RESEARCH PROJECT PORTFOLIO

The National Centre of Excellence in Desalination Australia holds a diverse portfolio of 33 research projects, spanning five research themes aligned with the *Australian Desalination Research Roadmap*. These research themes comprise: pre-treatment, reverse osmosis desalting, novel desalting, concentrate management, and social, environmental and economic issues.

The Centre has completed three competitive funding rounds open to 14 Participating Organisations, and its investment of $9.5 million will generate a total of $21.7 million in research activity with the support of 49 industry partners. Projects are selected by a Research Advisory Committee and investment is approved by the Centre Board. The Centre's research activity is funded under the Australian Government's Water for the Future initiative.

National Centre of Excellence in Desalination AUSTRALIA

Murdoch University
Dixon Road, Rockingham
Western Australia 6168
Email: info@desalination.edu.au
Telephone: +61 8 9360 7835
www.desalination.edu.au

Supported by:
Australian Government
Water for the Future

Pre-treatment

Modelling, monitoring and control of RO biofouling

Dr Ralf Cord-Ruwisch, ***Murdoch University***

with Nanyang Technological University, AquaMem Scientific Consultants, Valoriza and University of Alicante

Biofouling of RO membranes contributes to the costs of the process because of the need for regular membrane replacement. Biofouling is a complex process that involves binding of the membrane by bacterial biofilms feeding on organic contaminants in the feedwater and associated precipitation of organic macromolecules (e.g. biopolymers). This project aims to develop an online biosensor for monitoring of biodegradable contaminants and possibly biopolymers, and a concept computer-controlled biofilm reactor based on the above biosensor that can be used as an RO pretreatment for the removal of organic contaminants, limiting membrane fouling caused by biofilms and possibly also organic colloids.

Assessing the biofouling role of microbes in the desalination system; from the intake pipe to the RO membranes

Dr Sophie Leterme, ***Flinders University***

with SA Water and Singapore Membrane Technology Center

This project combines ecological, genomics, molecular and chemical expertise to assess the role played by microbial communities in biofouling Seawater Reverse Osmosis (SWRO) desalination plants. Our project aims to identify whether the extracellular polymeric substances (EPS) produced/organic matter contained in microbes are the main source of biofouling in pretreatment and membrane systems. A model of the desalination operating system will developed in the laboratory to identify which microbes can survive under various operating conditions ie chlorination, flow rates and acid treatment and whether they secrete EPS that then becomes a food source for the microbial communities. A comprehensive tool for biofouling assessment and risk-management will also be developed.

Evaluation of non-chemical pulsed power technology as an antifouling pre-treatment for RO desalination membranes

Prof. Stephen Gray, ***Victoria University***

with AquaMem Scientific Consultants and SA Water

The project will determine the efficacy of a non-chemical approach for prevention of bio-fouling. The proposed process is based on an alternating or pulsed electromagnetic field (EMF) that has been commercially demonstrated to be effective in industrial cooling systems for impeding (or reversing) biofouling and inhibiting scale formation. Laboratory based trials will be used to investigate the effect of the Dolphin pulsed EMF technology on biofilm growth and development, and on microbial populations in seawater.

Optimising low-pressure membrane pretreatment for desalination

Dr Pierre Le-Clech, ***The University of New South Wales***

with Curtin University, Siemens, Veolia and Water Corporation

Low-pressure porous membranes are increasingly considered for pre-treatment of sea and brackish waters. However, membrane fouling remains a major drawback, as it results in high operating, maintenance and cleaning costs. This project aims to better understand and to optimise the strategies currently used for fouling control. The relative efficiencies of both physical and maintenance chemical cleanings will be assessed on lab and pilot scales. The organic and inorganic natures of the irreversible fouling formed during long-term filtrations (and repeated cleanings) will be characterised in detail, allowing recommendations for sustainable operation and performance.

Membrane adsorption bioreactor hybrid system as a pre-treatment to RO desalination

Prof. S. (Vigi) Vigneswaran, ***University of Technology, Sydney***

with Gwangju Institute of Science and Technology, King Abdullah University of Science and Technology, Singapore Membrane Technology Center and The University of New South Wales

In this study, we will design an environmentally friendly, costeffective, pre-treatment process and membrane adsorption bioreactor hybrid system, through a detailed fundamental study, followed by semi-pilot studies in Sydney, and pilot scale studies in Korea and at the Rockingham Desalination Research Facility. We will optimise its design in terms of reduction of organic fouling and bio-fouling. This pre-treatment will be a sustainable alternative to chemically-intensive seawater reverse osmosis (SWRO) pre-treatment in removing particulate, microbial and organic micro-pollutants. It will be robust, eliminate the use of chemicals and will require little maintenance and energy. It will produce a biostable (low biofouling potential) reverse osmosis feed, applicable to both urban and remote coastal seawater desalination systems. It will be able to be retro-fitted into existing plants to reduce the carbon footprint.

The optimisation and improvement of direct filtration pre-treatment to reduce both organic and bio-fouling of RO membranes

Prof. S. (Vigi) Vigneswaran, ***University of Technology, Sydney***

with ProAlliance, Curtin University, Gwangju Institute of Science and Technology, Singapore Membrane Technology Center, King Abdullah University of Science and Technology and The University of New South Wales

The pre-treatment direct filtration system feeding the reverse osmosis (RO) unit is used for colloidal fouling reduction and is not efficient in controlling bio-fouling. A number of desalination plants face the problem of bio-fouling of both the cartridge filter and reverse osmosis membranes downstream of the direct filtration system. Traditionally ferric salts have been used as in-line flocculents in deep-bed filtration to remove solids, colloids and dissolved organics present in seawater. We aim to optimise the filtration and flocculation parameters to reduce both organic-fouling and bio-fouling on the RO membranes; identify techniques for evaluating bio- and organic fouling and develop appropriate solutions for direct filtration used as a pre-treatment in order to reduce fouling of RO membranes; and understand the fouling mechanisms on the RO membrane through water and foulant analysis and autopsy of membranes.

Non-brittle ceramic hollow fibre membranes

Prof. Huanting Wang, ***Monash University***

with The University of Queensland

This project aims to develop non-brittle ceramic hollow fibre membranes for pre-treatment of seawater in seawater desalination processes. Existing ceramic hollow fibre membranes tend to be brittle, and thus limit their widespread industrial applications. In this proposed research, non-brittle ceramic hollow fibre membranes will be developed via incorporation of ceramic nanofibres into porous ceramic structure. This project is expected to lead to a cost-effective technique for fabrication of ceramic hollow fibre membranes with high toughness and tunable pore sizes for efficient pre-treatment of seawater.

Reverse osmosis desalting

Fibre-optic sensor for water quality monitoring

Prof. Kamal Alameh, ***Edith Cowan University***

This project aims to develop a new type of water salinity and dissolved oxygen sensor based on optical fibre technology with demonstrated superior performance compared to existing sensors. The proposed optical fibre sensor will have high sensitivity and excellent discrimination capability, be corrosionfree, selective, economically efficient and suitable for use in environmental and process monitoring in desalination.

Development of cleaning guidelines for desalination membrane users

Dr Marlene Cran, ***Victoria University***

with Integrated Elements and Nalco

Scale and other foulants in feed water can build up on the surface of desalination membranes and significantly reduce their performance. While membrane suppliers provide generic guidelines for cleaning and sanitisation, they do not address specialised cleaning chemicals and regimes required for specific fouling issues. This project aims to develop a set of clean-in-place guidelines for desalination membrane users in the form of a comprehensive handbook, structured based on various scaling and fouling issues that affect Australian desalination membrane users.

Smart materials for corrosion management

Prof. Maria Forsyth, ***Deakin University***

with Monash University, Ohio State University, AECOM, ASIS Scientific and AusComposites

This study will address two key areas of interest in the management of corrosion problems associated with desalination: (1) Understanding the corrosion performance of existing materials components and structures within the complex environmental conditions of desalination plants exposed to major and minor threats including hypochlorite, water and soil problems; and (2) Development of dedicated, lower cost, maintenance materials, and life cycle extension to maximise output and efficiency in the desalination industry.

Development of universally applicable coatings and additives for state-of-the-art reverse osmosis and pretreatment membranes

Dr Melina Ginic-Markovic, ***Flinders University***

with Wind Prospect, SA Water and Siemens

Two key problems with current membrane technology are biofouling and mechanical degradation of the membranes. The objectives of this three-year project are to develop a coating for commercially available membranes, which will inhibit biofouling and/or biofoulant growth or reproduction, and to design and synthesise a 'universal' additive, which will improve the mechanical properties of membranes. The fabrication of an anti-biofouling, antimicrobial coating on RO and pretreatment desalination membranes will result in a minimum of at least four times bio-fouling improvement over commercially available membranes, while still maintaining competitive permeation flux and rejection properties.

Control of organic membrane fouling through limitation and control of extracellular microbial products

Prof. Goen Ho, ***Murdoch University***

with Environmental Biotechnology CRC, Nanyang Technological University (Singapore), University of California Irvine, Water Corporation, Chemistry Centre

The behaviour of model polysaccharide foulants on flux decline has been investigated and key bacterial species identified by molecular profiling of membrane autopsies. Clearly, bacterial extracellular polysaccharides (EPS) and bacterial biofilms are involved, although the exact contribution between the two is not well understood. The project will identify the source of most problematic EPS in order to develop the best removal strategies, identify which conditions increase EPS fouling of membranes and EPS production using suitable model polysaccharides and biofilm-forming bacterial isolates, and use forward osmosis as a simple testing platform for EPS fouling behaviour and compare with reverse osmosis.

Assisted forward osmosis for energy savings in RO desalination

Dr Pierre Le-Clech, ***The University of New South Wales***

with University of Nevada and Singapore Membrane Technology Center

The novel concept of assisted forward osmosis (AFO) will be applied as a pretreatment step for reverse osmosis (RO) desalination, resulting in significant dilution of the sea/brackish waters and optimisation of the use of renewable energy. In AFO, a slight pressure is applied to the feed side, resulting in greater dilution and pre-pressurization of the RO feed, and thus significant reduction in the energy cost for RO operation. Anti-fouling strategies will be investigated to decrease operational costs, detailed modelling will be performed to optimise the process, and novel membranes will be studied for this specific osmotic application.

Real time detection and management of biofouling conditioning films in seawater reverse osmosis

A/Prof. Greg Leslie, ***The University of New South Wales***

with University of South Australia, SA Water, Sydney Water and InPhaze

Reducing the impact of biofilms on RO membranes requires early detection and prevention of the development of organic conditioning films. This project seeks to adapt and evaluate impedance spectroscopy for on-line monitoring of the deposition of conditioning films and the development of biofouling. An important outcome of this project will be the provision of desalination plant operators with tools to combat the insidious problem of biofouling in RO plants.

Highly productive and selective bio-organic hybrid membrane water filters

Prof. Michael J. Monteiro, ***The University of Queensland***

This project will develop novel bio-organic hybrid membranes with high selectivity, high water permeation rates and with low energy requirements. This research aims to deliver the next generation in membrane technology by replicating nature’s own filtration process.

Mitigation of membrane biofouling using natural polysaccharide surface coating

Dr Thuy Tran, ***CSIRO***

This project forms the first phase of a three-phase research program aiming to develop a novel, scalable, non-toxic and cost-effective anti-biofouling technology using natural polysaccharide coatings. The key objectives of this project are to develop a platform technology to form durable covalent bonds between the polysaccharides and existing membrane surfaces and to demonstrate the anti-biofouling effects of the polysaccharide coatings.

Membrane flocculation hybrid system as pretreatment to brackish and sea water reverse osmosis desalination system: Emphasis on chemical use reduction and recovery

Prof. S Vigneswaran, ***University of Technology, Sydney***

with State Water NSW, Coliban Water and Steri-flow Filtration Systems

This project will establish and evaluate a novel immersed membrane flocculation hybrid pretreatment system as an effective pre-treatment to RO membrane separation processes.

Novel desalting

High water recovery inland desalination using membrane distillation with ceramic membranes

Prof. Joe da Costa, ***The University of Queensland***

This project aims to trial a new thermally based robust ceramic desalination membrane to achieve higher water recoveries at lower capital and operating costs.

Tjuntjunjarra remote inland indigenous community solar/waste energy groundwater desalination project

Dr Trevor Pryor, ***Murdoch University***

with University of Technology, Sydney, WA Department of Housing, Parsons Brinckerhoff, memsys clearwater (Singapore), Institute of Filtration and Techniques of Separation (France), Singapore Membrane Technology Center

This research project originated from the needs of the Tjuntjunjarra community, located 800km northeast of Kalgoorlie. The project partners from industry, government, community service providers, and research institutes aim to develop a suitable and sustainable desalination system for providing drinking water in remote areas, with a strong focus on reliability. The project aims to overcome the problem of intermittency of renewable energy resources by developing a cost-effective hybrid solar/waste thermal system to power an innovative thermal vacuum-multi-effect-membrane-distillation desalination system.

Fertilisers as draw solutes for forward osmosis desalination: A novel approach for fertigation in the Murray Darling Basin

Dr Ho Kyong Shon, ***University of Technology, Sydney***

with State Water NSW and Korea University

Forward osmosis (FO) technology is particularly suitable when the separation of draw solute and desalinated water is not essential, and could be applied in agriculture where a diluted fertiliser draw solution containing desalinated water can be directly used for fertilised irrigation (fertigation) instead of further separation. This project aims to evaluate the potential of various forms of fertilisers for use as FO draw solute and then optimise the process parameters for desalination of brackish groundwater, ultimately leading to the design of a pilot scale FO desalination unit for application in fertigation.

Developing highly conductive graphene electrodes for capacitive desalination

Prof. Linda Zou, ***University of South Australia***

with SA Water

Capacitive deionisation (CDI) is a promising alternative technology in desalination. CDI targets the removal of salt ions that are a small percentage of the feed solution. Most other technologies aim to shift water, which accounts for 90% of the feed solution, resulting in CDI requiring less energy to operate. This project will build on existing CDI research to develop and evaluate the potential of using graphene-nano platelets as novel electrode materials in capacitive desalination.

Concentrate management

Transverse vibrational motion enhanced submerged hollow fibre membrane crystalliser

Prof. Vicki Chen, ***The University of New South Wales***

with Singapore Membrane Technology Center

Membrane distillation crystallisers provide a promising alternative to recover high quality water as well as valuable precipitates from brackish to hypersaline saline waters. However, the technical challenges to large scale implementation include controlling mass and heat transfer to mitigate concentration polarisation and fouling and reduction of energy usage (particularly electrical energy for pumping). Recently, we have shown that low frequency, small displacement, transverse vibrational motion has been shown to be highly effective in controlling cake formation in membrane bioreactors by providing shear directly to the membrane surface. In this project, a novel design combining a submerged hollow membrane distillation configuration with transverse mechanical shear will be studied to control temperature polarisation as well as fouling and crystal detachment on the membrane surface. The potential for a single vessel reactor/crystalliser will be explored as well as the potential to better utilise renewable energy sources.

Management of brine disposal into inland ecosystems

A/Prof. Ray Froend, ***Edith Cowan University***

with Rio Tinto (Dampier Salt), Water Corporation, WA Centre of Excellence in Ecohydrology and WA Department of Environment and Conservation

Inland disposal and/or use of brine 'waste' from desalination plants and groundwater pumping is a significant management issue, in particular in inland Australia. This multi-staged project aims to evaluate brine discharge using an ecosystem services perspective, and develop and test protocols and guidelines for the management of brine in inland aquatic and terrestrial ecosystems.

Reverse osmosis brine management by membrane distillation crystallisation

Prof. Stephen Gray, ***Victoria University***

with CSIRO, GWMWater, Siemens and Osmoflo

This project aims to demonstrate the use of membrane distillation as a technique to recover water from RO brine and to decrease the evaporation pond area required for the treatment of RO brine.

Evaluation of vibratory shear membrane technology for concentrate minimisation and brine recovery/recycling

A/Prof. Anna Heitz, ***Curtin University***

with Orica Watercare, Water Corporation, Monash University, New Logic Research Inc. and University of Texas El Paso

A key factor slowing the adaption of desalination treatment technologies is the management of concentrate produced from desalination processes. A novel and innovative membrane technology for concentrate management is currently used for industrial wastewater applications, however there is minimal information on the application of this technology for the treatment of reverse osmosis concentrate. In this project, a full-scale automated demonstration unit will be installed to treat brine waste produced from an ion exchange process. The project will also combine the membrane technology with other waste minimisation technologies to achieve a zero liquid discharge system.

Continuous silica removal during desalination for increased water recovery

Dr Nicholas Milne, Prof. Stephen Gray and Dr Peter Sanciolo, ***Victoria University***

with Origin Energy

The current NCEDA project "Silica removal from groundwater for reverse osmosis water recovery enhancement and waste brine volume reduction" is investigating the chemistry of silica removal. This project is providing insight into how silica may be removed from water at high pH, and has identified a number of adsorbents, their capacity and the kinetics of silica removal. However, to utilise the outcomes from this understanding of the chemistry, a process must be designed that is economic and is able to be successfully controlled. A continuous silica removal process with semi-continuous regeneration of the adsorbent is proposed, which incorporates the use of stainless steel membranes for separation of the abrasive adsorbent and for dewatering of the concentrated adsorbent stream.

Brine management guidelines

Dr Peter Sanciolo, ***Victoria University***

with Smart Water Fund, GWMWater and Integrated Elements

Brine management guidelines will be produced to offer a variety of alternative processes to the conventional practice of employing solar evaporation ponds. The brine management guidelines will incorporate a decision tree selection guide to assist practitioners to define and identify brine management solutions, as well as providing design information.

Silica removal from groundwater for reverse osmosis water recovery enhancement and waste brine volume reduction

Dr Peter Sanciolo, ***Victoria University***

with Hatch, Origin Energy, Minara Resources and University of Texas El Paso

This project will investigate the opportunity to achieve high water recovery (above 95% of the feed flow) and low waste brine volumes (less than 5% of the feed flow) in the reverse osmosis desalination of bore water using an inter-stage treatment to remove silica – one of the major scale precursor species present in bore water. It is possible to generate RO brines with silica concentrations of approximately 1000 mg/L without silica scale formation. For a groundwater containing 100 mg/L silica, this would equate to a 90% water recovery. It is proposed that the remaining brine concentrate be further treated by precipitation and coagulation, and/or adsorption onto activated alumina, and/or seeded precipitation to allow further RO treatment of the brine and thus achieve water recoveries above 95%.

Application of capacitive deionisation in inland brackish water desalination

Prof. Linda Zou, ***University of South Australia***

With Power and Water Corporation, SA Water, Water Quality Research Australia and LT Green Energy

The overall objective of this project is to transfer capacitive deionisation technology into applications for inland drinking water supply and direct agricultural use by desalting brackish groundwater. Site trials in a regional inland Northern Territory location will be conducted to investigate the full operational performance of the technologies. The key outcomes will establish the feasibility of this novel technology in real-world situations, and provide answers to a series of technical challenges faced when applying this new desalination technology for inland water supply and for direct agricultural uses.

Social, environmental and economic issues

Development of a novel low grade heat driven desalination technology

Prof. Hui Tong Chua, ***The University of Western Australia***

with Western Australian Geothermal Centre of Excellence and industry partners

Multi-Effect-Distillation (MED) is an established low-grade heat driven technology that can deal with any water contaminants and salinity levels. The Western Australian Geothermal Centre of Excellence has developed a novel technology which boosts the efficiency standard of MED by more than 30% in terms of freshwater yield with a standard coolant temperature of 20°C. This project will provide a gateway towards commercialisation of the novel MED technology.

Public perception of, and response to, desalination in Australia

Dr Tanya King, ***Deakin University***

with Victoria University, Murdoch University, Edith Cowan University, Melbourne Water and Yarra Valley Water

This integrated social research program will establish a national benchmark on public perceptions of desalination in relation to environmental, technical, water quality and social factors, as well as investigating how water professionals and water users currently communicate.

Reuse of reverse osmosis membranes

Dr Pierre Le-Clech, ***The University of New South Wales***

with Victoria University, Monash University, SkyJuice Foundation, Water Corporation, DOW Chemical, SA Water and Sydney Water

This project will investigate alternative and valuable usages of end-of-life desalination membranes. Opportunities such as cost effective reuse in lower specification applications, potential recycling of valuable materials and the conversion of RO into microporous separation devices will be assessed both technically and financially.

Nanostructure of diatoms: A predictive model for species sustainability

Dr Sophie Leterme, ***Flinders University***

with SARDI and SA Water

This project combines ecological, chemical and molecular expertise to understand the impact of brine discharge on the composition of the microbial community and on the morphological flexibility of the frustules of diatoms. A model of how the diatoms react to desalination discharge will be developed.

Assessing and mitigating environmental impacts of SWRO outfalls on key benthic marine organisms

Dr Julie Mondon, ***Deakin University***

with The University of Western Australia

This study addresses the possible impacts of hypersaline discharge from SWRO plants on recipient marine ecosystems by generating environmental tolerance and biomarker data that are lacking for both Western Australia and Victorian systems. We aim to develop a detailed understanding of the salinity and toxin tolerances of marine species in the vicinity of SWRO outfalls to mitigate environmental impacts and contribute to bio-monitoring tools. The project will measure environmental tolerances, develop biomarker tools, identify bioindicator species, and develop risk assessment and mitigation strategies.