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H_2O Innovation and Nanostone Water set to jointly lead a larger commercialisation of ceramic membrane technology

Canada's H_2O Innovation Inc and US-based Nanostone Water Inc have signed a strategic agreement under which they aim to jointly lead a larger commercialisation of ceramic membrane technology.

H_2O Innovation which designs and provides custom-built and integrated water treatment systems based on membrane filtration technology – for municipal, industrial, energy and natural resources end-users – says that the arrangement with US manufacturer of ceramic ultrafiltration (UF) membranes strengthens its position as a ceramic membrane system integrator in the water sector.

The relationship between the two companies began in 2016 when Nanostone contracted H_2O Innovation to design and fabricate two pilot units. Their success prompted Nanostone to contract H_2O Innovation to upgrade its existing fleet of pilot units – especially the controls elements.

The Canadian firm used the Nanostone pilot systems in several project studies and was impressed with the technology's performance.

One study resulted in the purchase of a full-scale system for an application in the Midwest, where H_2O Innovation had previously installed polymeric UF membranes.

The companies have been independently engaged in a programme to retrofit existing polymeric microfiltration/UF membrane systems, for the last two years, and it has resulted in several successful contracts in Texas and the Dakotas (*Membrane Technology*, October 2018, pages 5–6).

'We are very excited to partner up with the Nanostone team. As an engineered product supplier primarily focused on membrane technology, it is important to constantly renew ourselves and use the best membrane for each application,' commented Frédéric Dugré, President and CEO, H_2O Innovation.

'Whilst we will continue to commercialise polymeric ultrafiltration, reverse osmosis and membrane bioreactors, ceramic ultrafiltration will enable us to address different market needs – it is basically another string to our bow.'

(Also see 'Ceramic ultrafiltration and cooling tower blowdown recovery', *Membrane Technology*, October 2015, pages 8–9).

For further information, visit:
www.h2oinnovation.com & www.nanostone.com

Lanxess reorganises its water treatment business to focus on ion-exchange resins

German speciality chemicals company Lanxess Deutschland GmbH is reorganising its water treatment technologies business to enable it to focus on ion-exchange resins and intends to grow primarily in markets for high-end applications.

As part of this realignment it reports that is selling its reverse osmosis (RO) membranes business to French sustainable resource management group SUEZ (*see page 2 of this issue*).

Commenting on the move, Matthias Zachert, Lanxess' chairman of the board of management, said: 'The membrane business no longer fits in with our strategic focus on speciality chemicals. We are convinced that under the SUEZ umbrella, the business has the necessary conditions to develop its full growth potential in the future.'

The membranes that play an important role in the treatment of brackish and sea

Continued on page 14...

Contents

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(The content of this newsletter is compiled from a variety of sources, including press releases.)

SUEZ buys Lanxess' RO membrane portfolio

France's SUEZ, which operates largely in the water treatment and waste management sectors, is acquiring Lanxess' RO membrane portfolio.

Lanxess Deutschland GmbH, a German speciality chemicals company is selling the membranes business as part of a realignment, which will enable it to focus on ion-exchange resins *(see page 1 of this issue)*. The deal is expected to be completed in the coming months, following consultation with the relevant workers' council.

The membrane business will become part SUEZ's Water Technologies & Solutions product portfolio. According to the French company, the acquisition falls in line with its strategy to grow and invest in the industrial water market. It will enable it to deploy complementary RO technology in adjacent and growing sectors, and to increase global production of membranes.

The agreement to purchase the Lanxess' RO product line includes the membranes, raw materials and production facility located in Bitterfeld, Germany, along with the expected transition of its channel distributors and production employees directly connected to the membrane line.

'As customers today expand their need for brackish water membranes, this RO product line enables us to quickly and effectively expand our product portfolio to meet that need,' commented Yuvbir Singh, CEO, Water Technologies & Solutions, SUEZ.

'The Lanxess RO membrane portfolio is complementary to our existing RO offering. We are very excited to bring this membrane technology to our customers and grow in new ways around the world.'

For further information, visit: www.suez.com, http://lpt.lanxess.com & http://lanxess.com

H_2O Innovation secures a further three new projects in North America

Canada's H_2O Innovation Inc, which designs and provides custom-built and integrated water treatment systems based on membrane filtration technology, has been awarded a further three new projects in North America totalling C$5.8 million.

These follow seven new projects in the same region totalling C$7.6 million recently secured by the company, as reported in *Membrane Technology*, July 2020 (pages 2–3).

In Texas, the City of Pearland has selected H_2O Innovation to supply a membrane filtration system for its new surface-water treatment plant. The company's FiberFlex™ membrane filtration system will have a net filtrate capacity of 38 611.1 m^3 (10.2 million gallons) of potable water a day by treating water from the American Canal fed from the Brazos River.

The firm has also been awarded a contract to design, build, deliver and commission a containerised reverse osmosis (RO) system as part of the City of Santa Monica's Sustainable Water Infrastructure Project (SWIP), in California.

The RO system will treat a combination of storm-water/urban runoff and brackish groundwater at the Santa Monica Urban Runoff Recycling Facility (SMURRF) to produce up to 1892.7 m^3 (0.5 million gallons) per day. The final product – as part of the city's SWIP – will be blended with other water for groundwater recharge and indirect potable reuse. This is the second project H_2O Innovation has signed with the city for its SWIP programme.

The third project is for the Ministry of Transportation of Quebec (MTQ), which is replacing infrastructure at an existing highway rest stop located in Lavaltrie.

A membrane bioreactor (MBR) will be installed in a new service building. It will meet Leadership in Energy and Environmental Design (LEED) requirements and, as a result, the MBR permeate will be recycled and used to flush toilets.

For further information, visit: www.h2oinnovation.com

Microdyn-Nadir launches new brand for hollow-fibre PVDF UF modules

Germany's Microdyn-Nadir GmbH, a supplier of membrane products, and the water treatment business unit of Mann+Hummel, has launched a new brand for its hollow-fibre polyvinylidene fluoride (PVDF) ultrafiltration (UF) product line.

Previously offered under OLTREcap, the newly branded Microdyn PureULTRA hollow-fibre UF products still focus on water treatment and pretreatment for reverse osmosis (RO) and nanofiltration (NF) as primary applications. The modules are used to treat surface and ground water, sea water and tertiary treated wastewater.

According to the company, PureULTRA UF modules can operate at a low pressure and optimum flux, which reduces operating costs for customers. Highly hydrophilic, modified PVDF hollow fibre offers high tensile strength and chemical tolerance, resulting in increased overall membrane service life, even after exposure to aggressive cleaning regimes, says the firm.

The modules are available in three configurations –with varying membrane area per model.

Towards the end of last year Microdyn-Nadir launched its newly-improved MICRODYN BIO-CEL® membrane bioreactor module (*Membrane Technology*, October 2019, page 2).

For further information, visit:
www.microdyn-nadir.com/microdyn-pureultra

De Nora forms specialised business dedicated to the marine sector

Industrie De Nora SpA, a provider of electrodes and coatings for electrochemical processes, has created a new legal entity in the USA to facilitate its global growth strategy within the maritime industry.

The established company, called De Nora Marine Technologies Llc, provides products and industry expertise to address growing calls for advanced water treatment technologies, in line with increasingly stringent environmental regulations.

De Nora says that it will use its new entity to deliver global business growth. This will be achieved through acquisitions and organically through sales of its Balpure ballast water treatment system (BWTS) and other soon-to-be launched advanced water treatment technologies.

De Nora Marine Technologies has its headquarters at De Nora's facility in Sugarland Texas, USA, and is headed up Matt Granitto, its general manager, with existing project teams and global operational bases continuing to operate under the new entity.

The formation of De Nora Marine Technologies comes at a critical time for the shipping industry where owners and operators face a plethora of important investment decisions regarding compliance with new environmental regulations, including the Ballast Water Management Convention (BWMC) and the International Convention for the Prevention of Pollution from Ships (MARPOL).

As demand for high-quality water treatment technologies grows exponentially, the new streamlined entity aims to offer customers products developed and managed by a team with an insight necessary to simplify the normally complex decisions associated with purchasing water treatment technology.

Earlier in 2020, De Nora, reported that had combined product management of its SORB™ inorganic contaminant removal technologies, including arsenic and nitrate removal, with its UAT™ membrane filtration technologies.

The company says that combining technologies under the same leadership reflects its commitment to addressing the rising concern of increasingly contaminated water sources in a way that best serves its customers with effective pretreatment to post-treatment technologies.

For further information, visit: www.denora.com

Test-kit simplifies water chemistry testing for cooling-water system health

In order to ensure the efficient and optimal performance of cooling-water systems, Ecolab Inc's business Nalco Water has introduced Rapid Bio Intelligence – a total aerobic bacteria test-kit that is designed to simplify water chemistry testing and compliance for cooling-water systems.

Ecolab Inc – a supplier of water, hygiene and energy technologies and services to the food, energy, healthcare, industrial and hospitality markets – says that maintaining efficient cooling water system performance is vital to protecting assets, complying with safety and environmental regulations and controlling operating costs.

Pedro Sancha, Senior Vice President and General Manager of Global Light Industries, Nalco Water, explained: 'If left untreated, populations of waterborne bacteria can double within cooling water systems in as little as 20 minutes.'

'Nalco Water's Rapid Bio Intelligence is a mobile app-driven test-kit to monitor cooling water quality with quick and reliable results. Operators can quickly implement or alter bacterial control strategies to help keep cooling-water systems operating safely and efficiently.'

Rapid Bio Intelligence delivers results in minutes, with no incubation required – compared with traditional field-based testing that can take 48 hours or more to yield results. Accurate results are obtained through the use of a smartphone, which helps to eliminate operator error.

The Rapid Bio Intelligence system consists of the three components described below.

- A test-kit that determines the total amount of bacteria present in a water sample in as little as 15 minutes (the Rapid Bio Intelligence test is not strain-specific and does not measure *Legionella* bacteria).
- The Nalco Water E-data mobile app, which quickly reads the test-kit result. The total bacteria amount is displayed in industry standard units: CFU/ml (colony forming units/millilitre).
- ECOLAB3D cloud-based digital platform which stores Rapid Bio Intelligence test results to trend performance over time.

For further information, visit:
www.ecolab.com/rapidbiointel

Packaged system delivers sterile, sustainable, high-quality water

Axium Process – a UK-based manufacturer of hygienic process systems, which specialises in cross-flow filtration and separation technology – has introduced a system for water purification applications.

Called "Good to Go", the packaged system delivers commercially sterile, sustainable, high-quality water, bypassing the need for ion-exchange beds and chemical treatment processes.

Based on reverse osmosis technology, it is used for applications where low conductivity (salt removed) water is required and can be used in conjunction with complementary processes such as carbon filtration and ultraviolet (UV) treatment – providing a robust and

versatile system that tackles almost every water purification application, says the company.

Delivered as a packaged unit, and requiring only minimal operator intervention and low maintenance, it is supplied with high-rejection low-energy membranes; stainless steel housings; pipework; cartridge filter; conductivity monitor; feed-pressure switches; variable-area flowmeters and an inverter-controlled pump.

For further information, visit: www.axiumprocess.com

Entegris acquires supplier of yield-enhancing analytical instruments

In the USA, Entegris Inc, which specialises in contamination control and materials-handling technologies for manufacturing environments, has acquired Global Measurement Technologies Inc (GMTI), a provider of analytical instruments for critical processes in semiconductor production, and its manufacturing partner Clean Room Plastics Inc.

Located in Chandler, Arizona, GMTI – which supplies yield-enhancing analytical instruments for chemical mechanical planarization (CMP) slurries – is now part of the Advanced Materials Handling (AMH) Division of Entegris.

The acquired company designs and produces high precision analytical instruments for CMP slurries and formulated cleaning chemistries used in the semiconductor manufacturing process. Its technology is designed to ensure precise consistency of complex blended chemistries to enable high yields in the CMP and formulated cleaning processes.

'The acquisition of GMTI enhances Entegris' position as the premier supplier for yield-enhancement systems and technologies for the semiconductor market. Greater materials intensity and greater materials purity will be the primary defining factors of the next generation of semiconductor performance,' said Bertrand Loy, President and CEO, Entegris.

Entegris recently bought Sinmat, a manufacturer of CMP slurries, in a move that expands its portfolio of speciality chemicals (*Membrane Technology*, March 2020, page 3).

For further information, visit: www.entegris.com & www.gmtechinc.com

Synder adds OptimaFlow series elements to its product range

Synder Filtration, which specialises in microfiltration (MF), ultrafiltration (UF) and nanofiltration (NF), recently introduced the OptimaFlow Series elements.

They are available for all existing UF and MF standard and MAX membrane types in the same common element sizes and models. Custom models are available upon request.

The firm, which is based in Vacaville, California, USA, says that multiple OptimaFlow trials have been conducted on milk and whey protein concentration applications throughout the dairy industry over the past year – yielding positive results. These products are now being used to replace standard sanitary elements at several dairy plant installations worldwide.

By working closely with vendors to improve current designs, the company says that it has managed to increase the effective membrane area by nearly 10%, compared with a standard 31-mil spacer element. This has been done through optimisation of element construction and material selection, which results in higher element throughput.

For further information, visit: https://synderfiltration.com

Xylem establishes UK OEM centre of excellence

Global water technology company Xylem Water Solutions has invested in an OEM European Centre of Excellence (CoE), based at its facility in Axminster, UK.

The firm says that this centre will focus on OEM innovation – expanding the group's current portfolio through a range of customised "plug and play" products.

At the centre a dedicated team of engineers will work on prototypes and, when approved, create and assemble full production models. Specialist facilities will ensure all OEM configured products are fully tested whilst qualified technical engineers will be dedicated to OEM quoting, and responsible for drawings, specifications, order entry and constructing bills of materials.

Paul Winnett, General Manager, OEM & Building Services, Xylem Water Solutions, explained: 'Our Axminster facility is committed to meeting customer demand and consistently delivers high quality, efficient products and best-in-class service.'

'Customers can make significant efficiency gains and cost savings by outsourcing their processes to Xylem – what could take 7–14 days in a factory, or at their own facilities, Xylem can now turn around and ship within 1–2 days.'

This is one of several investments Xylem is making in European centres of excellence focused on specific markets.

The company has also recently established a multidisciplinary centre for water, wastewater and energy technologies at its regional headquarters in Singapore (*Membrane Technology*, February 2020, page 2).

For further information, visit: www.xylem.com/en-uk

Surface-modification technologies protect metal filter elements

Porvair Filtration Group has developed a range of surface-modification technologies that can be applied to metallic filter elements.

They are designed to enhance material properties in challenging environments – improving filter performance and lifetime.

The specialist filtration and environmental technologies group says that the technology is ideal for use in refinery or chemical processes where hot or corrosive fluids would otherwise be detrimental to filter service life or integrity.

The technologies comprise:

- Porvair Sinterguard® PHC, which extends the service life of 316 stainless steel and exotic alloys in highly corrosive fluid environments; and
- Porvair Sinterguard® HTR, which extends the service life of 316L stainless steel and exotic alloys at elevated temperatures.

As reported recently, the firm has also released a range of resin bonded filters for applications involving aggressive chemicals (*Membrane Technology*, March 2020, page 2).

For further information, visit: www.porvair.com & www.porvairfiltration.com

Cryosectioning diagnosis and enzymatic cleaning of reverse osmosis membrane biofouling: Part I

Mohiuddin Md. Taimur Khan, Applied Energy Program, Los Alamos National Laboratory, Los Alamos, New Mexico, USA and Department of Civil and Environmental Engineering, Washington State University, Richland, Washington, USA; William Mickols, The Dow Chemical Co, FilmTec R&D, Edina, Minnesota, USA; Steffen Danielsen, Novozymes A/S, Bagsvaerd, Denmark; Keith Thomsen, Environmental Restoration Department, Lawrence Livermore National Laboratory, Livermore, California, USA; and Anne Camper, Center for Biofilm Engineering, Montana State University, Bozeman, Montana, USA

Biofouling of reverse osmosis membranes is one of the main reasons for the flux decline in water reuse applications in the filtration industry. A simple screening approach to evaluate such membranes for their propensity to biofouling and a means of removing biofoulants, without changing surface physicochemical properties, would be of benefit to this sector. The objectives of this research are to investigate the mode of action of *Subtilisin* protease- and lipase-based enzymatic cleaning of thin-film composite reverse osmosis membrane biofoulants, and characterise the effects of the biofilm-resistant membrane surfaces by using cryosectioning of the membrane with biofilm on its surface. The first instalment of this article, which appears here, provides an introduction to the research, the materials and methods used and the first part of the results, which discusses biofilm formation, and quantitative measurements and visualisation of biofoulants on reverse osmosis membranes. Part II will be published in the September 2020 issue of *Membrane Technology*.

Biofouling of reverse osmosis (RO) membranes is one of the main reasons for flux decline in water reuse applications in the filtration industry.

A simple screening approach, to evaluate RO membranes for their propensity to biofouling, would be a benefit to the industry. The application of environment-friendly enzymes to remove biofoulants from a thin-film composite (TFC) RO membrane without changing the RO membrane surface's physicochemical properties is a challenging and new concept. Furthermore, there should be a more reliable diagnosis tool, which can be used for investigating membrane surfaces subjected to biofoulants.

In this study, initial biochemical characterisation of biofilm formation potential and biofouling on commercially available polyamide aromatic thin-film RO membrane surfaces (BW30) from FilmTec Corp were investigated, without filtration, in a laboratory using rotating disc reactor systems.

At the end of the operation, the accumulated biofoulants on the TFC RO surfaces were treated with enzymes based on *Subtilisin* protease and lipase at neutral pH (~ 7) and doses of 50 ppm, 100 ppm and 150 ppm, with the contract times for 18 hours and 36 hours.

Membrane swatches were fixed on removable coupons and exposed to water with indigenous microorganisms supplemented with 1.5 mg/l organic carbon under continuous flow. After the biofilms formed, the membrane swatches were removed for analysis.

Live/dead staining, epifluorescence microscopy measurements, and 5-µm thickness cryosections of enzyme and physically treated biofouled membranes revealed that *Subtilisin* protease- and lipase-based enzymes at 100 ppm and 18 hours contact time were optimal for removing most of the cells and proteins from the RO surfaces.

Based on image analyses of 5-µm thick cryosections, the accumulation of hydrated biofoulants on the RO surfaces exceeded 0.74 µm/day. The morphology of the biofilm and the location of active and dead cell zones could be related to the membrane surface properties, and general biofouling accumulation was associated with changes in the surface chemistry of the membranes.

Biofouling phenomena

The decrease in performance of RO membranes in wastewater reuse and purification of sea/brackish water systems caused by biofouling is a major concern.[1–5]

The biofouling phenomena can have the following adverse effects on RO systems: membrane flux decline, increased differential pressure and feed pressure, membrane biodegradation, increased salt passage, substantial decrease in boron rejection and increased energy requirements.[5–9]

The long-term effect of flux decline on an RO membrane is primarily caused by combined deposition of feed-water components rejected by the membrane (sparingly soluble inorganic compounds, colloidal or particulate matter and dissolved organics) and/or the attachment and growth of microorganisms (biofilm formation) on the RO membrane surface.[10, 11]

The decline in membrane performance can be attributed to the increase in both the hydraulic resistance and the transmembrane osmotic pressure of the fouled membrane.[7] These phenomena may be because of the narrowing of the flow channels across the RO membrane surface caused by biofouling.[4, 12]

Cleaning

Biofouling is the one of the least understood and controlled fouling mechanisms and the multiplication of cells and simultaneous production of extracellular polymeric substances (EPS), inside the biofoulants on the membrane, causes a decline in the productivity.[13]

RO systems used for water and wastewater treatment are exposed to microorganisms and their byproducts, which cause this biofouling.[9, 14] Bacterial cell surfaces contain lipopolysaccharides (LPS) and EPS, which play a role in bacterial–surface interactions[15] and are potential players in membrane fouling.

Fouling requires frequent chemical cleaning, which ultimately shortens membrane service life, thus increasing the operation and maintenance costs of RO membrane plants. A decline in permeate flux can be directly related to an increase in operating costs and can trigger the need for periodic chemical cleaning, which requires additional workers and chemicals, and ultimately results in the premature replacement of the membrane.[9, 16]

Furthermore, biofouling can alter surface chemistries, narrowing the flow channels across the RO and nanofiltration (NF) surfaces.[4, 12] It is reasonable to assume that biofouling of the RO membranes is ubiquitous and it is important to deal with this process rather than expect that it can be prevented.

Many cleaning options are currently available to treat biofilm formation on affected membranes in an attempt to restore an acceptable level of permeate flux.

In laboratory-scale studies, the induction of an electrical field may be used to reduce the influence of a layer of polarised biofoulants,[17–21] and higher electric charge density may kill microorganisms, which also biodegrade several compounds in the system.[19, 21]

In addition, irradiation using ultraviolet (UV) light is also commonly used and has been studied using pilot-scale systems.[9, 22]

Physical cleaning methods are also available for the treatment of fouled membranes and include vibration, air sparge, hydraulic cleaning and back-permeation with carbon dioxide.[23]

Enzymatic cleaners

The use of enzymatic cleaners is of interest because they operate under mild conditions, which is a positive factor for their application to cleaning membranes that are sensitive to chemicals, pH and/or temperature.[24]

Enzymes are environment-friendly natural products that not only improve cleaning efficiency, but also reduce the amount of chemicals needed and energy costs.[25] Neutral pH enzyme-based cleaners have been marketed as an alternative method for cleaning RO/ultrafiltration (UF) systems.

EPS are major components of membrane bioreactor (MBR) biofoulants and enzymes have been investigated as a common cleaning agent to overcome EPS protein foulants.[26] It was assumed that enzymes cleave the proteins into pieces that are small enough to be rinsed from the system.[27] In several studies[25, 27, 28] enzymes were used to clean organic foulants from UF membranes used in the dairy industry.

Based on the above observations, we hypothesised that different natural polygalactouranases, and protease, lipase and dextranase-based enzymes would efficiently remove biofoulants from RO surfaces without altering the membrane surface properties.

Several biofilm assays and surface characterisation methods are available.[4, 5, 13, 29–33] The selection of the most suitable and optimum assay protocols is also a critical step during the membrane development process. We applied several methods to characterise the membrane surface before and after foulant formation, and also characterised the foulants.[4, 5, 34]

The cryosectioning assay of RO membranes with and without foulants after staining with fluorescent probe was first reported by Khan *et al.*,[5] and compared those assay data with other characterisation methods. It was categorically illustrated that the cryosectioning data corroborate other data.

The objectives of the research described in the article are to investigate the mode of action of *Subtilisin* protease- and lipase-based enzymatic cleaning of TFC RO membrane biofoulants, and characterise the effects of the biofilm-resistant TFC surfaces by using cryosectioning of the membrane with biofilm on its surface.

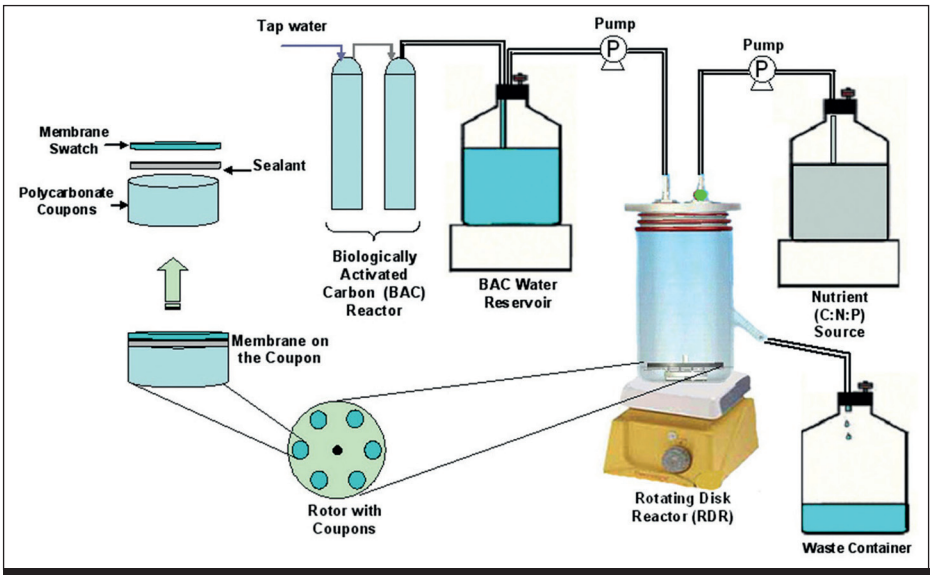

Figure 1. The schematic of the reactor set-up. The reverse osmosis (RO) swatches are attached to the polycarbonate coupons with silicon rubber sealant.[ ]

Materials and methods

Membrane type

In order to observe biofilm formation and its impact on RO membrane surfaces, commercially available polyamide aromatic TFC RO (Dow BW30) membranes (FilmTec Corp, Dow Chemical Co, USA) were examined.

Detailed information about the heterogeneity and chemistry of these surfaces and of the aromatic groups on RO surfaces is proprietary. There is an uneven distribution of microbiocide attached to the polyamide backbone of the RO surfaces.

General performances of these surfaces are that at 125 psi (0.86 MPa) applied pressure and 2000 ppm initial concentration of NaCl in deionised (DI) water, the membrane productivity and water permeability coefficient/%salt passage (A-value/%SP) ratio were 32 gfd (5.4 cm/h) and 0.16, respectively, for the RO membranes. The NaCl rejection was ~ 99.6% for RO surfaces.

Reactor set-up

The biofilm formation study was carried out in three rotating-disk reactor (RDR) systems (Biosurface Technologies Corp, USA). The reactor set-up is shown in **Figure 1**.

Each reactor contains six separate, removable polycarbonate coupons (12.7 mm in diameter). The RO membrane swatches were cut from flat-sheet rolls and boiled in nano-pure water for 10 min (according to the manufacturer's instructions, which removed the residual chemicals and any surface contamination and did not change the surface structure and chemistry of these membranes).

After being cooled to room temperature and prior to use, the membranes swatches were washed several times with nano-pure water. The membrane swatches were adhered to removable polycarbonate coupons with silicon rubber sealant (Dow Corning, USA) and placed in the rotor of the RDR.

The RDR has a variable speed rotating drum, an operating volume of 250 ml and a

high surface-area to volume ratio. The rotor disk has a diameter of 7.0 ± 0.2 cm and contains six evenly spaced holes, each of which has a diameter of 1.27 ± 0.1 cm. Six polycarbonate coupons can be placed into the holes. The centre of each hole is located 2.55 ± 0.03 cm from the centre of the disk. Further details about the RDR can be found elsewhere.[5]

Moreover, in these systems well-defined hydrodynamic conditions and retention time on biofilm can be maintained. The rotation speed of the rotor in the RDR is 50 rpm and the hydraulic retention time was 3.5 h. The temperature was ambient (25°C) and pH was 7.5 ± 0.5.

The reactors were fed continuously with Bozeman (Montana, USA) tap water. This was passed through a granular activated carbon (GAC) column and a biologically activated carbon (BAC) column operated in up-flow mode as a source of indigenous microorganisms. These columns remove the majority of the background carbon from the tap water.

To enhance the growth of the biofilm, the biologically treated water was amended with nutrients (C : N : P) (equimolar concentrations of glutamic acid, glucose, galactose and arabinose were used for the carbon source; whilst KNO_3 and K_2HPO_4 were used for the nitrogen and phosphorous source, respectively). These constituents (C, N and P) were added to the reactors at a 100 : 10 : 1 (molar ratio) basis. The operating conditions and analyses are shown in **Table 1**.

Each reactor was operated continuously for 28 days to ensure good biofilm growth. Colony forming units (CFU) in the BAC water were measured in triplicate using R2A agar (Fisher Scientific, Illinois, USA) incubated at room temperature for seven days.

After colonisation, the membranes were carefully removed from the coupons using a sterilised razor blade and hemostat without disturbing the biofilm. The RO and NF swatches, with biofoulants, were cut into pieces with sterilised scissors for the assays described in Table 1.

Operating conditions	Parameters and values
Period of run	28 days
Sampling frequency	Twice in 28 days
Average CFU/ml in biologically activated carbon (BAC) treated water	(1.41 ~ 2.01) × 10^4
Membrane assays	Images of live/dead cells and cryosectioning on day-8 and day-21
Nutrient condition (C : N : P)	1.5 mg/l of C : 0.18 mg/l of N : 0.04 mg/l of P
Flow rate of nutrient	42% of total influent flow-rate
Flow rate of BAC treated water	58% of total influent flow-rate

Table 1. Operating conditions of the rotating disc reactors and biofouling assays used in replicate experiments.

Visualisation and quantification of membrane biofoulants

The Live/Dead BacLight^{TM} bacterial viability kit for microscopy and quantitative assay (Invitrogen/Molecular Probes, Oregon, USA) was used for staining live and dead cells on the surface of the RO and NF membranes.

Equal amounts (1.5 µl/ml) of SYTO 9 (3.34 mM) and propidium iodide (20 mM) dyes were diluted in 1 ml of nano-pure water, and after proper dilution and vortexing, dyes were added to the top surface of the membrane and incubated for 1 hour in the dark.

After incubation the excess dye was carefully washed off with nano-pure water and the stained cells were observed under an epifluorescence microscope (Nikon, Eclipse E800, Japan) with a 100× objective.

Fifteen to twenty images of live and dead cells in the top layer of biofilm on the membrane surfaces were captured and analysed using MetaMorph software (Molecular Devices Corp, USA).

For cryosectioning, the RO and NF membrane swatches with biofoulants were stained without disturbing the biofilm using the same procedures described earlier. Detailed procedures are described elsewhere.[4, 30]

Briefly, a cryostat (Leica CM 1850, Germany) was used to cut sections with a thickness of 5.0 µm. The sectioned layer of the biofoulants and membranes was placed on a positively charged microscope slide (Fisher Scientific, Illinois, USA) and observed and imaged again using the epifluorescence microscope (Nikon, Eclipse E800, Japan), with a 20× objective.

The cryosections of stained biofilms on membranes were analysed with MetaMorph software to calculate the regions of live and dead cells and the thickness of accumulated biofoulants on the membrane surfaces. Each image has a distribution of live (green) and dead (red) cells along the thickness of biofilm on the membrane. A line scan was done, using the MetaMorph software, across the slices of membranes with biofoulants.

Each line-scan generated two profiles depending on the location of live and dead cells inside the biofilms. To calculate the thickness of live and dead cell regions, the width at the mid-height of each distribution was measured. Using the width at the mid-height of each profile, the software calculated the thickness of each profile in terms of live and dead cell regions. For each membrane swatch, 8–10 slices of membranes were imaged (three images per slice) and from each image, five different line-scans were generated for analysis.

Enzyme treatment

The stock enzyme is a mixture of *Subtilisin* protease and Lipase. The proteinase is from *Bacillus lentu* and the Lipase is from *Humicola lanuginosus*. The enzyme commission (EC) numbers are EC 3.4.21.62 and EC 3.1.1.3 for protease and Lipase, respectively.

This enzyme was developed and provided by the Novozymes A/S, Denmark, and diluted using autoclaved and then filtered (through 0.2 µm polyvinylidene fluoride disc filter, from Millipore, USA) nano-pure water at neutral pH, at room temperature, to final concentrations of 50 ppm, 100 ppm and 150 ppm. Detailed information about the composition, characteristics, biodegradability and chemistry of these enzymes is proprietary.

The RO membrane swatches were removed from the RDR after biofilm formation and soaked in diluted enzymes for either 18 hours or 36 hours, with the exception of the membrane on coupon #1 and #6 (positive controls). The swatches of the positive control membranes with biofoulant and those following cleaning of the biofoulants with nano-pure water and a sterilised soft rubber scrubber (VWR, Denver, USA) were used for other assays as discussed below.

In our previous study,[5] there was no change to surface morphology and chemical compositions during this physical cleaning procedure of virgin membranes. After incubation and cleaning with the enzymes, the membrane swatches were air dried for 1 hour without further cleaning prior to membrane assays parallel to the control membrane (swatches on coupon #1 and #6) and also virgin RO surface assays. During incubation of the membranes with the enzyme, ambient temperature and neutral pH were maintained.

Results and discussion

Biofilm formation, and quantitative measurements and visualisation of biofoulants on RO membranes

Distribution of live and dead cells on the RO surfaces — **Figure 2** shows representative

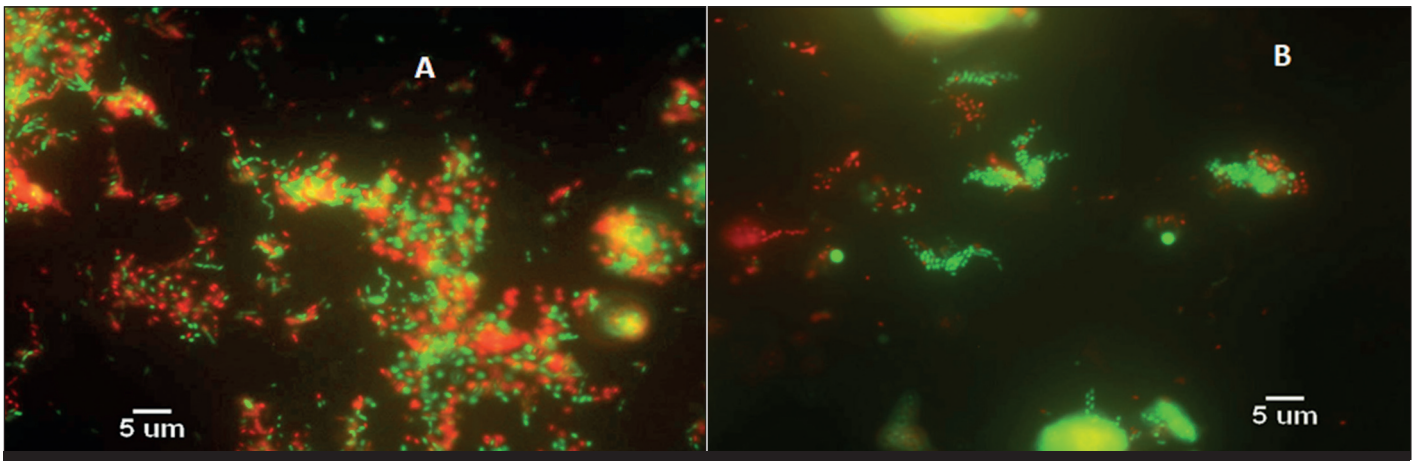

Figure 2. Images and distribution of live and dead cells on the surfaces of RO membrane swatches: (A) and (B) on day-8 and day-21, respectively, after staining using the Live/Dead BacLight™ Bacterial Viability Kit.

images of the orientation of live (green) and dead (red) cells on the top surface of biofoulants formed on RO surfaces.

The RO membranes had more organisms, and the relative numbers of live and dead cells were comparable (approximately 50% live and 50% dead cells). Cells mostly existed as clumps. This may be related to differences in the membrane surface chemical composition and characteristics. Furthermore, there were more dead cells on the RO surfaces, which means that the aromatic groups are more likely to disinfect the accumulated organisms.

As a point of comparison, Vrouwenvelder and van der Kooij[8] used acridine orange and epifluorescence microscopy to locate cells on RO biofoulants and found high concentrations of active biomass on the feed side of the membranes in 12 of 13 treatment plants investigated. In their studies, they attributed the biomass accumulation to biochemical properties of feed solutions and were not specifically related to membrane properties.

In addition to end-point sampling, a time series for biofilm formation was obtained. At the initial sampling time, there were more cells (**Figure 2A**) and the cell numbers decreased over time (**Figure 2B**). This suggests that the biofilms on the RO surfaces reached a pseudo-steady state through simultaneous attachment and detachment.

Recent controlled studies show that biofilm formation is a highly regulated process, with different genes of bacteria being expressed at different stages.[35, 36]

Depending on the nutrient concentrations above the membrane surfaces, chemotactic responses of planktonic cells are enhanced, which can increase biofilm formation.[37] However, the genes responsible for chemotaxis, motility and other physicochemical responses of bacteria depend on several parameters of external environment, which vary dynamically.[35, 38] These phenomena may have contributed to the development of the biofilm and the accumulations seen in Figure 2.

Previous work has also shown that under similar aquatic and biological environments, the biofoulant density depends on the membrane surface properties.[4] In this work, where RO membranes were used, it appears that membrane surface chemistry controls the biofoulant formation on these surfaces.

Quantification of biofoulant thickness and parameters — **Figure 3A** shows representative cryosectioned images of biofoulants on RO surfaces. The arrows indicate the position of membranes underneath the biofoulants.

Most of the cells nearest to the membrane surfaces were dead (red) and those near the top regions are mostly alive (green). It appears that the activities of aromatic groups on RO surfaces, respectively, were effective up to a certain thickness of biofilm for inactivating the cells inside the biofilm.

Clusters of cells (live and/or dead) with hollow pockets were observed (Figure 3A). The areas in the figure that are circled show the hollow pockets inside the biofoulant. This is indicative of spatial variation of the porosity inside the biofouling,[39] which is likely to be related to spatial distribution of diffusivity of the influent through the biofoulants and onto the membrane surfaces.

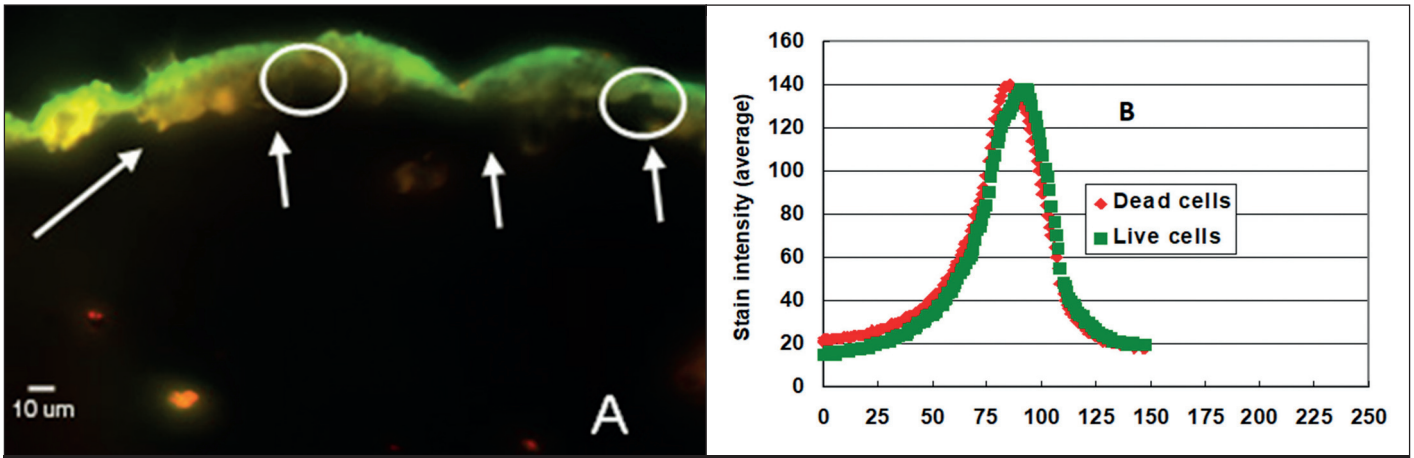

Figure 3. (A) The representative 5 µm cryosections of RO membranes with biofoulants after staining using the LIVE/DEAD BacLight™ Bacterial Viability Kit on day-28. The arrows indicate the position of membrane under the biofoulant and circles show the hollow pockets inside the biofoulant. (B) The profiles of live and dead cell regions in the biofilms on RO membranes after line-scanning the respective cryosections.

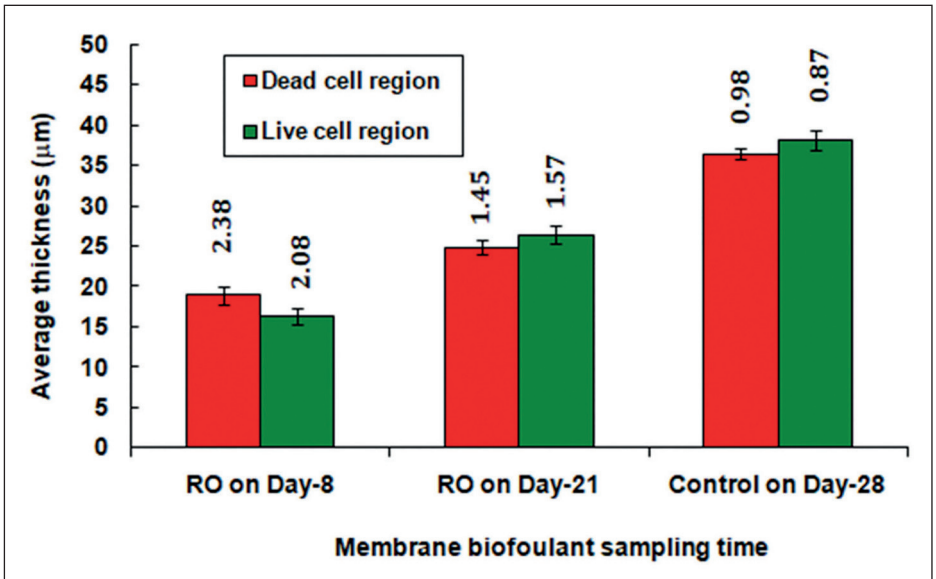

Figure 4. Average thickness of live and dead cells regions in the biofoulants on the surfaces of RO membranes on day-8 and day-21. Error bars show the ± *standard error of mean*, which varied from 0.61 μm to 1.35 μm. The values on the bar of each live and dead cell regions show the average accumulation rate (μm/day) of live and dead cell regions in the biofoulants on the membrane surfaces during the operational period in each phase.

Line scans of these images were used to provide information on the distribution of live and dead cells in the biofouling layer in terms of respective staining intensities, and representative images are shown in **Figure 3B**.

The skewness and intensity of distributions of the regions with live and dead cells depends on the number of cells along the section of biofilm. This distribution varies across the surface and probably depends on the surface morphology and properties of the membrane.[40]

The peaks of staining intensity (Figure 3B) for live cells on the RO surfaces were closer to the biofilm–fluid interface than that for dead cells. In other words, dead cells were in closer proximity to the membrane surfaces and the live cells were at the top of the biofilm. The peak staining intensities of the dead and live cell regions are separated by 2.4–5.5 μm for the RO surface.

The average thickness of live and dead cell regions in the hydrated biofoulants is shown in **Figure 4**. The accumulated thicknesses of live and dead cells are similar on each day, which is in good agreement with the images obtained using the microscope (Figure 2).

Time series analysis also illustrated that the biofouling layers on RO surfaces increased from 5–12 μm in two weeks (from initial sampling on day-8). The thickness did not continue to increase with a longer period of time, again suggesting that it reached a pseudo-steady state.

Parallel to the biofilm thickness, the membrane biofilm structure and activity are also important parameters[39] and with similar biofilm thickness on the polyamide aromatic RO surfaces, the porosity distributions may vary,[5] which will provide different diffusivities.

The observation of the changes in biofilm thickness with time could be related to both biological and physical parameters in the reactors. Studies by Kirisits and Parsek[41] and Yeon *et al.*[42] demonstrated that several disrupting quorum-sensing signals/molecules were responsible at different stages of biofilm formation. However, these studies are strain and media dependent and may not be appropriate for the mixed population biofilms used in this study.

It is important to note that based on the microscopic observations, higher cell densities were observed on day-8 (Figure 2A) than those at the end of experiment, on day-21 (Figure 2B). Observations of organisms on the top surface of biofilm obtained using microscopy do not allow for adequate description of the biofilm morphology on membrane surfaces.

In contrast, the cryosections of biofilm gave much more information about the morphology of the biofoulants and distributions of live and dead cells on RO surfaces. It must be noted that these observations are relative and only appropriate for the experimental conditions tested; other experimental conditions may give different results.

Second instalment

The second instalment of this article, which will be published in the September 2020 issue of *Membrane Technology*, will continue coverage of the results by looking at the mode of action of enzymatic cleaning of RO membrane biofoulants and will end with conclusions.

Acknowledgements

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RESEARCH TRENDS

Hydrogen selective palladium–alumina composite membranes prepared by ALD

Hydrogen gas is crucial for upcoming transportation technologies and is key for many chemical processes. Moreover, this gas is considered as one of the best clean energy carriers, which could help tackle the major environmental issues our society is facing. World-scale liquid hydrogen production units, dedicated to the hydrogen energy market, are now being built. These require a cost-effective and efficient means of separating hydrogen gas from other species. The principal route to producing pure hydrogen is based on membrane-based separation and purification technologies. The authors of this paper provide details of a novel strategy enabling the fabrication of hydrogen selective palladium–alumina (Pd/Al_2O_3) composite membranes using atomic layer deposition (ALD). The ALD of palladium was based on the reaction of palladium hexafluoroacetylacetonate $Pd(hfac)_2$ and formalin at 220°C, and allowed for the preparation of embedded Pd nanoclusters confined within the pores of a γ-Al_2O_3 membrane layer on a tubular ceramic support. Gas permeation and separation measurements of the prepared membranes were carried out and values above 1000 GPU were measured for the hydrogen flux. Promising permselectivities were obtained at a moderate temperature of 188°C ($\alpha^*_{H2/N2}$ ~ 23 and $\alpha^*_{H2/CO2}$ ~ 13) together with attractive separation factors of $F_{H2/N2}$ ~ 16 and $F_{H2/CO2}$ ~ 9. The results presented demonstrate the proof of concept for the fabrication of hydrogen selective Pd/Al_2O_3 composite membranes using ALD. Furthermore, this strategy could be extended to the design of other gas selective or catalytic membrane materials, composed of different metals and their alloys conformally deposited on tubular ceramic supports, with a high surface-to-volume ratio.

M. Weber, M. Drobek, B. Rebière, C. Charmette, J. Cartier, A. Julbe and M. Bechelany:
J. of Membrane Science,
Volume 596, 117701, (15 February 2020).
https://doi.org/10.1016/j.memsci.2019.117701

Evaluation of different cleaning strategies for different types of FO membrane fouling and scaling

In this study, various cleaning methods are investigated to effectively control membrane fouling (that is, organic fouling, colloidal fouling and scaling) in forward osmosis (FO). Simple physical cleanings (hydraulic flushing and osmotic back-washing) are firstly employed to remove membrane fouling. Both methods achieved higher than 95% efficiency and osmotic back-washing has a better efficiency for organic fouling and scaling in long-term operation, but colloidal fouling was not removed. To enhance the efficiency, intense physical cleanings (air scouring and the combination of various physical cleaning) and chemical cleanings (that is, ethylenediaminetetraacetic acid, low pH and high pH) were conducted, but could not remove the fouling layer possibly because of the polymerisation of silica colloids. Lastly, four hybrid mitigation methods – low pH draw solution, pulsed flow, high crossflow, and periodic sparging of CO_2 saturated solution – followed by hydraulic flushing were examined. The combination of CO_2 saturated solution and hydraulic flushing completely removed the fouling layer because CO_2 bubbles weakened the interaction between the fouling layer and the membrane surface. Periodic air scouring also exhibited similar effect on the fouling layer. Therefore, periodic air scouring has the potential to be a more feasible option to control silica colloidal fouling but not organic fouling.

Y. Kim, S. Li and N. Ghaffour:
J. of Membrane Science,
Volume 596, 117731, (15 February 2020).
https://doi.org/10.1016/j.memsci.2019.117731

High-flux thin-film nanocomposites with embedded boron nitride nanotubes for nanofiltration

In this research, boron nitride nanotubes (BNNTs) are investigated as nanomaterials for the fabrication of a thin-film nanocomposite (TFN) membrane. A novel TFN membrane was obtained by incorporating BNNTs into a polyamide thin, selective layer prepared via interfacial polymerisation. The addition of just 0.02 wt% of BNNTs led to a four-fold increase in pure water permeance, with no loss in rejection for divalent salts, methylene blue or humic acid, compared with the pure polyamide membrane. Loadings higher than 0.02 wt% of BNNTs led to agglomeration, with overall loss of performance. For the membranes containing 0.02 wt% BNNTs, pure water permeance was 4.5 LMH/bar, with > 90% rejection of $MgSO_4$ and > 80% rejection of $CaCl_2$. Fouling tests with humic acid showed a flux recovery ratio of > 95%, with ~50% lower flux loss during the fouling cycle, compared with the polyamide-only membrane. These values represent a significant improvement over both commercial polyamide membranes and TFN membranes incorporating carbon nanotubes. The authors assert that the very small quantity of BNNTs needed to produce the enhanced performance opens the way to their use in water treatment applications where nanofiltration membranes are subject to severe organic fouling.

S. Casanova, T.-Y. Liu, Y.-M. J. Chew, A. Livingston and D. Mattia:
J. of Membrane Science,
Volume 597, 117749, (1 March 2020).
https://doi.org/10.1016/j.memsci.2019.117749

Preparation of patterned membranes using casting knife construction techniques

Although membrane technology has matured, some processes would still benefit from increased membrane fluxes. In addition to improved material selection or preparation condition approaches, increasing the active area of a membrane through the use of patterned membranes offers another more generic approach. High fluxes and low fouling are practically highly desired in all membrane processes. One generic way to realise this is by introducing surface patterns on the membrane to increase the active area and the surface roughness. A new method of preparing flat-sheet patterned membranes using a patterned knife, combined with a modified phase inversion process, is discussed in this paper. After casting the polymer solution, the patterned knife shapes the top surface into the desired pattern. Non-solvent is sprayed immediately after the passage of the knife to rapidly solidify the polymer and preserve the pattern. To construct the patterned knife, different materials and techniques were evaluated: an aluminium knife shaped by electrical discharge micro-machining; a gypsum knife shaped by powder-based 3D-printing; and an acrylate resin, shaped by photo-polymerisation 3D-printing (stereolithography). As such, replacing the conventional non-solvent contact in the phase inversion via immersion by spraying, already increased membrane permeance, but a significant further increase of permeance resulted from the increased surface area realised through the patterning. The required viscosity of the casting solution to obtain good patterns was 7.5–10 Pa.s.

L. Marbelia, A. Ilyas, M. Dierick, J. Qian, C. Achille, R. Ameloot and I.F.J. Vankelecom:
J. of Membrane Science,
Volume 597, 117621 (1 March 2020).
https://doi.org/10.1016/j.memsci.2019.117621

PATENTS

Secondary battery separator with no substrate

Applicant: **LG Chem Ltd, Korea**
This invention relates to a secondary battery separator for ensuring the insulation between a cathode and an anode. The separator, which does not have a polyolefin substrate, is composed of a membrane structure comprising a fibrous support, inorganic particles and a binder. According to the inventors, it has improved dimensional stability.
Patent number: WO/2020/050559
Inventors: M.J. Kim, K.W. Nam, S.H. Lee and J.A. Lee
Publication date: 12 March 2020

Combinatorial membrane-based systems for use in dewatering and concentrating applications

Applicant: **J. Jani, India**
Various membrane-based processes and their combinations are described by this patent. For example, it covers forward osmosis, reverse osmosis, nanofiltration, ultrafiltration, membrane bioreactor units, osmotic distillation and membrane distillation. These technologies can be used for various applications, including dilution, concentration, dewatering, separation, purification, fractionation or extraction of different solvents. The patent says that they can be applied to various sources of water, wastewater, active pharmaceutical ingredients, food and beverage sources, and dairy products. They also can be used in industrial and domestic applications that involve recovering water from inlet sources.
Patent number: WO/2020/049579
Inventor: J. Jani
Publication date: 12 March 2020

System and method for producing pure water

Applicant: **Nomura Micro Science Co Ltd, Japan**
A system and method for pure-water production form the subject of this patent. They are capable of stably producing pure water for a long period, say the inventors. The pure-water production system described is based on a reverse osmosis (RO) membrane device, an ultraviolet oxidation unit, an electric deionisation component and a treated water pipe that sequentially connects these devices in the order in which they are listed. This system is characterised in that: the electric deionisation device comprises a cation exchange membrane and an anion exchange membrane, which are alternately arranged; a concentration chamber and a desalting chamber, which are alternately arranged between the cation exchange membrane and the anion exchange membrane; and a pair of electrode chambers which are arranged outside the cation exchange membrane and the anion exchange membrane. The pipe is connected to the electric deionisation device in such a manner that treated water from the ultraviolet oxidation device is supplied to at least the desalting chamber of the electric deionisation device. The pure-water production system is also provided with a first bypass pipe that supplies permeate from the membrane-based RO device to the electrode chambers of the electric deionisation device, without involving the intermediate ultraviolet oxidation unit.
Patent number: WO/2020/045061
Inventors: M. Iiyama and H. Kimoto
Publication date: 5 March 2020

High-recovery variable-volume RO membrane system

Applicants: **Veolia Water Solutions & Technologies Support, France; B.R. Mack, UK**; and **K. Rollings, USA**
A high-recovery, variable-volume reverse osmosis (RO) system is discussed by this patent. According to the abstract, the volume of concentrate cycled through the RO system is reduced in response to an increase in the recovery level. Reducing the volume of concentrate cycled through the RO system reduces the cycle time of highly saturated concentrate passing through the system. Furthermore, reducing the cycle time of concentrate passing through the RO system tends to minimise or reduce membrane scaling.
Patent number: WO/2020/046569
Inventors: B.R. Mack and K. Rollings
Publication date: 5 March 2020

Gas separation system

Applicant: **Hitachi Zosen Corp, Japan**
This patent provides details of a gas separation system that maintains low, compressor-power consumption, whilst keeping the amount of return gas to a minimum and separating the gas mixture at a high level of purification. The system described has first and second separation membrane modules. The latter is connected to the first separation membrane module. Non-permeable gas from the first module serves as supply gas. A third separation membrane module is connected to the first module, with permeable gas from the first module serving as supply gas. Piping connects a compressor to the supply opening for the first separation membrane module. Permeable gas from the second separation membrane module is supplied to the third separation membrane module, and the non-permeable gas from the third separation membrane module is pressurised to a designated pressure by the compressor, and serves as supply gas for the first separation membrane module. The separation coefficient for the separation membrane is equal to or greater than the minimum separation coefficient necessary to satisfy the required degree of purification for the gas that is to be processed.
Patent number: WO/2020/044992
Inventors: M. Itakura, Y. Asari and M. Okada
Publication date: 5 March 2020

Antifouling agent for separation membranes

Applicant: **Kurita Water Industries Ltd, Japan**
This invention concerns an antifouling agent for use with separation membranes. It is capable of effectively preventing fouling of an ultrafiltration (UF) film (or microfiltration (MF) film) that is used for membrane-based separation treatment of water. The water that is to be treated contains polyvalent metal ions and a corrosive substance. The antifouling agent for the UF (or MF) films contains a phosphonic acid compound. An antifouling method is described, in which the phosphonic acid compound is added to the water that is to be subjected to membrane-based separation treatment (using UF or MF processes).
Patent number: WO/2020/045004
Inventors: T. Shigeno and T. Shigeno
Publication date: 5 March 2020

Treatment apparatus for separating charged compositions from a water stream

Applicant: **University of Vermont and State Agricultural College, USA**
A method and apparatus for use in a water treatment system designed to separate charged compositions from a water stream are detailed by this patent. An electric filtration cell is described that includes a fluid passageway, and a filtration membrane and first and second electrodes, configured to provide an oscillating electric field across the filtration membrane in order to separate charged compositions on a first side of the membrane. The water treatment system is used to separate charged compositions from the water stream. It includes a

device that generates an electromagnetic field within the passageway. In one embodiment, the system is configured to separate struvite and/or vivianite on the first side of the membrane. In another embodiment, it is configured to separate salt on a first side of the membrane.
Patent number: WO/2020/051403
Inventors: A.R. Badireddy and Y. Shen
Publication date: 12 March 2020

Ultrafiltration membranes for dairy protein separation

Applicant: **Campbell Membrane Techologies Inc, USA**
Uncharged ultrafiltration (UF) membranes are traditionally used to concentrate dairy proteins. In order to prevent loss of protein, membranes that have a small pore size are often selected. However, these membranes have low flow-rates per unit area (low flux). Conversely, membranes with larger pore sizes can operate at a higher flux, but at the expense of higher losses of protein. This means that there remains a need for filtration membranes for the concentration of dairy proteins that possess a high flux and low losses. This disclosure is concerned with negatively charged filtration membranes and methods of making and using them – for example, in the concentration and/or filtration of dairy products.
Patent number: WO/2020/051229
Inventor: J.E. Tomaschke
Publication date: 12 March 2020

Lithium-ion permselective membrane and recovery device

Applicant: **Fujifilm Corp, Japan**
This patent provides details of a lithium-ion permselective membrane that has excellent membrane formability and Li^+ (lithium ion) selectivity; a lithium-ion recovery device and a lithium-containing compound-recovery device having excellent Li^+ selectivity; and a lithium-ion recovery method. The lithium-ion permselective membrane contains a lithium-ion conductor and a specific polymer with an anionic group.
Patent number: WO/2020/049884
Inventor: Y. Iizuka
Publication date: 12 March 2020

PET ultrafiltration membrane and method for producing it

Applicant: **Toray Advanced Materials Korea Inc, Korea**
This invention relates to a polyethylene terephthalate (PET) ultrafiltration (UF) membrane and a method for producing it. According to the inventors, the PET UF membrane exhibits hydrophilic properties, which means that it possesses excellent fouling resistance to hydrophobic organic substances. In addition, it also has a pore structure with favourable water permeation, and excellent mechanical strength and water permeability.
Patent number: WO/2020/050617
Inventors: J.W. Lim and S.P. Hong
Publication date: 12 March 2020

Bio-electrochemical reactor

Applicants: **Suez Groupe; Institut National de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture (IRSTEA); Centre National de la Recherche Scientifique; Institut National Polytechnique de Toulouse**; and **Institut National de la Recherche Agronomique (INRA) – France**
A bio-electrochemical reactor is discussed by this patent. It comprises an anode chamber, with at least two bio-anodes, and an anodic electrolyte comprising anodic electroactive microorganisms. The structure also incorporates a cathode chamber with at least one bio-cathode and a cathodic electrolyte comprising cathodic electroactive microorganisms. The anode chamber is separated from the cathode chamber by – running from the anode chamber to the cathode chamber – a cation exchange membrane and an anion exchange membrane. These membranes are separated from each other by an inter-membrane chamber. The reactor also includes a means for applying a potential difference between the interconnected bio-anodes and the bio-cathode(s). The bio-anodes and bio-cathode(s) have active surfaces such that the total active surface of the bio-cathode(s) is greater than the total active surface of the two bio-anodes. This invention also relates to a method for regenerating the activity of the bio-anodes of the reactor and to the use of the reactor for the electrosynthesis of organic acids and/or alcohols from organic waste.
Patent number: WO/2020/053529
Inventors: A. Bergel, N. Bernet, E. Blanchet, T. Bouchez, B. Erable, L. Etcheverry, A. Huyard, E. Le Quemener, P. Mauricrace, S. Moreau, J. Tian and E. Trably
Publication date: 19 March 2020

Polybenzimidazole membranes for redox flow batteries

Applicant: **University of South Carolina, USA**
Increasing demands on the energy sector have created a new need for large-scale energy storage devices. According to this patent, as yet, redox flow batteries have an unmet potential to efficiently store large amounts of energy and meet related cost requirements. What is required is an ion-exchange membrane for a redox flow battery that exhibits high ionic conductivity and can operate under high current loads whilst also being highly stable and durable in challenging environments. This patent discusses redox flow battery membranes, redox flow batteries incorporating these membranes and methods of forming the membranes.
The membranes include a polybenzimidazole (PBI) gel membrane – which is capable of incorporating a high liquid content, without loss of structure – that is formed according to a process that includes *in situ* hydrolysis of a polyphosphoric acid solvent. The membranes are imbibed with an electrolyte (redox flow battery supporting) such as sulphuric acid and can operate at high ionic conductivities of about 100 mS/cm or greater. In addition, redox flow batteries incorporating the PBI-based membranes can operate at high current densities of about 100 mA/cm^2 or greater.
Patent number: WO/2020/056275
Inventors: B.C. Benicewicz, L. Wang, F. Huang, A.T. Pingitore and L. Murdock
Publication date: 19 March 2020

These patent summaries are based on materials from the World Intellectual Property Organization's Patentscope database https://patentscope.wipo.int.

EVENTS CALENDAR

5–9 October 2020
WEFTEC 2020 (93rd Annual Technical Exhibition & Conference)
(virtual format)
Contact: Water Environment Federation (WEF), 601 Wythe Street, Alexandria VA 22314, USA
Tel: +1 571 830 1545, Fax: +1 703 684 2492
www.weftec.org

4–5 November 2020
The Water Show Africa 2020
Johannesburg, South Africa
Contact: Terrapinn Holdings Ltd, Wren House, 43 Hatton Garden, London EC1N 8EL, UK
Tel: +44 20 7608 7030; Fax: +44 20 7608 7040
www.terrapinn.com/exhibition/water-africa/Conference.stm

8–11 November 2020
MELPRO 2020
Prague, Czech Republic
Contact: Česká Membránová Platforma z.s. (CZEMP), Mánesova 1580, 470 01 Česká Lípa, Czech Republic
Tel: +420 724 865 177
Email: conference@czemp.cz
www.melpro.cz
www.czemp.cz

30 November to 2 December 2020
Oman Energy & Water Conference & Exhibition 2020
Muscat, Oman
Contact: Oman Energy & Water Exhibition & Conference 2020, 1st Floor, SABCO Building, Wattayah, Muscat, Sultanate of Oman
Tel: +968 2466 0124, Fax: +968 2466 0125/126
Email: info@omanexpo.com
www.energyandwateroman.com

6–11 December 2020
International Congress on Membranes & Membrane Processes (ICOM 2020)
London, UK
Contact: Elsevier Conferences, Elsevier Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK
Tel: +44 1865 843000, Fax: +44 1865 843010
or
Janet Seabrook
Tel: +44 1392 285868
Email: JM.Seabrook@elsevier.com
www.icom2020.co.uk

10–12 December 2020
International Conference on 'Sustainable Technologies in Water Treatment and Desalination' (STWTD – 2020)
Kerala, India
Contact: The Convener, STWTD 2020, Department of Chemical Engineering, National Institute of Technology, Calicut, Kerala, India 673601
Tel: +91 495 228 5466,
Fax: +91 495 228 5463
Email: desal@nitc.ac.in
http://stwtd2020.nitc.ac.in

16–18 May 2021
Global Water Summit 2020
Madrid, Spain
Contact: Roxy Ali, Global Water Intelligence, Media Analytics Ltd, Suite C, Kingsmead House, Oxpens Road, Oxford OX1 1XX, UK
Tel: +44 1865 204208
Email: roxy.ali@globalwaterintel.com
www.watermeetsmoney.com

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water are manufactured by Lanxess at its site in Bitterfeld, Germany. SUEZ will take over this plant and the research facilities with all employees.

Lanxess says that it is further expanding its ion-exchange resins business and plans to build a new production facility in the coming years at a cost of between €80 million and €120 million. The new facility, which is scheduled to be completed within five years, will have a production capacity of between 20 000 m^3 and 30 000 m^3.

The company currently manufactures ion-exchange resins at its sites in Leverkusen and Bitterfeld, in Germany, and Jhagadia, India. It says that it is in the process of deciding on the location for the new facility.

'We invest in additional capacities for ion-exchange resins in order to be able to meet the growing global demand. At the same time, we want to grow especially in promising market segments,' continued Zachert.

Bettina Blottko, who is the head of Lanxess' Liquid Purification Technologies business unit, added: 'With our applications for water filter cartridges, we are already one of the leading manufacturers.'

'We are now additionally focusing on highly specialised applications that are characterised by high demand and strong growth – for example, in the field of biotechnology, the semiconductor industry or in the selective removal of metals, such as for the battery industry. With our technological diversity, we are ideally positioned for this.'

For further information, visit: http://lpt.lanxess.com, http://lanxess.com & www.suez.com

Strategic partnership aims to solidify IDE Technologies' strong presence in India

Desalination and water treatment systems company IDE Technologies has formed a partnership with India's Chem Process Systems Private Ltd, which specialises in heat-transfer, evaporation and crystallisation systems.

The partnership will be highly beneficial say the companies because IDE Technologies' wide array of low-to-medium salinity desalination and water treatment systems will be complemented by Chem Process' crystallisers – providing customers with end-to-end zero liquid discharge (ZLD) technologies.

In addition, Chem Process will be able to use IDE Technologies' centrifugal compressors in its evaporators, which have already been serving the water treatment industry for over five decades, expanding Chem Process' portfolio for IWT and the small-to-medium size thermal sea-water desalination market.

IDE Technologies says that combining its membrane and thermal technologies with Chem Process' wide portfolio of evaporators and crystallisers will address the full water-treatment needs of all industrial clients that require MLD treatment or up to ZLD water treatment – in a competitive and creative manner.

'This highly strategic partnership will solidify IDE's already strong presence in India, enabling the company to continue to actively expand its activities in the Indian market, and nurture our strong and fruitful collaborations with local businesses, partners and communities, explained Michael Tramer, VP Sales & Marketing, IDE Technologies.

'We are keen to address the growing water challenges in India, and are committed to enabling the Indian industries to comply with increasingly stringent environmental regulations, whilst enabling the local governments to meet their water demand in full.'

For further information, visit: www.ide-tech.com & www.chemprosys.com