensitive membrane, and if you have too many bacteria they will simply eat it up. You need prefiltration technology to take out all the bacteria and viruses, then you can use the RO membrane much longer.'

Using a UF membrane as a pre-treatment system increases the life of the RO membrane, although as it is a porous membrane it cannot remove salts – that is still very much the preserve of the RO membrane. This is a distinct technological trend, Mr Steis notes.

UF is also used in water and wastewater treatment as well as industrial process water treatments. 'We think it is one of the key technologies for water treatment in future,' Mr Steis notes. UF's big advantage, which makes it an ideal partner for RO, is that it produces a consistent quality of permeate regardless of the condition of the feedwater. It is a combination of technologies that is being used in the new terminal of the Beijing airport.

The company is also involved in a large seawater desalination project in Abu Dhabi, producing boiler feedwater for a power plant. This has recently just gone into production. Another project in Italy is along similar lines.

RO is increasing its toehold in the Middle East, where traditionally thermal systems have reigned supreme, he notes. 'They needed to get used to the new technology – customers ask for references, and we are now in a position to provide references for all applications on a global basis.'

Mr Steis says that the economic downturn has not hit the sector in a dramatic fashion. 'We haven't seen projects where they have been in the bidding process and have fallen apart, though some have been delayed. We have already seen in the past that with bigger projects there is more delay. The impact is different in different regions – China is booming, and putting a lot of money into infrastructure.'

There is a larger impact in the EU, he notes. 'There are some delays, but not as much as in other industry segments.' Inge, a newcomer founded in 2000, is still on a steep growth path he says, and thus is weathering the storm. 'The global question mark is, is UF really the technology for the future? We believe it is, and a lot of market studies confirm this, though we cannot take this for granted.' Market studies, he notes, predict a growth in membrane technologies of 15% to 22% per year. 'We are a very fast-growing market. I think membrane technologies in general, RO and UF, will see these growth rates. It is a very good opportunity to grow our business.'

The Middle East Desalination Research Center

Shannon McCarthy, The Middle East Desalination Research Center's (MEDRC's) deputy centre director, explains that the non-profit research centre, established 12 years ago, has a large portfolio of multi-national research projects covering various desalination topics. 'One of the main areas is RO membrane technology and hybrid technology research, and renewable energy for smaller systems,' she explains.

There is also a focus on environmental issues such as brine disposal and material selection against such issues as corrosion. 'All technical topics of interest to the desalination industry,' she observes. The final reports are posted on the website, and there is now a portfolio of 78 projects, half of which have been completed.

MEDRC is funded by the governments that make up its executive board, and came out of the Middle East peace process. Its sponsors include Israel, Palestine and Jordan, Qatar, the US, Japan, Korea and The Netherlands. MEDRC puts in 50% of the funding for projects and its partners contribute the remainder.

At its inauguration, MEDRC undertook a survey of needs in desalination technology, and outlined ten main technical topics. Proposals are also accepted annually, and its advisors assess each one to ensure each project makes a real contribution to the development of desalination. Its Research Advisory Council consists of 21 experts from the industry and academia, as well as various ministries across the Middle East.

MEDRC also works with universities and government bodies across the Middle East-North Africa region, fostering training and capacity building programmes. Another current aim is to build a centre of excellence with the Palestinian Water Authority and help build a research programme looking at current and future needs in education and training.

MEDRC is also branching out into water reuse and practical projects to meet the immediate needs of countries where it has cooperation with the government bodies. Currently it is looking at the training needs for the Red Sea-Dead Sea project, which is still at the desktop stage, and the centre may be asked to coordinate the practical training of technicians, operators and plant managers if it goes ahead. The ambitious $5 billion water transfer project will involve construction of four major desalination plants. 'It would resolve all the water needs of the area,' Ms McCarthy explains.

be protected,' Mr Klinko notes. 'I don't think that there are major issues of impacts, they just need to be understood and explained to the public in outreach programmes.'

The main issue remains how to safely and effectively integrate a large-scale desal plant into the environment with minimal environmental impact. Another is the energy requirement. Membrane systems require a feed pressurised to above the osmotic pressure in the system in order to work. 'Membrane manufacturers have addressed the issue by designing more efficient, lower energy seawater membranes over the last decade, and the product offerings show they have been addressing the issue. The problem becomes one of pre-treatment, because desalination membranes stop everything in the feedwater, and builders of systems need to embrace more robust and effective pre-treatment that removes the fouling constituents to the degree needed to allow the membranes to operate at peak efficiency.'

The lack of pre-treatment means that the salt flux shown on the manufacturers' specifications is often greater than that achieved in reality. 'It is a matter of the economics at a local site. The stakeholders at plants have not accepted that pre-treatment costs money and that they have to spend a little more on pre-treatment and gain long-term benefits in operating costs.'

It is, he notes, the old capex versus opex conundrum. 'Most places clients are still requiring desalination plants on a hard bid construction basis, which means contractors are trying to provide them at a low cost. But there is a move afoot by some clients to work on a design-build basis where a best value balance between capex and long term operating costs is considered.' Mr Klinko believes that may be a trend for clients and stakeholders, to increasingly embrace a holistic approach in future.

Effect of the economic downturn

He says the economic crisis has 'slowed but not cancelled' projects. 'There is not a lot in the [US] stimulus package for desal in general but people are still thirsty. The economic slowdown has slowed the number of people moving from Michigan to Miami, so the utilities in Florida have perhaps not had to build additional capacity. In general you see clients studying and planning and being a little reflective about their water resources and how to husband them with the current situation. Plans for construction are still there, and while we may not see as many construction starts, it is a pause and not a complete cancellation of projects.' The company has clients that are moving forward 'really because they have to', he explains. 'There is a level of service that utilities must provide for water and wastewater, and they need to make progress towards providing it.'

Desal membrane modules. Credit: Brent Alspach

Brent Alspach, who leads Malcolm Pirnie's desalination knowledge team, says that the biggest project the company is participating in is in Florida, where a group of utilities on the north-east coast have commissioned a first phase study to look at a number of aspects including water quality specifications.

The Coquina Coast project will involve a number of studies in this initial phase, and the plant (if it goes ahead) will serve 11 parties. The company is working with Sinclair Knight Merz, the Australian desal experts, who are in the running to win the Melbourne desalination contract.

Malcolm Pirnie is also involved in a number of other, smaller projects in the US, notably in California. It has cone water quality studies for Poseidon relating to the Carlsbad plant, notably looking at corrosion control in the pipe loops, determining the effect of desalinated water on the condition of the pipes, and looking at control strategies to prevent corrosion. 'It's an important factor that doesn't get the attention it needs,' notes Mr Alspach.

Again, this system serves a number of clients, and this raises an important issue of water quality. 'It is necessary to make sure that the water coming out of the desal plant is compatible with the water in the networks it will go to,' Mr Alspach notes. 'It cannot be all things to all people. You have got to work out what each party needs to do to condition the water.' Each receiving party will have a different quality of water in their network, and as the desalination plant will produce only one type it is necessary for each of the clients to work out how this will blend with their own supply. There are various issues, such as stability of the water quality and corrosion, which water agencies are aware of and work to resolve.

The company is also working for the

Progress in desalination

Marc van Eekeren, Director Marketing and Business Development at Royal Haskoning, and Senior Desalination Expert Aleksandar Vlaski give their views on the rapidly progressing technology in the field of desalination. Pre-treatment is a key issue, Mr Vlaski notes. 'Efficient desalination involving Reverse Osmosis (RO) technology needs good pre-treatment – it is essential for cost-effectiveness and water quality. It is something the Gulf region discovered over the last ten years and is focusing on.' Ultrafiltration (UF) is an important new alternative pre-treatment, and is gradually replacing traditional rapid sand filtration,' he suggests. 'It is rapidly becoming state of the art in pre-treatment world-wide, especially in the Gulf region.'

'Nanofiltration (NF) is also being explored, particularly coupled with thermal desalination. NF membranes are being used to remove the scaling ions that can cause significant problems in thermal, as well as RO membrane processes,' Mr Vlaski says.

A remarkable potential of up to 40% increase in output has been reported in the Gulf with existing multistage flash evaporation (MSF) plants using these membranes for pre-treatment. In some cases this removes or reduces the need for installing additional desalination plant capacity.

In the Gulf, particularly over the last couple of years, significant problems have been experienced with algal blooms. Considering that safety of water supply remains the highest priority, ideas for the development of vast water storage reservoirs are emerging. In the event of a bloom there would be sufficient good quality water in storage that the plant can eventually shut off its sea intake. 'This means longer detention times in reservoirs, and an increased risk of microbiological pollution. For this reason disinfection (for instance, UV) is expected to be introduced in tandem to prevent any problems from bacteriological activity, which may provide a significant opportunity for manufacturers.'

Reduction of energy consumption has been a major issue in desalination in the past decade. In the past year, the high volatility and extreme fuel prices (which reached over $100 a barrel) has caused operators world-wide to cast around for further ways to optimise energy use. The application of modern turbine or pressure exchange energy recovery devices has become standard in desalination installations world-wide. Such devices enable considerable energy and operational costs savings. 'Without energy recovery the RO requires, in the Gulf, 7.5 kWh/m^3, which can be reduced to 5 kWh/m^3. Where the salinity is lower, e.g. in the Mediterranean and North Atlantic, a plant with energy recovery operates standardly at <4 KWh/m^3.' Mr van Eekeren adds: 'At Israel's massive Ashkelon plant, energy from the brine stream is being recovered on a large scale providing significant savings on operational costs.'

With energy recovery optimised, the focus is shifting to alternative and renewable energy sources. Mr Vlaski says: 'We have recently witnessed the emergence of ideas for coupling desalination facilities to concentrated solar power plants, which have already been promoted and built on a large scale in Spain and California.' Here specially constructed solar thermal collectors are used to generate thermal energy which is converted with steam turbines into electricity. Combined with thermal desalination, the overall thermal efficiency of the process could significantly be increased. Theoretically one square kilometre of land in an arid area could produce 250 GWh/year of electricity and 60 million m^3/year by combining these technologies.

In the Gulf, nuclear energy is also being considered as a power source in combination with desalination. Royal Haskoning partners with Dutch energy expert KEMA on studies and projects that deal with the interface between energy and desalination, Mr Vlaski explains.

Membrane technologies are also being deployed and investigated for the purpose of generating electricity, he notes, again with higher fuel prices as a driver. The so-called Blue Energy concept applies Reversed Electro Dialysis (RED) for generating electricity from waters of different salinities, such as abundantly available at estuaries of big rivers such as the River Rhine in the Netherlands. On average 13,000 m^3/sec of fresh Rhine River water mixes with saline North Sea seawater. 'Under such circumstances in principle a tremendous amount of potential energy is lost,' Mr van Eekeren explains. The RED process basically converts the potential energy existing between two water streams of different salinities into electricity, generated by ions separated through the application of dedicated electrodialysis membranes. This concept is currently at the research stage, with one of the major Dutch electricity companies, Eneco, a leading partner in the Blue Energy consortium in cooperation with technology institute Wetsus and Royal Haskoning involved with the design of a dedicated pilot plant.

Aquaflex Pilot Plant. Credit: Aquastill, The Netherlands

Another competing electricity generation technology is Pressure-Retarded RO, in which the energy potential existing between the two streams of differing salinity is converted into kinetic energy that drives turbines and generates electricity. The Netherlands is particularly involved in the development and investigation phase of both membrane related electricity generation technologies.

Brine management is another hot desalination topic. The zero liquid discharge concept is becoming increasingly attractive in this context, Mr van Eekeren says. Mr Vlaski explains that there are two approaches – the 'Dutch' approach aims to ease the burden on RO membranes through softening (calcium removal) and reduced fouling of UF membranes (by disabling the fouling interaction between natural organic matter and calcium), as well as reducing RO scaling and increasing the overall output of UF/RO plants. This process could further be supplemented by ion exchange which further decreases the ionic burden on the RO and theoretically enables very high recoveries (greater than 95%). The resulting by-product from the pellet softener could be used by industries such as glass manufacturing. These concepts are in a development phase and still have to be proven. However, they hold significant potential for the future, Mr Vlaski notes.

The other zero liquid discharge approach originates from industrial applications, and largely relies on crystallisation and evaporation technologies. Evaporative technologies can also be considered to dry out highly-concentrated brines into a salt crystals product. One example of a potentially interesting zero liquid discharge approach involves the combination of three proprietary technologies of Aquastill (high performance membrane distillation) of the Netherlands, and AquaTrate and AquaVap of AquaTec Inc., USA. The overall distillate water recovery of the combination of these processes surpasses 95%, with dry salts as product at the end of the process. 'It is interesting,' notes Mr Vlaski, 'that Aquastill's membrane modules are expected on the market by the end of this year.'

There are numerous other developments states Mr van Eekeren. PUB, in Singapore, has on trial an osmotic membrane bioreactor, a new technology involving Forward Osmosis that aims to reduce operational costs connected to water re-use by 20%. The country is working with Waternet, the water-cycle company of Amsterdam, and Dutch partners on developing this concept. AiRO is another concept under testing by the largest Dutch water company Vitens, aiming at improved (NF) membrane cleaning by means of air flushing. The same company has applied its own Optiflux RO membranes concept at several locations, enabling higher fluxes and more cost-efficient operation of its installations.

Other research has focused on charging the membrane – bacteria are negatively charged, so negatively charging the membrane should repel them and possibly limit biofouling. Anti-scalants are a key weapon against membranes' scaling, and it is being increasingly acknowledged that the brand and type is important. Mr van Eekern says: 'Any organic contaminants in the anti-scalant will concentrate on top of the membrane and cause biofouling. You need a very pure anti-scalant to avoid such problems.

'The desalination market remains extremely dynamic and productive. These new technological developments are bound to considerably improve the desalination arsenal and open new venues and possibilities for sustainable water supply and management,' concludes Mr Vlaski.

regional water overseer in the Monterrey area, where there are three competing potential desalination projects. 'They don't need three, and the regional water district commissioned a team to evaluate and determine the information gaps based on the literature. We are not there to say one is better than another, but to let the regional authority have more information to work with so it can see how viable each one is.' Malcolm Pirnie is examining the water quality aspects for this project.

Another small 2MGD plant is proposed in the Santa Cruz, California area, where two water districts are joining forces on the project. An expert from the University of California Santa Cruz is determining the economics of the sharing agreement, Mr Alspach notes, and Malcolm Pirnie is providing technical support. 'This is looking at how the operating costs will work if one party needs more water than the other,' he comments. 'It is necessary to ensure that the cost-sharing agreement is equitable.'

This trend towards several districts combining to make one plant viable 'makes sense', he adds. 'Not every water agency that needs water is located on the coast, or there may not be many suitable sites. It makes sense to have one facility of significant capacity to serve as many clients as possible.'

Other issues arise if the water is to be used for irrigation. 'Boron is not regulated, and an agency would want to publish its boron levels in its annual report so that customers will know and can plan accordingly,' Mr Alspach explains. Some plants are particularly sensitive to boron, so farmers must be aware of this if they receive a desalinated supply. Desalinated water is also extremely low in total dissolved solids (TDS), and thus is deficient in some minerals that are valuable to plants such as calcium, magnesium and sulphate. These issues are known and planned for, he adds – 'We are not having to reinvent the wheel.'

Again, he says that desalination is a growth industry, citing Australia's take-up of the technology. 'Ten years ago Australia was not thinking about desalination at all, and now it has two operating plants of significant capacity, one under construction and three more in planning. Over a very short period of time it has come a long way.'

The water situation in the US is not quite as acute in most areas, so water agencies are looking over the long term at areas where the population is likely to outstrip supply. Globally, Mr Alspach says, 'we are aware that the occurrence is on the rise.' Lifecycle costs are an important consideration, he notes, with power being up to half the operating costs of a plant. 'I think in the long run the cost of other potable supplies will go up enough to make seawater desalination, by comparison, economical,' he notes.

He adds: 'If you are in an area like California, with 20 million people and no other undeveloped sources, do the economics of desalination really matter?' There is a 'long way to go' in leveraging conservation, reuse and leakage reduction, he says, but ultimately 'there is only so much you can do. You will get to a point where, no matter what the cost, you have to have it.' ●

IWA membrane technology conference

This year's IWA Membrane Technology Conference will be held 1-3 September, 2009 in Beijing, China. **XIA HUANG** and **ROGER BEN AIM** outline the topics which will be covered in these discussions.

After Seoul (2004) and Harrogate (2007), Beijing will host the IWA Membrane Technology Conference (IWA-MTC) this coming September. After receiving more than 500 abstracts that were reviewed, we can see that a wide variety of membrane technology aspects and main features of membrane processes and applications will be presented from around the globe at this conference.

At a crucial moment for water management, this conference will bring all the membrane specialists together for discussion of what has been done and what needs to be done. The work and research of scientists and engineers that are making membrane technology more promising and more suitable for the sustainable management of water will be presented at this global event, highlighting major achievements and challenges in membrane technologies:

- How to decrease energy demand for desalination by reverse osmosis?
- What should we expect from forward osmosis today and tomorrow?
- Are there alternatives more sustainable than RO for desalination?
- How to combine the use of renewable energy and membrane technology?
- Can we optimize and upgrade low pressure membrane treatment, MF and UF to enhance removal of the microconsituents of concern for drinking water applications?
- Should membrane technologies allow removal of microconstituents at wastewater treatment plants?
- Are we going towards a standardization of low pressure membranes MF and UF similar to the standardization that already achieved for high pressure membranes, RO and NF?
- What is the right place for NF membranes?
- What are the first conclusions of the large research programmes concerning membrane bioreactor (MBR) and membrane desalination launched in Europe, Asia (Korea and Singapore) and other parts of the world?
- Based on life cycle analysis, can ceramic membranes be competitive with polymeric membranes?
- Can membrane technology become a low cost technology for developing countries?
- How can nanomaterials improve membrane processes and what should we expect in the short- and long-term?

These questions and many others will be discussed during the oral and poster sessions at the conference. Plenary and keynote speakers will provide main overview and introduction to the subject areas. A full programme will be available on the website of IWA-MTC soon: www.iwa-mtc2009.org

With good balance between papers coming from research labs and papers coming from engineering and operating companies such as membrane and membrane equipment manufacturers, Beijing will really be the place for experts from academia and industry interested in membrane science and technology to exchange information this September.

Despite the economic crisis, or even due to the economic crisis and the efforts made everywhere for boosting development of the green economy, membrane technologies still have a bright future.

Last but not least, IWA-MTC conference is a world event with the participation of more than 30 countries. Being organized in Beijing, it will bring opportunities to meet the Chinese membrane community which will be largely represented during this conference. As China is one of the largest membrane markets currently, attendance at this conference and exhibition provides opportunities to visit the exhibition, which will have several booths from Chinese companies providing first-hand experience.

On behalf of the membrane specialty group of IWA and the local organizing committee of the IWA-MTC, we cordially invite you to attend this event which is expected to be one of the largest 'membrane and water events' ever organised.