Pilot facilities

Supplementary Report 2016

Overview of pilot test facilitates established as part of the research program

Australian Water Recycling
Centre of Excellence

Pilot facilities

:: Purpose

This report provides examples of the Australian Water Recycling Centre of Excellence support for pilot scale evaluation of new and novel pilot technologies for use in Australia's unique circumstances.

:: Background

A key objective under the Funding Agreement with the Australian Government was "Providing facilities to researchers and industry to support the development of new technologies and practices including pilot test facilities".

In addressing this objective, the Centre invested in a range of projects that have involved the commissioning, testing, and evaluation of pilot technologies novel to Australia.

In using pilot test facilities (including pilot plants), the knowledge and skills gained through theoretical or laboratory testing of technology and processes is tested at an expanded scale in field trials, serving to ratify the laboratory results and provide greater confidence that the technology in question can translate to practicable applications within an industry setting.

:: Pilot facilities

The following pages provide an overview of pilot test facilities that were implemented as part of the Centre's research program.

About the Australian Water Recycling Centre of Excellence
The Australian Water Recycling Centre of Excellence (the Centre) is an Australia-wide, independent research organisation launched in 2010 with Australian Government funding through its National Urban Water and Desalination Plan and support (financial and in-kind) from the Queensland Government. The Centre manages a $40 million research program, coordinating 42 research projects with the support of more than 100 partners from the research, government, utility and private enterprise sectors. Our overall objective is to demonstrate how water recycling can be a practical and viable option to achieving water security.

Acknowledgements
The Australian Water Recycling Centre of Excellence is grateful for the contributions made to a number of its research projects by industry partners through the hosting of pilot test facilities, in particular by: Queensland Urban Utilities (Qld); Yarra Valley Water, Western Water, Melbourne Water, Warrnambool Cheese and Butter (Vic); Tas Water, Australian Antarctic Division (Tas); and N and WA Pezzaniti and Treasury Wine Estates (SA).

Optimal Technology

Project Partners
Uni of Queensland (project leader); GHD; QUU; Wide Bay Water; Melbourne Water;

Project Description
The aim of the Affordable and Sustainable Water Recycling through Optimal Technology Integration project was to investigate and develop integrated treatment train(s) that can achieve a water quality fit for recycling at a lower energy/chemical input and reduced capital and operating costs compared to current schemes.

Anaerobic membrane bioreactor (AnMBR), carrier-based sidestream and mainstream anammox processes were demonstrated at pilot-scale for the first time in Australia.

The project team completed design, installation and commissioning of two new wastewater treatment trains at Queensland Urban Utilities' Innovation Centre at Luggage Point, Qld:

1. Anaerobic membrane bioreactor (AnMBR) for C removal + mainstream anammox for N removal; and
2. High rate activated sludge (HRAS) system for C removal + sequencing batch reactor (SBR) for N removal + sidestream anammox.

Two anammox reactors to enrich anammox organisms were also commissioned:
1. A suspended culture to enrich biomass in granular form; and
2. A carrier-based culture to enrich biomass in biofilm form.

Outcomes
The pilot-scale mainstream anammox process achieved an overall ammonium removal of 60-80%. The treatment train combining AnMBR and mainstream anammox treatment has the potential to decrease the overall costs (based on NPV calculations) by up to 32% compared to current technology for a wastewater plant treating 100 ML/d of sewage and where the target total N concentration in the effluent is 10 mgN/L.

The successful enrichment of anammox biomass and demonstration of the anammox process in pilot-scale through this project has the potential to significantly decrease the overall cost of wastewater treatment.

This project was the first pilot-scale demonstration plant of a carrier-based anammox process in Australia. Due to its potential economic and environmental benefits, industry partners have decided to support the further pilot-scale trails of all key novel technologies proposed by this project for at least another year after the end of the current project.

Green Chemicals for Biofouling Removal

Project Partners
Uni of Queensland (Project Leader); Veolia Water; Seqwater; NCEDA

Project Description
Biofouling is generally regarded as a major issue in reverse osmosis (RO) membrane filtration. Chemical cleanings with alkaline and disinfection agents are typically applied to restore the treatment capacity by removing organic foulants and stopping bacterial re-growth, respectively. Sodium bisulphite (SBS) is the current strategy to control biofilm formation during membrane storage due to its efficiency and low price. However, SBS preservation solutions are not stable leading to additional costs of maintenance and operation especially for large RO plants.

This study, also conducted at Queensland Urban Utilities' Innovation Centre at Luggage Point, investigated the feasibility of using free nitrous acid (FNA) as a novel low cost cleaning agent and as a novel preservation agent.

Outcomes
The project team showed that FNA-based cleaning improved permeability by 20-29% and reduced differential pressure drop by 28-38%. For membrane storage, no significant microbial growth occurred within 4 months when using FNA as a preservation solution.

Cost–benefit analysis showed that FNA is a cost-effective solution for biofouling removal and long-term preservation in RO filtration applications. The cost-benefit analysis showed that cleaning strategies employing FNA were priced at 0.22-0.53$US/m3 compared to 1.73-2.34$US/m3 for processes using NaOH/HCl.

The research team have commenced discussions with a local membrane manufacturer to compare and benchmark the use of FNA against other commercial cleaning solutions. An international partner is considering undertaking a comparison of FNA with DBNPA using shock dosing for biofouling prevention.

In-line Sensor for Detection of Cross-connections

Project Partners

CSIRO (Project Leader); Smart Water Fund; Melbourne Water; Yarra Valley Water; Western Water;

Project Description

Due to the possibility of cross-connections of recycled water intrusion into potable water systems, there is a need for sensors to help detect cross-connections to protect the investment in water recycling infrastructure and public health, as well as manage public perception and supplier reputational risks. The research carried out in this project sought to explore the application of UV absorbance and UV fluorescence for detecting cross-connections.

Outcomes

UV fluorescence was found to offer superior sensitivity when compared to UV absorbance, and offered improved affordability in enabling excitation of fluorescence to be carried out. Operational prototypes were developed with a component cost under AU$200, and production scaling would be expected to further reduced costs.

The final prototype was able to detect under 1% recycled water in a potable water. A test rig, incorporating a paired fluorescence sensor and an electrical conductivity sensor was demonstrated to work effectively in two field trials conducted on varying water quality types at Brushy Creek (Yarra Valley Water) and Surbiton Park (Western Water).

The fluorescence prototype has been demonstrated to provide an excellent means of differentiating water quality over long periods of time at low cost. Commercialisation options for the fluorescence sensor are being evaluated by the Centre together with the CSIRO. Further trials and evaluation of the sensor have been agreed with CSIRO and City West Water.

Pasteurisation

Project Partners
Victoria Uni (Project Leader); Melbourne Water; SA Water; AWQC; Carollo Engineers; PTG; WJP Solutions

Project Description
Suspended particles present in the wastewater can protect pathogens from UV and chlorination disinfection processes. This project investigated the feasibility of using pasteurisation rather than UV and free chlorination disinfection processes for the production of Class A water from unfiltered secondary effluent. Pasteurisation has, however, not been used for wastewater disinfection in Australia and there is no Australian data available to inform regulatory authorities as to the reliability and efficacy of pasteurisation for the disinfection of unfiltered Australian municipal wastewater.

This project assessed the suitability of pasteurisation for future increases in Class A recycled water production at Melbourne Water's Eastern Treatment Plant and for decentralised recycled water schemes more typical of integrated water management. The pilot plant used in this project, supplied by Pasteurization Technology Group (PTG), operates as a High Temperature Short Time (HTST) system, with contact times in the contact chamber of less than one minute at flows greater than 500 L/minute.

Outcomes
At temperatures between 75°C and 69°C and a contact chamber contact time of 30 seconds, log reductions values (LRVs) between 1 and 5 were achieved with a surrogate pathogen (MS2). The trial also showed that doubling the contact time by halving the flow rate can increase the contact chamber LRV at 72°C from 2.4 to 4. Variations in feedwater quality parameters such as Turbidity, pH and TOC were found to have little effect on the LRV achieved.

When comparing pasteurisation with conventional pathogen removal using UV, membranes and/or chlorination, there are several potential benefits. These include a reduction in the need for filtration and chemical use, producing less harmful disinfection by-products, a smaller carbon footprint and lower running costs. This makes pasteurisation a potentially more sustainable and less expensive way to produce Class A water from secondary treated effluent.

The project provided validation data to inform the Victorian Department of Health's decision making processes regarding the use of currently available wastewater pasteurisation technology for the production of Class A water. The research team also drafted a Validation Protocol that will be further developed through the Centre's investment in a national validation framework.

Robust Recycling

Project Partners
Victoria Uni (Project Leader); Uni of Melbourne; AAD; Veolia Water; AECOM

Project Description
An advanced water treatment plant (AWTP) plant consisting of seven water treatment barriers was constructed to implement water recycling at Davis Station, Antarctica. The AWTP was constructed by the Australian Antarctic Division (AAD) and operated at Self's Point Wastewater Treatment Plant (SPWWTP) in Hobart, Tasmania for approximately 10 months from August, 2014 to June, 2015.

The plant was fed secondary treated effluent while at SPWWTP, and the treatment train consisted of ozonation, ceramic microfiltration (MF), biological activated carbon (BAC), reverse osmosis (RO), ultra-violet disinfection (UV), calcite contactor and chlorination.

The aims of the trial were to demonstrate the reliability of the treatment plant with regard to product water quality, effluent water quality, and ability of the plant to operate unattended, as well as to identify the maintenance requirements and energy consumption of the plant.

Outcomes
Product water quality data and critical control points (CCPs) from the operation were consistent with production of potable quality product water. The AWTP waste stream (RO concentrate) was of low environmental impact. This was supported by toxicity and bioassay data for the RO concentrate when compared to feed water. A pressure decay test (PDT) was used on the RO system to claim LRV credits, and it operated reliably throughout the demonstration.

The extra treatment barriers required to achieve an acceptable overall LRV and the need for lower environmental impact at Davis Station, resulted in the energy consumption for water recycling being higher than conventional advanced water recycling systems. The AWTP used 1.93 kW.h/m3 of energy when operated for 15 hours per day (12.6 kL/day), compared to a predicted 1.27 kW.h/m3 for continuous operation at larger scale (10 ML/day). However, installation of the AWTP at Davis Station is expected to reduce energy consumption for the provision of water at the station by 69%, as currently cold, hypersaline water is desalinated to produce potable water.

The knowledge and expertise gained will be used to implement similar advanced treatment plants at other Australian Antarctic and sub-Antarctic research stations, significantly mitigating the environmental impact of discharge from Antarctic bases. In future, it could also provide water for other applications, both non-potable (toilet flushing and laundry; station laboratory use) and potable uses in remote regions across Australia.

The draft Recycled Water Quality Management Plan was identified by industry participants as a document that could provide valuable assistance to other regional and remote regions with planning and implementing water recycling schemes.

Ceramic Membrane

Project Partners
Victoria Uni (Project Leader); Melbourne Water; SE Water; WRA; Black & Veatch; PWN Technologies

Project Description
This project primarily focussed on the technical and economic viability of water recycling using ceramic membrane technology. Water treatment using membrane filtration for potable and recycling purposes is now a common yet still growing treatment technology option. However, the issue of membrane fouling is an ongoing limitation to membrane process productivity and cost-effectiveness, particularly in the context of wastewater reclamation.

This project featured a trial on a 25 m2 ceramic microfiltration membrane pilot plant based on the CeraMac process from PWN Technologies. The plant was coupled to an ozone injection system and the combined process operated using municipal secondary effluent from Melbourne Water's Eastern Treatment Plant (ETP).

Outcomes
Major technical outcomes were:

- Maximum sustainable flux for membrane filtration without ozonisation or coagulation was 50 L/m2.h.
- Addition of inline coagulation enhanced sustainable flux between 100 L/m2.h and 150 L/m2.h.
- Ozonisation and coagulation applied together reached 182 L/m2.h flux; as this flux was limited by the ozone equipment on site, higher fluxes may have been achievable.
- Demonstrating the viability of ceramic membranes as a pathogen barrier, the log removal value for bacteria and protozoa based on E.coli was greater than 3.2 and the virus removal potential using the virus surrogate MS2 delivered a measured log removal value of 4.0.

Economic assessment of ceramic membranes based on a 22 megalitre per day plant showed that their high flux and long life are key features that help reduce their capital and operating expense. Net present value analysis showed that the operating expense of ceramic membranes was cheaper than polymeric membranes over the life of the plant irrespective of replacement scenario (15, 20 or 25 years).

High flux operation for challenging waters such as secondary effluent, and enhanced total disinfection are features with significant benefits for waste water recycling. Ceramic membranes could reduce chemical cleaning, and their robustness and longevity allows smaller plant size and greater operational freedom.

The project showed that the process configuration of ceramic membranes with ozonation has real potential, and the pilot plant has been relocated to Western Australia Water Corporation to continue the assessment of the comparative value of ceramic membranes against existing technologies for different water types across WA.

Increasing Recycled Wastewater Use in Irrigation

Project Partners

SARDI (Project Leader); Goyder Institute of Water Research; Uni of Adelaide; N & WA Pezzaniti; Treasury Wine Estates

Project Description

This project involved two agronomic field experiments seeking to enhance the value of recycled wastewater for irrigation by overcoming the constraint of salinity. Investigations focussed on wine grapes and almonds located in established recycled wastewater irrigation districts to the south and north of Adelaide, South Australia.

Over two seasons, the project assessed whether various changes to vineyard floor management could reduce soil and vine salinity. In a salt affected almond orchard, the project assessed the sensitivity of almond growth stages to the removal of the salt stress at different times through the growth cycle.

Outcomes

At the McLaren Vale vineyard, redirecting rainfall from the mid-row to the drip line reduced average soil salinity by 27% and concentrations of sodium and chloride in juice by 28%. Shallow ripping of compacted wheel lines further reduced under-vine soil salinity by 11% and the concentrations of sodium and chloride in juice by 17%.

An impermeable layer buried in mid-row soils to redirect rainfall and shallow ripping of compacted soils have potential as salinity management options without using additional irrigation water - an important development particularly when water is scarce. Rainfall redirection treatments show promise for assessment with other locations and cropping systems.

At the Northern Adelaide Plains almond orchard, application of non-saline water at pre-harvest was 31% more effective at reducing sodium and chlorine levels in almond trees than flushing the plants with non-saline water post-harvest. Late season leaf samples revealed that the trees were most sensitive to reduced salt load between pit-hardening and harvest.

Sodium and chloride uptake in almonds was lowest when non-saline irrigation was applied during periods of leaf emergence and shoot growth. Identification of the best time of the season to supplement recycled water with non-saline water improves the health of the trees and allows the use of a climate resilient water source.

While the two-season investigation period with almonds was too short to elicit a yield response to different timings of reduced salt load, research into the response of almonds to the timing of salt stress will continue with support from the South Australia River Murray Sustainability program through to the 2017 season.

Water Recycling in Food Industries

Project Partners
CSIRO (Project Leader); AMPC; MLA; Kellogg; ADI Systems; Warrnambool Cheese & Butter; Bega Cheese.

Project Description
In recent years, Australia's agri-food industry has made significant progress in reducing its reliance on fresh water by adopting water-saving initiatives, improving efficiencies, and increasing water recycling. While many individual food processing companies have invested in water recycling systems, generally Australia's meat, dairy and food processing industries have been slow to adopt water recycling initiatives. A number of technologies are now available for treating wastewater to obtain the required quality of water that is 'fit for purpose' while being economically viable and conforming to the appropriate regulatory guidelines.

Tools and frameworks developed by this project, successfully demonstrated through case studies, are available for industry to assist with decision-making on wastewater treatment and water recycling options.

Outcomes
The project addressed a range of technological, economic, regulatory and consumer-based issues. Pilot plant trials at a large dairy manufacturing site in collaboration with ADI Systems demonstrated that dairy processing wastewater can be recycled through a treatment comprising a P removal system followed by a membrane bioreactor, followed by a reverse osmosis system and an ultraviolet light/chlorination disinfection system. This will successfully produce water of the required chemical and microbiological quality for the dairy factory to meet potable standards and therefore enable water reuse within its production facilities.

Other outcomes from the project included:

- A framework for selecting technologies for wastewater treatment for recycling and irrigation.
- An economic assessment tool to evaluate the value proposition for different water treatment, recycling and irrigation options.
- A framework for operating within appropriate regulatory guidelines.
- Validation of tools and frameworks through case studies in the dairy, food and meat sectors.

:: Ongoing Evaluation

Four pilot plants will continue operation beyond the Centre's formal association with the project.

CSIRO will continue further field evaluation of the inline sensor for cross-connection detection with City West Water, Victoria, to allow commercialisation opportunities to be pursued.

The ceramic membrane pilot facility has been transferred to Water Corporation (WA) for further field evaluation with source waters of varying water quality across a number of regions in the state.

The robust recycling pilot plant will continue further field evaluation by Tas Water and the AAD at Self's Point, Tasmania before a planned transfer to Davis Station in Antarctica in the 2017-18 summer months.

The pilot adoption of optimal treatment technologies will continue. QUU will be considering options for incorporation of sidestream anammox and other technologies into the treatment train at Luggage Point, while Melbourne Water is considering incorporating both anammox sidestream and mainstream applications into primary treatment processes.

The findings from the field trials irrigating almonds with recycled water in the North Adelaide Plains had implications for the wider almond industry and other tree crops in Australia and overseas. In recognition of this, the South Australian Government's River Murray Sustainability Program has extended the research initiative through the 2017 season.

The responsibility for operation of the continuing facilities and trials will rest solely with the relevant project partners who have indicated the desire to see the testing and optimisation continue. The Centre will maintain communication with the project teams, and it is envisaged that data collected during this time will be available for communication of the project outcomes tom the wider water industry sectors.

:: Legacy learnings

The involvement of pilot facilities in delivering project outcomes has provided the Centre with valuable insights into a range of issues that would be relevant to similar organisations pursuing research projects incorporating such facilities.

There were delays in the construction and commissioning of some facilities, which in turn delayed the delivery of project milestones and directly impacted what the project team could realistically and practically achieve in the timeframe available. These delays were often outside the control of the team or the Centre. In one particular case, already stringent state-based OH&S requirements tightened further, requiring the project team to undertake a significant amount of additional site preparation prior to installation of the facility.

In one project there was a decision to change the scope (and therefore design) of the facility midway through the construction phase, due to results coming from continued work in the laboratory. This caused some delay in project delivery but ultimately led to a much better project outcome.

For operational reasons, one pilot plant was located in a different state to the research team, with the team itself spread across various sectors (research and private industry) and geographical locations. This presented unique challenges in project management and highlighted the effectiveness of good project leadership and the advantages of having a Project Advisory Committee to help advise on project activities.