Annual Programs Update

2008 - 2009

Water Quality Research Australia Limited

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Executive Summary

Water security continues to be a major focus for all Australians as demonstrated by the significant investment in water initiatives at both the federal and state levels and the number of investigations into new and alternative water sources. Much of the emphasis has been on water quantity, but water quality can never be taken for granted. Through its members, Water Quality Research Australia is bringing together key water research groups and industry to conduct targeted, priority research to address current and emerging public health issues in water quality. WQRA's ultimate objective is to fulfil the aims of our vision 'safe water for Australians', and to engage with all in Australia who aspire to provision of high quality research and education in water quality.

During the first full year of WQRA's operation, there has been a significant emphasis on designing the WQRA Research Portfolio to ensure a balance between addressing the industry's immediate water quality issues and being able to provide pre-emptive scientific information on possible emerging issues. Crucial to identifying issues of concern to the Australian water community, has been the high level of engagement and commitment of the WQRA Members to provide insight into research and development requirements.

During 2008-09 the key achievements in the Research Programs were:

- Appointment of the Research Program Managers
- Transition of CRCWQT research projects to WQRA
- Determination of the WQRA Research Priorities by Members
- Selection of a shortlist of project concepts that address WQRA Research Priorities
- Formation of the Project Review Team from a cross section of professionals from within the WQRA Membership
- Consultation with research and industry Members to assist in the development of research proposals from the short-listed project concepts
- WQRA financial support approved for the first round of the NHMRC Partnerships Project Initiative
- Establishment of funding policies and processes for supporting ARC/NHMRC research proposals from WQRA research members
- Execution of the first WQRA Research Agreement
- Consolidation of relationships with key stakeholders in the water research community both nationally and globally
- Submission to the National Water Commission in response to the Biennial Assessment of Progress against NWI – 2009

In addition to developing the Research Program, WQRA has sought to build capacity in water research by supporting young scientists through the initiatives of the WQRA Education Program. The last 12 months has seen the Education Program achieve:

- Appointment of the Education Program Co-ordinator
- Transition of remaining CRCWQT PhD students to WQRA
- Development of the WQRA PhD Scholarships initiative with two new PhD students enrolled with WQRA support
- A successful Summer Scholarships Initiative for undergraduate students
- Establishment of a small grants scheme to provide funding for specific post-graduate student activities
- Formation of the WQRA Education Committee
- Revision of the Education Program processes for project selection and candidate appointment, to ensure that WQRA is supporting high quality research being undertaken by exceptional students

A vital component in the research cycle is the transfer of outcomes to enable uptake of results and to provide tangible benefits to the industry. To achieve technology transfer, it is critical that the end-users - the Australian Water industry and regulators - are involved throughout the whole project cycle: from conception to implementation. It is also imperative that progress reports and final research results are disseminated to Members. To achieve this objective, over the last year WQRA has:

- Overseen the delivery of 20 CRCWQT final reports
- Worked with industry partners during the formation of project proposals, to ensure that new R&D projects that are commissioned are fulfilling an industry need
- Provided project updates through quarterly Members Meetings

In addition, many WQRA members have presented CRCWQT/WQRA research outcomes through conference presentations or journal publications.

The past year has seen much activity in the design and implementation of the research priorities for WQRA. This will lay solid foundations for the coming years as WQRA consolidates its research programs with new R&D projects to provide high quality scientific outcomes that will benefit WQRA Members and their stakeholders.

Introduction

With the impact of drought, climate change and population growth causing increasing stress on existing potable supplies, Australians are constantly looking towards alternative sources of water to supplement traditional water supplies. Options being implemented or investigated around the country include wastewater recycling, stormwater harvesting, groundwater sources and desalination. This diversity presents greater complexity in the management of water and therefore many challenges for the industry and policy makers. While much of the emphasis has been on water quantity, water quality can never be taken for granted.

Targeted research outcomes from WQRA play a pivotal role in building the confidence of the community and regulators in the water industry's ability to provide safe and acceptable water products and services – whether these are potable or alternative water sources, or an integrated combination of sources. Through its membership, Water Quality Research Australia is bringing together key water research groups and industry across Australia to conduct targeted, priority research to address current and emerging public health issues in water quality.

The core aims of WQRA are to:

- Conduct and advocate for high quality research on priority issues for the Australian Water Industry relating to public health and acceptability aspects of water
- Adopt a risk-based approach to research to underpin the implementation and further development of relevant Australian guidelines for drinking water and recycled water
- Facilitate knowledge transfer and the up-take of the outcomes of the research in the industry
- Build capacity and capability for the industry

The WQRA Programs are designed to ensure delivery on the core aims of the company to benefit both Members and key stakeholders, including the Australian public.

To achieve these outcomes, WQRA has organised its research into four main programs:

- Drinking Water Research Program
- Wastewater Research Program
- Recycled Water Research Program
- Education Program

The key focus of WQRA's Research Programs is on addressing the critical water quality research needs of Australia's water industry with an emphasis on public health impacts to the community, in both traditional and alternative sources of water. On-going scientific discovery provides improved understanding of existing and emerging risks and pathways to address and manage these risks to ensure safe water for all Australians.

The WQRA Education Program seeks to build the future capacity of the water industry by encouraging high quality students to undertake training in research with a focus on water issues, thus providing both an avenue to help the industry address the imminent skills shortage as well as contributing to WQRA's overall research program,

Whilst much of the research agenda is biased towards the urban centres of Australia, WQRA continues to undertake research to improve water quality and public health in remote areas, especially with regard to access to appropriate drinking water for remote Indigenous communities. While many of the issues are similar to those in urban water supplies, the solutions need to take account of the diversity of infrastructure and social conditions in rural and remote areas.

Research Programs Overview

Research Objectives

To ensure a smooth transition from the Co-operative Research Centre for Water Quality and Treatment (CRCWQT) to WQRA and to minimise the hiatus in research outputs, a small number of significant projects with external funding were approved by the WQRA Board in early 2008. These projects, coupled with existing projects, which were initiated, but not completed, during the term of the CRCWQT as well as projects that were transferred from the CRCWQT at its closure, formed the base of the current research programs.

WQRA's Research Programs aim to address key water industry scientific and technical knowledge gaps and emerging risks. Research projects funded by WQRA serve to support the industry by underpinning the decision-making process with weight-of-evidence based science and research outcomes.

The core outcomes that WQRA is seeking to deliver to the industry and key stakeholders through the WQRA Research Program are:

- To have an improved and rational understanding of issues in relation to public health risk, in current water sources but also in relation to the introduction and integration of new and alternative water products and services into the urban water product and service cycle. In doing so, research will close critical knowledge gaps and provide the evidence to support and inform the development of public health policy and management plans, and
- To be able to better identify appropriate intervention strategies to address these risks. This will include the development of targeted management and monitoring systems to support public health outcomes.

The development of the initial WQRA research portfolio has been a core objective during the year. Defining the immediate and emerging issues which are crucial research questions for the Australian water community has been a priority to ensure that members' funds are invested judiciously.

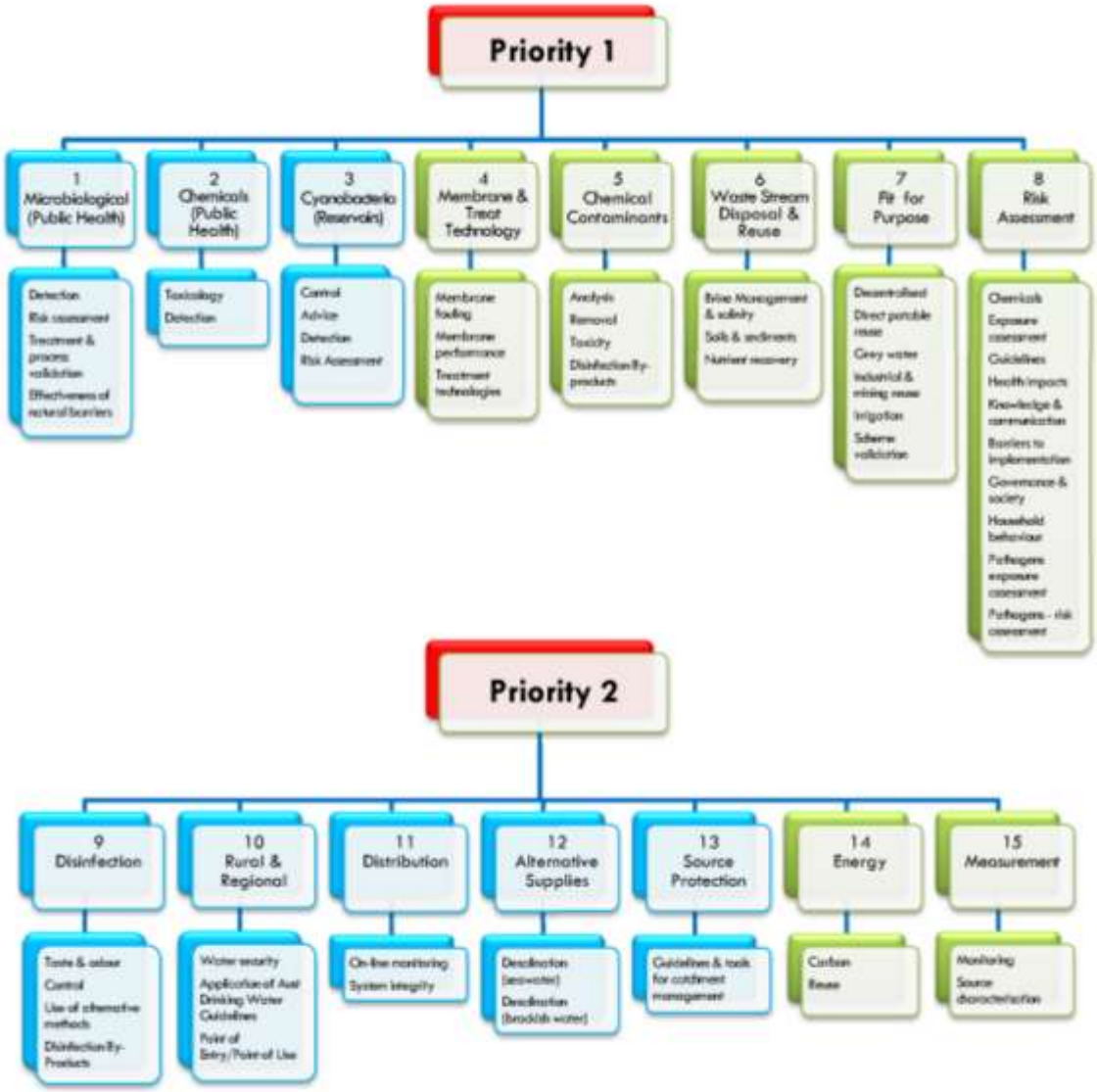
Determining the WQRA Priority Research Issues

In late 2008, member organisations and other stakeholders were invited to attend two workshops to discuss and determine the current priority research issues for the respective programs. An extensive list of topics was collated and members were asked to allocate their votes according to their organisation's priorities. When the votes were processed the list of issues was divided into three groups. The first, with the majority of votes, were identified as priority one issues and the bulk of the research investment was directed to these priorities. The second group had fewer votes, but were still critical industry issues and were designated priority two issues. The third group were determined as lower priorities and were not progressed further. From these workshops fifteen high priority research issues were consolidated.

Although many priorities overlapped across the Research Programs, eight priorities were assigned to the Drinking Water Program and seven to the Wastewater and Recycled Water Programs. These industry-driven research issues have formed the basis of project development and investment in the first year in not only the Research Programs but also the research projects undertaken in the Education Program initiatives. The Priorities are shown below.

WQRA research priorities from voting on issues, November 2008

(blue = Drinking Water issues, green = Wastewater/Recycled Water)



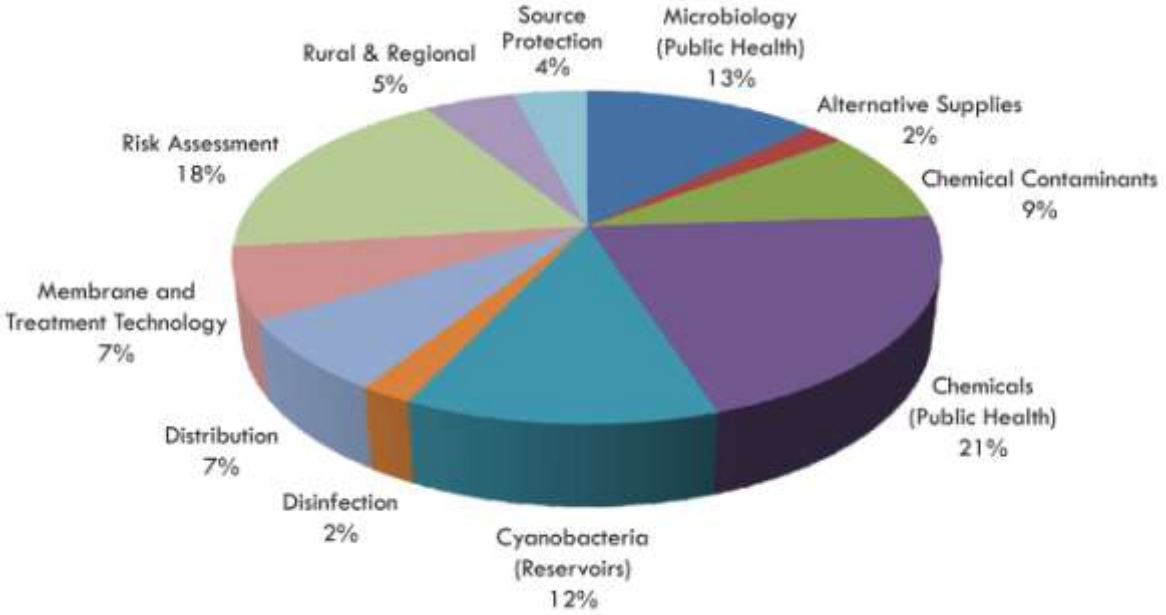
Project Concept Selection and Development

Following the September and October 2008 workshops, an invitation was extended to all WQRA Research Members to develop brief project concepts which focussed on addressing the WQRA Research Priority Issues that were identified. The intent of the project concept was for research teams to provide a brief project outline, research methodology and approximate budget, as well as identifying potential industry partners/support.

In total, seventy-four project concepts were submitted for consideration and prioritisation by WQRA members. In addition to the submission of a written project concept, project leaders were allocated a three minute time slot per project to give an 'Elevator Pitch' at the 2008 AGM. This provided not only an opportunity for Members to listen to an overview of the proposed project concept and to ask questions on the concepts, prior to decision making, but to also determine what the research capabilities of the different research groups, within the WQRA membership, were.

After two rounds of voting - the first at the AGM and the second at a general meeting (December 2008) - a suite of twenty-five short-listed concepts was selected to be developed into full project proposals.

Allocation of short-listed project concepts against research priority areas



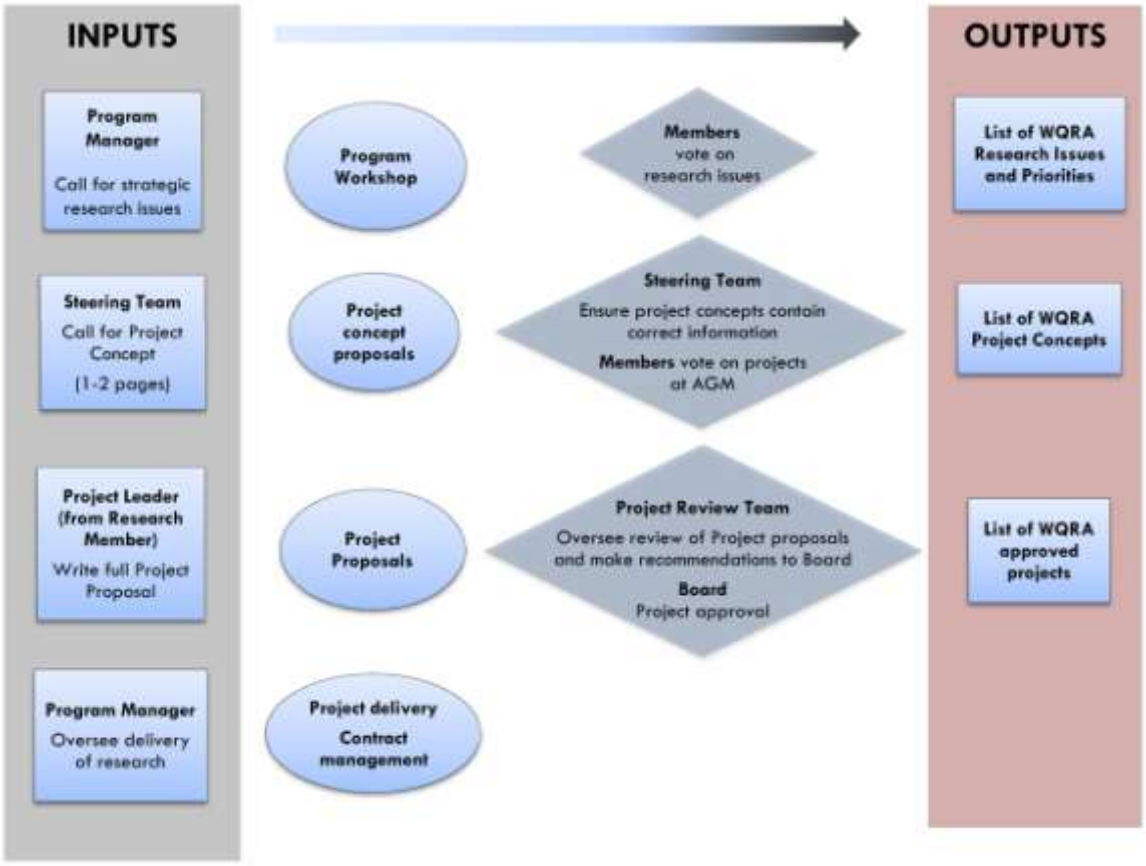
Following the short-listing of project concepts, successful research teams were invited to submit a project proposal for Board approval. To ensure consistency in applications, a standardised template for submission of project proposals was developed as well as a set of project selection criteria for transparency of project assessment. The project proposal template focused not only on the project outline and budget, but also on the research team's capability in the specified area, management of IP and intended pathways of disseminating the research outcomes to industry. Project budgets were designed on a milestone payment basis, and included both cash funding and in-kind contributions for each milestone. As a criterion for submission, each project proposal needed to be endorsed by a minimum of two industry members to ensure that the proposed research project was fulfilling an industry need and that there was industry engagement from the beginning of the project. This also afforded industry members with an opportunity to have input into the research proposal prior to approval and commencement.

No specific deadline was set for full project proposal submission to WQRA to enable research teams the opportunity to fully develop the research proposals with industry input and to enable a flow through of projects to the Board for review and approval at regular intervals.

In the first instance, each proposal was submitted to the relevant Program Manager for assessment and comment, followed by extensive interaction with the Program Manager during the preparation of project proposals to ensure that all the assessment criteria were addressed.

The proposal was then submitted to the Project Steering Team and the Project Review Team for review and finalisation, prior to submission to the Board for a funding decision.

WQRA project selection process



Project Review Team

To ensure that each project proposal was subjected to a rigorous evaluation with input from both industry and research members, a Project Review Team (PRT) was established. WQRA invited a cross section of professionals from both the industry and research sectors, ensuring diversity in both scientific expertise and geographical location in the members of the PRT. The WQRA Program Managers sit on the PRT, as *ex-officio* members, to act as a conduit for feedback between the PRT and the project leaders submitting the project. In addition, The WQRA CEO also sits on the PRT to provide a Board perspective. Their role is to review each project proposal and make a recommendation to the WQRA Board. The critical objectives of the PRT are to ensure that:

- Each project addresses at least one of the WQRA Research Priority Issues
- WQRA has a balanced Research Portfolio
- R&D is not being duplicated elsewhere
- Projects fulfil the Project Selection Criteria

The PRT reviews the project proposals for technical rigour and organisational capability and the project schedule to ensure that milestones are achievable within the time and budget allocations. In addition, a core function of the PRT is to determine whether the project proposal requires external peer review and appoint appropriate reviewers.

The PRT was consolidated in early 2009 and has been instrumental in reviewing project proposals that have been submitted following the short-listing of the project concepts in December 2008. In addition, the PRT has reviewed project concepts submitted for consideration for ARC Linkage support and made recommendations to the WQRA Board on the aligned project concepts. During the first year of WQRA, there has been a significant workload for the PRT in reviewing the initial project proposals, assisting in developing processes and templates and providing advice on both industry and research organisation viewpoints. WQRA is extremely grateful for the time and effort that the PRT has provided and recognises that the approval of projects has been expedited because of the efforts of the individual members of the PRT.

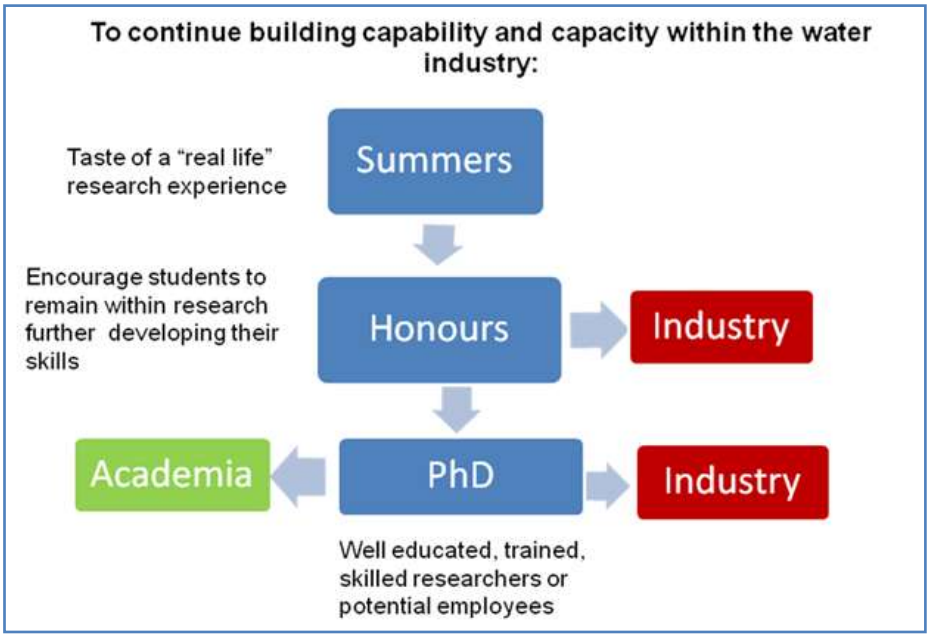
Education Program Overview

As with many sectors within Australia, the water industry is beginning to experience a significant shortage of trained and experienced professionals. The job market is becoming increasingly competitive for employers to attract suitable candidates in the workplace.

A key aim of WQRA is to assist the water industry to build capability and to attract and retain suitably qualified professionals. Thus a core objective of WQRA's Education Program, in addition to extending the research effort of WQRA, is to provide both graduate and undergraduate students with exposure to industry through their involvement with research projects which are aligned with the needs of the industry and with the appropriate skills and experience for employment in the water industry.

During 2008/09 WQRA has designed a range of initiatives under the Education Program which include undergraduate support through the awarding of summer scholarships, implementation of a small grants scheme to support specified activities and postgraduate support through a PhD scholarships initiative. The coming year will also see the implementation of another initiative to support undergraduates in their Honours year. The intent in selecting specific initiatives is to support students at various levels in their studies and enable the industry to have access to researchers at different academic levels and experience.

Education Program initiatives and goals



The Education Program assists in the establishment of a balanced portfolio of both applied and fundamental research to meet the needs of the water industry. It has been designed to attract high quality students across a wide range of targeted disciplines to investigate research topics of value to the industry and that have been identified during the WQRA research prioritisation process. At the completion of the student's research projects, which may be directly industry-linked or of a fundamental nature, a pool of trained research professionals with exposure to water industry issues will be available to contribute to the water industry. Furthermore, the Program provides a mechanism by which WQRA can leverage the in-kind expertise of a wider range of research providers for the relatively small investment of postgraduate scholarships and consumables/minor equipment, making it a truly collaborative Australia-wide organisation.

The CRCWQT experience demonstrated that support for students early in their research careers provided excellent exposure to this vital and complex Australian industry, and added incentives to stay involved with the industry by seeking employment following the completion of degrees. Final data from the CRC showed that 90% of graduates from the CRC Education Program were subsequently employed in the water sector or in related health or environmental areas.

In 2008-09 Member organisations participated in the Education Program by submitting a range of projects which resulted in an excellent summer scholarship program involving ten students from around the country. Discussions were held with many Member organisations to canvass ideas for new initiatives that could make the Education Program even more useful to industry members. Some of these ideas will be developed further over the course of the next year. Two new PhD students were enrolled in the past year.

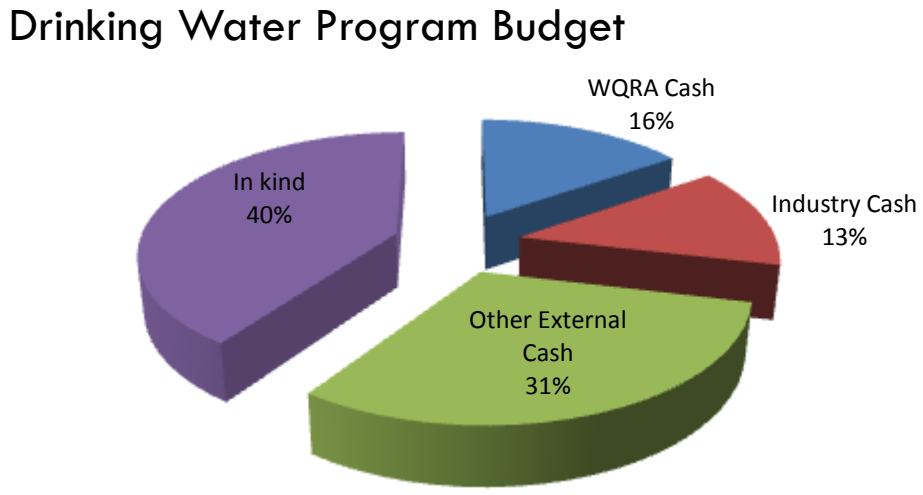
Drinking Water Program

The focus of the Drinking Water Program has been on the development of collaborative research projects that address critical knowledge gaps in the public health aspects of drinking water quality. In 2008-09 the main areas of research development have been in chemical and microbiological contaminants in water supplies, water supply quality in rural and remote regions, optimisation of treatment processes and distribution systems, and public perceptions of water supplies.

The key achievements for the Drinking Water Program include:

- Development of a draft information package, including diagrams, maps and tables, through the project 'Guidelines and Best Practice Documentation - Water Supply in Remote Indigenous Communities' for review by the National Water Commission. It is anticipated that the information package developed through this project will be launched during Water Week in 2009
- Completion of the CRCWQT report 'Towards a Risk Management Manual for Drinking Water Catchments and Sources' by Water Futures
- Engagement in the National Climate Change Adaptation Network and participation in stakeholder meetings
- The finalisation of the Global Water Research Coalition Project 'International Guidance Manual for management of Toxic Cyanobacteria' for the GWRC Board in November 2009, followed by public release in early 2010, and
- Continued support for the four Water Research Foundation projects in the DW Program, three of which are nearing completion of the final research reports, while the other commenced in March 2009 to investigate 'Alternative and Innovative Methods for Source Water Management of Algae and Cyanobacteria' and is expected to be completed at the end of 2011.

Total investment committed to the Drinking Water Program at 30 June 2009 – Total Budget $13,114,413



Drinking Water Project Updates

Existing WQRA projects

There were nine projects that were either transferred from the CRCWQT or initiated by the CRCWQT and contracted by WQRA. The projects underway during 2008-09 included:

WQRA Project 1001-08

Guidelines and Best Practice Documentation – Water Supply in Remote Indigenous Communities

Project Leader	Peter Taylor
Organisations Involved	CAT, Water Corporation, Power and Water, NSW Department of Health, National Water Commission
WQRA Funding	$0
Industry Funding	$0
Other External Funding	$250,000
In-Kind Contributions	No formal in-kind agreements
Total Project Value	$250,000
Expenditure to 30 June 2009	$225,000
Date of Board Approval	Pre WQRA
Start Date	March 2008
Status	On final milestone

Background and Relevance

A study by the Commonwealth Department of Families, Community Services and Indigenous Affairs in partnership with the Centre for Appropriate Technology and the Desert Knowledge CRC, in collaboration with the CRCWQT, demonstrated an effective process for engaging remote Indigenous communities in developing drinking water management plans. The visual and written information resources developed from this project were well received by the community members and were effective in enabling communities, with facilitation, to plan the management of their water resources and implement the Australian Drinking Water Guidelines.

The project further identified that the capacity of service providers, including government agencies and utilities, to implement a similar process with other communities could be significantly strengthened with appropriate resources.

In response to the outcomes of this project, the National Water Commission (NWC) developed a proposal to facilitate opportunities for collaborative work surrounding provision of potable water supply to remote Indigenous communities. A Workshop to explore these opportunities was held at the NWC on 23 March 2007. The main focus of the Workshop was on incorporating risk assessment approaches and local community empowerment in water supply arrangements.

The outcomes of the workshop led to the development of this current project. The purpose is to revise key documents, including aspects of the Australian Drinking Water Guidelines, and develop an information package, including materials such as diagrams, maps, and tables, that assists with preparing usable and understandable drinking water management plans.

Research Approach

The aim of the NWC project was to develop a Field Guide that will assist service providers, including government agencies and utilities, develop drinking water management plans in consultation and cooperation with remote Indigenous communities. The Field Guide consists of materials (e.g. booklets, pictures, and maps) containing the following:

- A summary of the policy, regulatory and formal requirements relevant to drinking water management in remote Indigenous communities across Australia
- A risk management framework that identifies common hazards to drinking water quality in remote Indigenous

communities (both health and aesthetic) and proposes risk mitigation strategies via infrastructure, products and/or procedures
- Standard design, installation and operating instructions for basic water supply infrastructure in remote Indigenous communities throughout Australia
- End-user products such as schematics and drinking water plans for trial Indigenous communities

Project Outcomes

The outcome of this project is to develop an information package including diagrams, maps, tables and posters, to assist small, remote indigenous communities prepare drinking water management plans. To support the implementation of the information package, training materials are also being developed to train facilitators who will deliver this product in small, remote indigenous communities.

Industry Uptake

The Field Guide generated is intended to be an easy to understand resource to assist service providers and remote Indigenous communities with water supply management. A major focus of the Guide is its localised approach, relying on community knowledge to generate the most effective guide to local water management. The materials include a manual for facilitators working with communities and there will be identification of opportunities for further investment to enhance adoption of this material and improve water planning in remote indigenous communities.

Progress During 2008-09

A draft Field Guide was trialled in four indigenous communities. The feedback received from these communities has been incorporated into a revised Field Guide that is currently undergoing a peer review through the NHMRC. The Field Guide will be publicly available by the end of 2009.

WQRA Project 1002-08

Towards a Risk Management Manual for Drinking Water Catchments and Sources

Project Leader	Dan Deere
Organisations Involved	Water Futures
WQRA Funding	Consultancy
Industry Funding	$5,000
Other External Funding	$0
In-Kind Contributions	$0
Total Project Value	$5,000
Expenditure to 30 June 2009	$5,000
Date of Board Approval	Residual from CRC
Start Date	October 2008
Status	Completed

Background and Relevance

The scope of work was to complete the Final Project Report for the "Towards a Risk Management Manual for Drinking Water Catchments and Sources (CRCWQT Project Number 202102)'. This report is now available on the WQRA website.

WQRA Project 1003-08

Evaluation of Integrated Membranes for Taste & Odours and Algal Toxin Control

Project Leader	Gayle Newcombe
Organisations Involved	AWQC, Veolia Water North America, United Water International, Water Research Foundation
WQRA Funding (CRCWQT Transferred)	$96,000
Industry Funding	$50,000
Other External Funding	$208,090
In-Kind Contributions	$199,410
Total Project Value	$553,500
Expenditure to 30 June 2009	$305,916
Date of Board Approval	Transferred from CRCWQT
Start Date	December 2007
Status	In progress

Background and Relevance

Tastes and odours and algal toxins associated with blue-green algae are an issue for water authorities world-wide. Membrane processes, particularly when used in conjunction with additional treatment technologies such as coagulation and/or activated carbon, have the potential to eliminate aesthetic and health issues relating to cyanobacteria. However, to date there has been no comprehensive, systematic study of combined water treatment processes including membranes.

Research Approach

This project will evaluate ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) membranes, in integrated treatment systems, for the removal of taste and odour compounds and cyanobacterial toxins.

Project Outcomes

The outcomes of the project will be:

- Determine the parameters controlling the effectiveness of NF and RO membranes for the retention of MIB, geosmin, cylindrospermopsin and the most common microcystin variants
- Develop a surrogate test to confirm the efficacy of these membranes
- Develop an UF-IMS ideally suited to the removal of dissolved cyanobacterial metabolites
- Determine the most effective treatment within an IMS for the removal of cyanobacteria cells
- Determine the extent of intracellular metabolite leakage expected from cyanobacteria cells during treatments such as MF or coagulation
- Identify the most effective IMS for the treatment of cyanobacteria and/or dissolved metabolites

Industry Uptake

Extracellular cyanobacterial metabolites are not well removed by conventional water treatment processes; however NF or a PAC/UF hybrid system may provide a feasible alternative. Such membrane processes are becoming increasingly widespread in the Australian water industry for the treatment of drinking water. While methods such as oxidation and powdered activated carbon adsorption alone currently exist for the removal of these cyanobacterial metabolites, the growth of membrane technology within the industry has increased and consequently the demand for expertise in the application of membranes for cyanobacterial metabolite removal is required.

Progress During 2008-09

A pilot plant study was completed by Veolia North America at the Eagle Creek Reservoir, Indianapolis, studying the removal efficiency of MIB and geosmin using powdered activated carbon as a pre-treatment to UF. Results of this study were included in the second periodic report to AwwaRF (now Water Research Foundation).

Experimental work on NF/RO removal efficiency trial commenced in August 2008 and was completed in June 2009. Two sets of testing were completed first using ultrapure water dosed with metabolites and second using

natural waters dosed with metabolites. Results show that NOM fouling only impacts cylindrospermopsin removal using loose NF membranes. Results also show that while tight NF membranes remove metabolites to above 85%, loose NF membranes remove lower amounts and the amount removed cannot be determined by the molecular weight of the metabolite. Charge and hydrophobicity of the metabolite are more important factors in determining the removal of microcystin variants than the pore size of the membrane for loose NF membranes.

Research regarding the removal of intact cyanobacterial cells has commenced and several jar tests evaluating the best coagulant and dose for pre-coagulation have been conducted. Trials involving pre-dosing of powdered activated carbon prior to MF have also occurred. Laboratory trials of an integrated membrane system will commence shortly.

WQRA Project 1004-08

Establishing Australian Health Based Targets for Microbial Water Quality

Project Leader	Martha Sinclair
Organisations Involved	Monash, NHMRC
WQRA Funding	$129,387
Industry Funding	$0
Other External Funding	$129,387
In-Kind Contributions	$107,971
Total Project Value	$366,745
Expenditure to 30 June 2009	$0
Date of Board Approval	November 2008
Start Date	Has not commenced
Status	Approved by NHMRC – due to commence during 2009-10

Project Objective:

The purpose of this project is to:

- develop health impact models for waterborne pathogens by using data from existing sources (surveillance data, microbiology laboratories, hospitals, health departments) on the frequency, severity and outcomes of gastroenteritis caused by enteric pathogens in Australia
- coordinate expert groups and workshop discussions in order to evaluate updated international weightings given to gastroenteritis outcomes, thereby facilitating appropriate interpretation of these weightings relevant to the Australian setting
- combine the outcomes of the two arms of the project to develop Australian-specific DALY models for key waterborne pathogens which can be incorporated into the ADWG and the AGWR

WQRA Project 1005-08

Alternative and Innovative Methods for Source Water Management of Algae and Cyanobacteria

Project Leader	Mike Burch
Organisations Involved	AWQC, National Cheng Kung University (Taiwan),Virginia Tech University (Virginia), University of Adelaide, Water Corporation
WQRA Funding (transferred from CRCWQT)	$220,000
Industry Funding	$25,000
Other External Funding	$138,889
In-Kind Contributions	$618,377
Total Project Value	$1,002,266
Expenditure to 30 June 2009	$18,763

Date of Board Approval	Transferred from CRCWQT
Start Date	March 2009
Status	In progress

Background and Relevance

Algicides have long had a role in reservoir management for control of algae and cyanobacteria. They have the attraction of terminating the problem at the source in the reservoir, and this is a "once-off", if treatment is successful. The algicide of choice is copper sulphate, which has been used widely to control algal blooms in water supply storages and lakes for over 100 years. It is generally regarded as effective, economical and safe for operators to use. Increasingly however, in both Australia and the US, copper is being regarded less favourably as the preferred option due to its adverse impacts on the aquatic ecosystem. In this context there is awareness within the water industry that the use of copper sulphate is unsustainable and alternatives need to be found. This project was formulated to review and evaluate possible alternatives to copper sulphate that have potential for application in water supply reservoirs.

Research Approach

This project will evaluate a range of alternative and innovative techniques for control of algae and cyanobacteria that have potential for application in drinking water reservoirs. The study will consider a range of commercial products and some other techniques that are available in the US, Australia and Asia but have differing degrees of acceptance and testing within the water industry. The methods or options to be tested include: Alternative Algicides - hydrogen peroxide-based compounds and chelated copper compounds; Algistats - modified clay for phosphorus binding and removal; Bioaugmentation agents - bacterial strains for nutrient conversion and reduction; Mixers - lake circulation devices for algal and cyanobacterial growth reduction; Ultrasound - low energy in situ ultrasound transducers for algal inhibition and Hybrid Ultrasound/Ozone algicide system - novel device based around treatment with a combination of ultrasound and ozone.

Progress During 2008-09

The first stage of this project was to undertake a literature review and include all alternative and innovative techniques for algal control, including assessing their potential application in drinking water supplies. This activity is in progress and is expected to be completed by September 2009.

Project Outcomes

The project output will be rigorous testing of the effectiveness, applications potential and cost of the alternatives to copper sulphate. The experimental testing is designed to assess the mechanisms of action or operation of the proposed control methods. The results will provide a comparison of a range of selected methods such as alternative algicides, nutrient removal and binding, lake circulation, ultrasound and other novel techniques with the current use of copper sulphate for control.

WQRA Project 1006-08

Implications for enumeration, toxicity and bloom formation. Are there more Toxins Genes than Cyanobacteria?

Project Leader	Chris Saint
Organisations Involved	AWQC, United Water International, University of Tennessee (USA), Water Research Foundation
WQRA Funding	$0
Industry Funding	$10,000
Other External Funding	$232,651
In-Kind Contributions	$270,521
Total Project Value	$483,784
Expenditure to 30 June 2009	$203,876
Date of Board Approval	Transferred from the CRCWQT
Start Date	October 2006
Status	Final report in preparation

Background and Relevance

DNA detection strategies such as real-time PCR can rapidly assess whether toxin genes are present in cyanobacteria and what type of organisms these may be. Despite these capabilities, some important knowledge gaps remain in terms of toxin production: if a set of cyanobacterial strains all produce the same toxin, what makes some strains produce more toxin than others; and how does this relate to the number and distribution of the toxin genes within the genome? These questions are important because in all reports where real-time PCR is used to detect the toxin genes, more toxin genes are observed than toxic algae present.

Research Approach

- Establish the relationship between cyanobacterial genes, especially toxin genes, and cells using real-time PCR, cell counts and flow cytometry
- Investigate the effect of growth on gene number
- Examine if the number of toxin genes affects toxin production
- Examine the potential of combined data to better forecast the growth of toxic cyanobacteria in water systems

Project Outcomes

- Growth-related effects on gene copies observed for several toxic species including *Cylindrospermopsis*, *Microcystis* and *Anabaena*
- Relationship between toxin genes and toxin production for *Cylindrospermopsis* and *Microcystis*
- Development of a predictor of bloom status

Industry Uptake

This work will provide a much deeper understanding of the data provided by real-time PCR and other methods of DNA detection in the context of toxic cyanobacteria. The better interpretation of this data is likely to provide the industry with enhanced tools monitoring and forecasting the growth of toxic cyanobacteria.

Progress During 2008-09

All experimentation is complete and the first draft of the project report has been prepared.

WQRA Project 1007-08

Methods for Measuring Toxins in Finished Waters

Project Leader	Andrew Humpage
Organisations Involved	AWQC, Water Research Foundation
WQRA Funding (transferred from the CRCWQT)	$75,000
Industry Funding	$0
Other External Funding	$192,111
In-Kind Contributions	$570,779
Total Project Value	$837,890
Expenditure to 30 June 2009	$228,689
Date of Board Approval	Transferred from the CRCWQT
Start Date	December 2006
Status	Draft final report submitted to the Water Research Foundation

Background and Relevance

The principal objective of this project was to investigate a range of biological assays that may be suitable for detecting toxins in finished drinking water. The methods tested were screening assays capable of detecting the effects of a range of toxins that are known to potentially contaminate source waters or that might be introduced deliberately into the drinking water stream. A key objective was to define bioassay-compatible methods for

quenching chlorine in finished water as both chlorine and some quenchers are known to interfere with current toxicity screening methods. The project was jointly funded by the CRC for Water Quality and Treatment, the Water Research Foundation (previously AwwaRF) and the United Kingdom Drinking Water Inspectorate. The project has now been transferred to Water Quality Research Australia.

Research Approach

Various standard and novel chlorine neutralising agents ("quenchers") were tested for (a) their effectiveness in removing free chlorine from water samples, and (b) their compatibility with a range of biological assay types. Representative assays from a range of modalities were tested (enzyme-linked immuno-sorbant assay (ELISA), mammalian and bacterial cell-based assays, enzyme-based assays, and an invertebrate assay). We also investigated the effects of the quenchers when the assays were used to detect a range of toxins. The draft final report provides recommendations for suitable quenchers that can be used with each assay type so that toxicity can be accurately determined in finished drinking waters.

Project Outcomes

The project is now finished, and a draft final report has been submitted to the Water Research Foundation for review by the PAC. Of the assays tested, the microcystin ELISA, the CheckLight bacterial assay, and the Artemia invertebrate assay have been found to be very sensitive to the presence of free chlorine, while the mammalian cell- and enzyme-based assays have proven to be quite robust. Ascorbate was found to be a quencher compatible with the ELISA and invertebrate systems, while thiosulphate was the best quencher for the bacterial system. Overall, these results suggest that free chlorine at the levels found in finished waters should not be an issue for most of the bioassays we currently use, as long as quenching methods are optimised where required.

Industry Uptake

This project will help enable implementation of a biosecurity toxicity screening protocol for water in the drinking water distribution system.

Progress During 2008-09

All experimental was completed and the draft final report was submitted to the Water Research Foundation.

WQRA Project 1008-08

Optimal Water Quality to Minimise Distribution System Problems

Project Leader	Mary Drikas
Organisations Involved	AWQC, Delft University of Technology, United Water International, SA Water, Grampians Wimmera Mallee Water, Water Corporation, Orica Watercare
WQRA Funding (transferred from the CRCWQT)	$232,858
Industry Funding	$327,500
Other External Funding	$0
In-Kind Contributions	$1,050,068
Total Project Value	$1,610,426
Expenditure to 30 June 2009	$205,250
Date of Board Approval	Transferred from the CRCWQT
Start Date	October 2006
Status	In progress

Background and Relevance

Provision of good quality water at the customer tap is the aim of all water utilities. This is usually achieved by management of raw water sources such as catchments and/or reservoirs followed by the use of one or more treatment processes. The treated water is then distributed to the customer via pipework systems networked to provide water from the distribution mains to the customer tap. Water utilities spend considerable time and money cleaning and flushing distribution systems to minimise water quality deterioration at the customer tap as the major response to distribution system issues. However one of the key parameters affecting water quality at the customer tap is the water quality that enters the distribution system and whilst water treatment is implemented by many water utilities, there has not been a focus on identifying the appropriate water quality to minimise water

quality deterioration in the distribution system. As particles and organic matter play a key role in water quality deterioration, the treatment processes should, at a minimum, provide effective removal of these components.

Research Approach

The aim of this project is to determine the extent of treatment necessary to produce water quality which minimises water quality deterioration after passage though the distribution system. This will be achieved by comparing the impact of a range of water qualities provided from four different treatment schemes on four parallel distribution test rigs, with detention time of three days, including two overnight stagnation periods and monitoring for a period of 12 – 18 months. The water entering the test rigs will be chlorinated to satisfy chlorine demand but with minimal chlorine residual entering the test rigs to maximise biofilm growth. The proposed treatment processes used to supply these test rigs are:

- Coagulation/sedimentation/high rate filtration as used in a conventional treatment plant to provide removal of particulates and some organics
- MIEX® for removal of organics followed by coagulation for solids removal, with and without granular activated carbon (GAC) for further removal of biodegradable organics
- Nanofiltration, with microfiltration as pre-treatment, to provide high purity water

A range of water quality parameters and analytical tools including on-line techniques will be used to monitor treated water quality and changes within the distribution systems. The key parameters to be monitored will include particle composition, microbial growth, NOM concentration and character, and biofilm growth. This will identify water quality parameters and analytical tools which are most suited for monitoring water quality within distribution systems and can be used to predict water quality deterioration.

Project Outcomes

It is intended to use information gained from this project to validate and build upon established modelling tools to enable the prediction of the water quality at the customer tap based on the water quality leaving the treatment plant. This will be an additional component to one of the already existing hydraulic distribution models.

Industry Uptake

The substantial external funding provided for this project from a number of industry partners highlights the interest in identifying the impact of incoming water quality on distribution performance and water quality reaching the customer tap.

Progress During 2008-09

- The distribution test rigs were constructed and installed at Mt Pleasant, SA. The distribution test rigs were pressure tested, soaked for several days with high chlorine and extensive flushing undertaken over a three month period (May – July) to achieve low particle counts in all systems
- Detailed documents for the control system were designed and the installation of the control systems completed. A number of identified faults with this installation took some months before they were addressed satisfactorily
- DCM Process Control have loaned and installed two S::CAN units to continuously monitor water quality from a number of points within each of the distribution test rigs. A sample board was constructed to enable control of the sampling. An online chlorine demand sensor has been installed (again on loan) to monitor residuals entering the distribution test rigs
- Modification of the research facility at Mt Pleasant, to house the treatment plants, construction of an additional shed to house the S::CANs and sampling pipework and associated site works has been completed. Instrument and minor plant acquisitions including purchase of chlorine dosing pumps and system feed pumps were completed
- The NF rig to be used in one of the treatment processes was upgraded and automation installed to enable continuous operation
- All treatment plants were modified and operated on a continuous basis to ensure satisfactory performance. Preliminary data has been collected from all treatment plants since June

WQRA Project 1009-09

Physico-chemical controls on growth, toxicity and succession of Microcystis and Anabaena species in Sydney water supply reservoirs

Project Leader	Professor David Waite
Organisations Involved	UNSW, Sydney Catchment Authority, ARC Linkage
WQRA Funding	$189,000
Industry Funding	$90,000
Other External Funding	$180,000
In-Kind Contributions	$609,912
Total Project Value	$1,068,912
Expenditure to 30 June 2009	$0
Date of Board Approval	March 2009
Start Date	September 2009
Status	Approved, but not commenced

Background and Relevance

Microcystis and *Anabaena* species have been identified as the major algae of concern in the Sydney water supply system with blooms (identified as >2000 organisms/mL) of these organisms frequently occurring in sections of Lakes Burragorang, Wingecaribee, Yarrunga and Nepean (DECC, 2005). Insight into the forms of nutrients that are most readily assimilated by *Microcystis* and *Anabaena* species prevalent in Lake Burragorang and other Sydney water supply reservoirs will assist in determining the key drivers to occurrence of blooms of these organisms, particularly when combined with an understanding of the spatial and temporal distribution of the forms of nutrients that predominate in the reservoirs of interest, the dynamics of transformation between these various forms and the key parameters of light and temperature. In addition, it now appears that, in addition to growth rate, the particular forms in which nutrients are acquired may influence the extent of toxin production. Thus, the findings of the project will also assist in elucidating the conditions under which toxin generation is expected.

Specific innovative aspects of this project are centred around the hypothesis that certain physicochemical conditions in the reservoirs of interest (most likely high organic content, iron limiting conditions) stimulate the production of the reactive oxygen species superoxide by *Microcystis* and *Anabaena* which assists in rendering both iron and phosphorus more bioavailable but which, in the process, increases the extent of both internal toxin synthesis and exudation. This hypothesis will be examined in laboratory batch and continuous cultures and the findings related back to the forms of nutrients and their transformation dynamics within the reservoirs of interest.

Mathematical models describing the transformation dynamics of both major and minor nutrients and the impact on nutrient uptake will be developed from the results obtained in batch and continuous culture. While such a model has been developed for transformations and uptake of iron by *Chattonella marina* at pH 8, particular challenges exist in determining appropriate rate constants of key processes at more acidic pHs though some recent progress in this regard has been made. While the models developed to date have focused on iron transformation dynamics and uptake kinetics, extension to include iron-phosphorus interactions represents an important developmental step. Aspects of this coupling at pH 8 are currently under investigation by Cl Waite's APAI doctoral student Mark Bligh (funded on ARC Project LP0561150) though particular development to extend this work to lower pHs more typical of freshwaters will be required.

The models that evolve from batch and continuous culture studies will provide a basis for interpretation of nutrient form and bioavailability within the reservoirs of interest under particular physical conditions (stratification behaviour, depth in the water column, mixing conditions, light regime, pH, etc). While we do not aim to produce models for nutrient form and availability under all conditions, the insights gained from controlled laboratory studies and "common sense" application to natural conditions should be possible when combined with a knowledge of the major nutrient inputs to the reservoirs coupled with some understanding of the hydrodynamics and transport time-scales within the reservoirs of interest.

Information will also be gained with respect to both genetic and chemical aspects of toxin production by both *Microcystis* and *Anabaena* which will i) enable comparison of quantitative PCR measures of toxin gene synthesis expression with the actual concentration of toxin produced, and ii) assist in the development of analytical approaches to measuring the concentration of toxin both within and external to cells. The latter information will be of particular value in assessing the possible impact of water treatment processes on toxin release as a result of cell lysis.

Research Approach

The objectives of this project are to:

- determine the key nutrient (N, P and Fe), light and temperature requirements of *Microcystis* and *Anabaena* species (including the impact of nutrient form and transformation dynamics on uptake kinetics) that typically occur in Lake Burragorang and other selected Sydney water supply reservoirs and to gain insight into the mode of nutrient acquisition by the organisms,
- assess the impact of nutrient availability and growth conditions on production of toxins by these *Microcystis* and *Anabaena* species
- relate the nutrient requirements, growth characteristics and exudate production of the *Microcystis* and *Anabaena* species to biogeochemical and physical conditions in Lake Burragorang and other Sydney water supply reservoirs

Project Outcomes

A key outcome of this project will be the development of knowledge that will assist in the management of water supply reservoirs such that water quality goals are met. In particular, information gained will assist in determining key factors responsible for growth of *Microcystis* and *Anabaena* species in the reservoirs of interest and will therefore provide insight into management options available to reduce both the occurrence of blooms and the toxicity potentially associated with these blooms. Additionally, insight into the spatial and temporal distribution of iron in the selected reservoirs (and the dynamics of interconversion between key iron species) will assist in understanding (and thus managing) aspects of water quality associated with deep storage extraction.

New fundamental insights into the means by which *Microcystis* and *Anabaena* acquire key nutrients should also result from these studies with implications to the understanding of the functioning of cyanobacteria in general. The hypothesised link between reactive oxygen species generation, nutrient acquisition and (possibly) toxin generation will, if confirmed, provide a major advance in our understanding of how these ancient organisms have learnt to adapt to an oxic environment.

The presence of toxic cyanobacteria in public water supplies presents a health threat that must be managed. Thus, SCA monitors the location of blooms within water supply reservoirs and modifies the off-take point as appropriate to ensure minimal entry of cyanobacteria into the supply system. While this approach is generally effective, the desire to (if at all possible) avoid high iron and manganese levels in deeper waters presents a lower limit to extraction depth. The outcomes of this project will inform the limit to extraction in the studied reservoirs with regard to toxic cyanobacteria.

Industry Uptake

The presence of toxic cyanobacteria in public water supplies presents a health threat that must be managed. Thus, the SCA monitors the location of blooms within water supply reservoirs and modifies the off-take point as appropriate to ensure minimal entry of cyanobacteria into the supply system. While this approach is generally effective, the desire to (if at all possible) avoid high iron and manganese levels in deeper waters presents a lower limit to extraction depth. The outcomes of this project will inform the limit to extraction in the studied reservoirs with regard to toxic cyanobacteria.

Progress During 2008-09

Project has not commenced

WQRA Project 1010-09

Characterisation and management of taste and odours from coal tar enamel lined mains

Project Leader	Felicity Roddick
Organisations Involved	RMIT, Melbourne Water, South East Water Limited, City West Water, Yarra Valley Water
WQRA Funding	$115,000
Industry Funding	$13,500
Other External Funding	$0
In-Kind Contributions	$165,040
Total Project Value	$293,540

Expenditure to 30 June 2009	$0
Date of Board Approval	April 2009
Start Date	August 2009
Status	Contract negotiation

Background and Relevance

The water supply companies in the Melbourne region have been suffering increased levels of customer complaints regarding taint. The taint appears to occur in water mains that are lined with Coal Tar Enamel (CTE). Complaints are more common in the warmer months.

CTE is composed of polynuclear aromatic hydrocarbons of higher molecular weight than the equivalent petroleum tar (bitumen). It has been used as a water pipe lining since the 1940's, but has recently been phased out. Literature reports on leaching of CTE indicate that some breakdown of the larger PAHs to smaller, more water-soluble PAHs can occur. There are also reports of PAH-degrading bacteria which can mineralise PAHs. Mineralisation is a multi-step process which reduces the PAHs ultimately to carbon dioxide. However, there are many intermediate compounds formed along the mineralisation pathway and some of these may be the source of taint.

Research Approach

Samples of tainted water will be analysed by GC/MS with confirmation by GC-Olfactory and taste panel. Once the molecule(s) causing the taint has been identified, we will attempt to reproduce it in the laboratory using chemical standards, to ensure that the correct taint has been identified. We will also attempt to reproduce the taint from precursors in the pipes and water – microbiological systems may play an important role as the taint compounds could be microbial metabolites.

Remediation of tainted water or prevention strategies will be investigated during the final stage of the project. The strategies to be investigated will be determined by the chemistry of the taint compound(s) and the mechanisms by which they form and then enter the water column.

- Taste tests will be run using a panel of volunteer tasters. We will also prepare taste test for the water company technical staff (those who investigate the customer complaints) to ensure that we have identified the correct taint

Toxicity of the taint-causing chemicals and any treatment process will be checked against international toxicology databases.

Project Outcomes

This project aims to:

- Identify chemicals responsible for T & O from coal tar enamel lined pipes. A desktop survey of the toxicity of these chemicals is included
- Replicate and investigate the mechanism of tainting by laboratory simulation, and to analyse any disinfection by-products
- Investigate methods for eliminating the T & O, and to verify that recommended treatment does not produce toxic by-products

Industry Uptake

The three water retailers in Melbourne are keen to find a solution to this taint problem. They have made a big commitment in funding this project and are involved in the sampling design and management recommendations.

Progress During 2008-09

Project has not commenced.

WQRA Project 1011 - 09

Health effects of Drinking Water from Rainwater Tanks

Project Leader	Karin Leder
Organisations Involved	Monash University, Dept of Health SA, AWQC
WQRA Funding (transferred from	$260,797

CRCWQT)

Industry Funding	$0
Other External Funding	$844,313
In-Kind Contributions	$110,304
Total Project Value	$1,215,414
Expenditure to 30 June 2009	$1,180,144
Date of Board Approval	Transferred from CRCWQT
Start Date	November 2006
Status	Completed

Background and Relevance

Despite the widespread use of rainwater for drinking in rural Australia, health authorities do not endorse its use in urban areas where safe, disinfected tap water supplies are readily available because it is recognised that the microbiological quality of rainwater is variable and it may sometimes cause illness. Uncertainty over the degree of risk has also made some water utilities and developers reluctant to provide untreated rainwater for bathroom or laundry use due to the possibility of inadvertent consumption. This epidemiological study examined whether micro-organisms in untreated rainwater contributed significantly to gastroenteritis among people who drank the water. The National Health and Medical Research Council provided Project Grant support of $844,313 over three years for the epidemiological study, and the CRC provided additional funding to significantly expand the water quality monitoring component.

Research Approach

The study used a double-blinded randomised controlled trial methodology which was developed for a previous CRC study of tap water in Melbourne. Three hundred households in the Adelaide region that already drank untreated rainwater were provided with either real or sham (non-functional) water treatment devices to treat their water. The households recorded details of their health for one year, and then the two groups were compared to determine whether removal of microbial pathogens from rainwater made a significant difference to rates of gastroenteritis. Microbial indicator organisms and pathogens were also monitored in a subset of rainwater tanks.

Project Outcomes

No significant difference was found in the rates of gastrointestinal illness between households drinking rainwater that had passed through real water treatment devices and those drinking rainwater that had passed through sham devices. This indicates that the risk of illness from bacterial or protozoan pathogens in collected rainwater is low for most members of the community. This finding may not apply to people with immune problems or those who have recently switched to drinking rainwater. Although indicators of faecal contamination are frequently found in rainwater tanks, pathogens appear to be relatively rare and generally occur in low numbers.

Industry Uptake

The outcome of this project will be invaluable in shaping policy on acceptable uses of rainwater in an urban setting serviced by an existing reticulated supply, and will be used by public health regulators to base their recommendations for the use of tank water for direct human consumption or situations where inadvertent consumption may occur. It will contribute to the ability of water suppliers to conserve conventional drinking water supplies by providing alternative water sources that are fit for purpose.

Progress During 2008-09

The water quality analysis was completed in 2008-09 and the project report was completed.

WQRA Project 1012-09

Technology Transfer Officer for Water and Wastewater in Remote Indigenous Communities

Project Leader	Peter Taylor
Organisations Involved	CAT
WQRA Funding	$110,000
Industry Funding	$0
Other External Funding	$0

In-Kind Contributions	$0
Total Project Value	$110,000
Expenditure to 30 June 2009	$0
Date of Board Approval	November 2008
Start Date	July 2009
Status	Due to commence in 2009-10

Background and Relevance

The Centre for Appropriate Technology's (CAT) Technology Transfer Officer (TTO) project dealing with water quality and treatment in Indigenous communities under the Cooperative Research Centre for Water Quality and Treatment (CRCWQT) finished with the completion of the CRC in June 2008. Water Quality Research Australia's (WQRA) new TTO project at CAT commenced in July 2009. This report summarises the outcomes of the role in the intermediary period.

During this period the TTO finalised CRCWQT research projects and initiated one new collaborative WQRA research project, provided technical advice to Indigenous communities and Commonwealth, State and Territory government agencies and supported larger CAT projects. The TTO also participated in several national and local Indigenous and water forums, published frequently in CAT's Our Place magazine and hosted a WQRA summer student.

Commencing from July 2009 the role of TTO will be delivering to the following priorities in regard to water quality and health:

- Provide a link between national and international water research and practice and Indigenous communities
- Provide a basis for coordination of research needs, practice and Indigenous knowledge between Commonwealth, state and territory agencies
- Facilitate the sharing of knowledge and practice amongst WQRA members for small water systems
- Facilitate a Small Water Supplies Community of Practice amongst WQRA members and maintain a network of WQRA members with an interest in small water systems – both nationally and internationally
- Provide a direct link between the needs of Indigenous people and research related to supplying safe drinking water and treatment knowledge, as well as a link to researchers regarding knowledge gaps and emerging issues in these remote locations

Progress During 2008-09

The TTO role continued to provide support in the transition from the CRCWQT to WQRA. Formal arrangements are now in place and WQRA will commence funding 50% of this position for the next two years. The role of TTO assisted in the finalisation of two CRCWQT research projects:

- 'Waterproofing Homelands' Kimberley Water Strategy Pilot: the completion and publication of the final report "Small water system reliability in remote Indigenous communities in the Kimberley", with key recommendations around the need for greater transparency, accountability and simplification in the governance of water supplies, regular planned maintenance programs and communication between residents and service delivery agencies
- Finalisation of Rainwater Harvesting Management Project for Mabunji Outstations with the following outcomes:
    - Analysis of water quality and quantity and identification of risk management processes
    - Identification of techniques for engaging householders in a demand-responsive approach for local water management strategies
    - Identification of technical improvements for robust and effective rainwater harvesting design
    - Economic analysis of costs and benefits of rainwater harvesting systems

One new WQRA research project was initiated:

- Scale Formation and Prevention in Indigenous Community Water Supplies: Continuing with previous community-based investigations around the management of hard water, CAT, in conjunction with the University of New South Wales, Power and Water Corporation in the Northern Territory and the Western Australian Water Corporation, is exploring the nature and extent of scale accumulation in order to develop longer term trials to address the problem

Technical advice

- Indigenous communities: The TTO responded to requests from five Indigenous communities and organisations across the Northern Territory and Western Australia in 2008-2009, providing technical support, water quality testing, and water management, technology and infrastructure advice
- Government agencies: The TTO provided technical advice on rainwater harvesting, water treatment and provided links to existing information and tools for management of water supplies to Commonwealth, Northern Territory and Western Australian government agencies

CAT projects

Three larger scale water-related projects have been continued or initiated in the past year:

- Mulga Bore Water Supply: Continuing from a previous assessment undertaken for Anmatjere Community Government Council, the TTO provided ongoing support for Mulga Bore community and Central Desert Shire and their water supply, including provision of a secure groundwater bore and an upgrade of storage tanks
- Feasibility of grassing Hermannsburg women's softball field: In response to MacDonnell Shire Council's request to explore options for grassing the field, various options were explored, including artificial covers, turf and seed lawns. Securing a sustainable source of water was key to the preferred options of using actual grass. The concept design stage is now developing details for using recycled water for the softball field
- Groundwater monitoring and demand management at Bonya: In response to earlier groundwater supply failures, CAT, in conjunction with South East Water of Melbourne, installed remote sensing technology on the groundwater bores and storage tanks at Bonya. This system will help to monitor community use of water and the response of the groundwater supply to its use. Data can be viewed and manipulated from any computer through an internet site and aims to help the community to use their water more sustainably

Smaller water and livelihood projects across CAT divisions were also supported, in particular associated with demand management in the regional offices and an evaluation of the Bushlight program

The TTO also contributed to the following larger projects undertaken by CAT:

- National Indigenous Infrastructure Guide: The TTO contributed to both the water and wastewater chapters of the Guide, produced in conjunction with the Department of Families, Housing, Community Services and Indigenous Affairs
- Molyhil Royalties Project: In conjunction with the Central Land Council, CAT continues to work with the native title holders of land being proposed for a molybdenum mine near the Plenty Highway (NT) to develop a staged infrastructure investment plan for five outstations from the expected mining royalties. The TTO contributed to developing the staged investment plan, particularly around water supply infrastructure
- National Water Commission (NWC) Guidelines and Best Practice Documentation Project: The TTO conducted one of the trials of the Community Water Planner Field Guide in Mandangala, in the Kimberley in Western Australia. Two visits, workshops and interviews with several residents contributed to the overall package developed for the NWC project
- Regional Infrastructure Management System for Small Remote Communities: The TTO contributed to the development of a web-based database to support Shires and Outstation Resource Agencies to manage the provision of essential and municipal services, in particular water infrastructure, and the maintenance of associated infrastructure in small remote communities

Presentations and Publications

The TTO presented at the following forums:

- University of Technology Sydney, final year engineering students: *Engineering in Remote and Overseas Context*, August 2008
- University of New South Wales, summer school students: *Water in Remote Indigenous Communities,* June 2009
- Challenges for Environmental Science and Engineering conference, Townsville: *Removal of nitrates from groundwater in remote Indigenous settings in arid Central Australia,* July 2009

The TTO also produced the following, for CAT's Our Place magazine:

- *Removing scale from household fittings and appliances. Bushtech #39*. Our Place, 32, August 2008
- *Water Treatment. Bushtech #42*. Our Place, 33, December 2008
- *Rainwater harvesting*. Our Place, 34, June 2009

Summer Student

The TTO hosted a WQRA summer scholarship student from December to February 2009. The program offered undergraduate students from a variety of disciplines the opportunity to undertake further research for ten weeks over summer. The 2009 project "Managing water demand in remote Australian Indigenous communities for improved livelihoods" helped a resource management student from Southern Cross University in Lismore to gain useful experience of Indigenous experience and supported an ongoing groundwater monitoring project undertaken by CAT.

WQRA Project 1013-09

Water Chemical Database

Project Leader	Paul Heaton
Organisations Involved	Power and Water, New Zealand Ministry of Health, Institute of Environmental Science and Research Limited, Pacific Islands Applied Geoscience Commission
WQRA Funding	$0
Industry Funding	$50,000
Other External Funding	$0
In-Kind Contributions	$0
Total Project Value	$50,000
Expenditure to 30 June 2009	$0
Date of Board Approval	Transferred from CRCWQT
Start Date	October 2008
Status	In progress

Background and Relevance

Australia is an urbanised country, with most of its population living in larger cities. The water supply and sanitation infrastructure provided in these large population areas is sophisticated and reliable and people typically receive a safe, reliable and adequate water supply to their homes. Water utilities in these urban centres are relatively well resourced and are able to have appropriately qualified people oversee the water treatment processes and monitor the water quality to protect public health.

The delivery of water to rural and remote communities is often the responsibility of a number of smaller organisations that generally lack technical capacity and expertise to effectively service, maintain and manage water supply systems. Often very small communities are responsible for managing their own water supplies and typically don't have ready access to resources for the storage and interpretation of water quality monitoring results.

Research Approach

The proposal is to develop a water quality data management system for use in Pacific Island countries, based on the Water Information New Zealand System. It will also be provided to the WHO International Network on Small Community Water Supply Management as a tool for general use in developing countries in Asia, Africa and South America.

The Water Quality Monitoring Database is planned in three parts. Those parts being delivered to the specification of NZAID are the core system and the enhanced system. A third part is the inclusion of chemical modules for WQRA, as detailed below:

- Inclusion of the Australian Drinking Water Guidelines as one of the baselines for monitoring compliance against within the database (similar to EPA, WHO Guidelines)
- Acknowledgement and inclusion of the WQRA logo within the database and other project products, as one of the sponsorship agencies

Addition of a chemical water quality module within the database, with preliminary analysis of data results, to add value to the interpretation of data for information and knowledge regarding water quality.

Project Outcomes

Water quality monitoring is carried out to verify the effectiveness of 'barriers' and the ultimate quality of the

water being supplied to consumers. Therefore water quality analysis and reporting remains an important component of the management of water supply systems and facilitating the interpretation of these results in reference to appropriate material will greatly assist small systems effectively manage and maintain their water supply to ensure the protection of public health.

Industry Uptake

The software developed is proposed to be available at no cost. It is anticipated that industry uptake will:

- Provide central storage location for data and analysis of historical water quality results
- Improve the overall management of small water supplies systems
- Better inform small communities about their water quality displayed in a readily understandable format
- Increase local capacity, understanding and responsibility for water quality issues in their community

Progress During 2008-09

A workshop was held in October 2008 (following the Drinking Water program Issues workshop). The outcomes of this workshop informed the additional elements that were required for the database. These elements are currently being developed and added to the database. The project is due to be completed at the end of 2009.

New WQRA projects

Progress has been made in developing the project proposals for the eighteen short-listed DW project concepts.

As of 30 June, five projects have been approved by Board, another five projects are being assessed by the Project Review Team and the remaining nine are being developed.

WQRA Project 1014 - 09

New methods for rapid detection of pesticides and other organic pollutants in unprotected catchments

Project Leader	Nicola Porter
Organisations Involved	RMIT, Melbourne Water, Goulburn Valley Water, Dept Primary Industries (VIC), ARC Linkage
WQRA Funding	$30,000
Industry Funding	$120,000
Other External Funding	$293,371
In-Kind Contributions	$232,103
Total Project Value	$675,474
Expenditure to 30 June 2009	$0
Date of Board Approval	November 2008
Start Date	January 2010
Status	Submitted to ARC May 2009, Pending ARC decision

Project Objective:

The aims of this project are to:

- Develop a rapid, robust, portable screening method for the detection of a range of pesticides and their environmental degradation products
- Develop a method, or series of methods, to detect compounds not currently monitored or considered to be a problem

WQRA Project 1015 - 09

Novel treatment methods for reduction of bromide and iodide in drinking water sources

Project Leader	Anna Heitz
Organisations Involved	Curtin, Water Corporation, ARC Linkage
WQRA Funding	$210,000
Industry Funding	$590,000
Other External Funding	$921,317
In-Kind Contributions	$912,053
Total Project Value	$2,633,370
Expenditure to 30 June 2009	$0
Date of Board Approval	April 2009
Start Date	January 2010
Status	Submitted to ARC May 2009, Pending ARC decision

Project Objective:

The purpose of this project is to:

- Draw together all relevant information on adverse impacts of elevated levels of bromide and iodide from related current water quality projects, and build on this information if necessary
- Find methods to minimise adverse impacts of elevated bromide and iodide concentrations by developing methods of bromide and iodide removal that are relatively easy to install and operate, and that are economically viable for installation in both metropolitan and regional schemes
- Determine if reducing the bromide and iodide concentrations reduce the concentration of DBPs and improve the organoleptic properties of chlorinated and chloraminated finished waters

WQRA Project 1016-09

Water, biota and air pollution – improving Australia's capacity for assessing and managing the risks to wildlife and humans

Project Leader	Beate Escher
Organisations Involved	EnTox, SEQ Water, Water Secure, CSIRO, ARC Linkage
WQRA Funding	$10,000
Industry Funding	$440,000
Other External Funding	$683,608
In-Kind Contributions	$119,302
Total Project Value	$1,252,910
Expenditure to 30 June 2009	$0
Date of Board Approval	April 2009
Start Date	January 2010
Status	Submitted to ARC May 2009, Pending ARC decision

Project Objective:

The National Research Centre for Environmental Toxicology and its partners plan to expand their research capacities in the evaluation of the risks of organic micropollutants at very low concentrations, where contamination of laboratory equipment and space poses a problem. The proposed clean room and a dedicated GC-MS for ultra-trace analysis will facilitate this type of front-end research. In addition there is the emerging concern about the hazards and risks of metabolite and transformation products of organic micropollutants world-wide, particularly in the context of advanced water treatment, and the proposed LC-MS-TOF will allow the exact identification and quantification of unknowns in complex matrices. The existing infrastructure for routine chemical analysis will act synergistically with the proposed addition that will be dedicated for high quality research at the frontier of detection limits.

WQRA Project 1018-09

Occurrence and management of NDMA and other nitrogenous disinfection by-products in Australian drinking and recycled waters

Project Leader	Gayle Newcombe
Organisations Involved	AWQC, Curtin, Monash
WQRA Funding	$258,331
Industry Funding	$0
Other External Funding	$0
In-Kind Contributions	$202,410
Total Project Value	$460,741
Expenditure to 30 June 2009	$0
Date of Board Approval	May 2009
Start Date	1 September 2009
Status	Approved - Not commenced

Project Objective:
The purpose of this project is to:

- Inform the Australian water industry of the health issues relating to nitrosamines and the implications for the Australian recycled water guidelines and Australian drinking water guidelines
- Undertake a comprehensive survey to identify the levels of nitrosamines in chloraminated drinking water supplies and chlorinated recycled water in Australia
- Undertake inter-laboratory comparisons with Curtin University
- Assist water authorities to identify the risk of exceeding current or future guidelines
- Identify operational parameters that affect the formation of nitrosamines and recommend options to minimise formation of these DBP's
- Identify any issues with nitrosamines that may arise from blending recycled/raw waters as drinking water sources
- Production of guidelines on the strategies that may be applied at water and recycled water treatment plants to minimise formation of these nitrosamines

WQRA Project 1019-09

Scale formation and prevention in small water supplies reliant on groundwater

Project Leader	Professor David Waite
Organisations Involved	UNSW, Power & Water, Water Corp
WQRA Funding	$80,639
Industry Funding	$20,000
Other External Funding	$0
In-Kind Contributions	$114,414
Total Project Value	$215,053
Expenditure to 30 June 2009	$0
Date of Board Approval	May 2009
Start Date	August 2009
Status	Approved - Not commenced

Project Objectives

The purpose of this project is to

- Review the major ion composition of waters considered to be a problem with regard to scale formation. This review will be based on existing data provided by Industry members
- To review methods for measuring the extent of scale formation and possible treatment approaches
- Based on the analysis of the potential extent of the scale problem and treatment options, provide recommendations on appropriate management actions

Based on the research outcomes, it is intended to prepare a Stage 2 project seeking Federal funding to support a comprehensive solution to address the problem of scaling in water supplies.

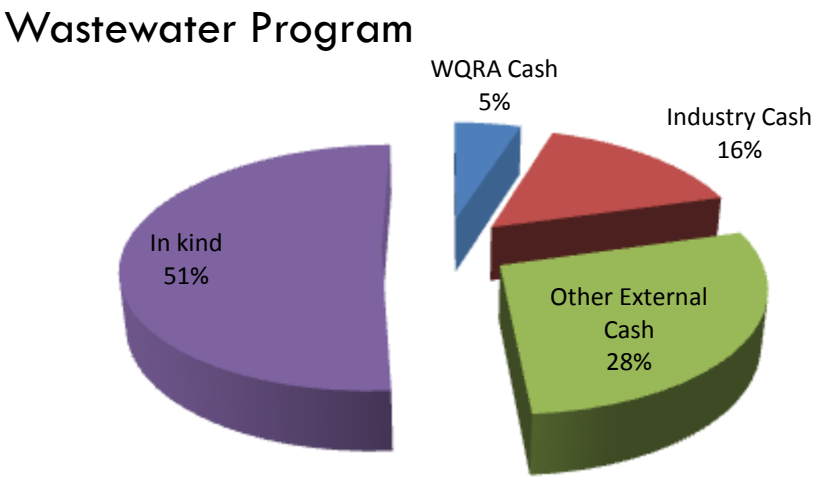
Wastewater and Recycled Water Program

The Wastewater (WW) and Recycled Water (RW) Research Programs are closely aligned with industry needs, originating under the CRCWQT through a series of industry-driven and funded workshops and projects. In late 2008, under the auspices of the newly formed WQRA, a workshop was held to identify current and future priority industry issues for these programs. Key issues identified included membrane and treatment technologies, chemical contaminants, waste stream disposal and reuse, fit for purpose technologies and risk assessment. Project development has subsequently focused on these areas, in addition to completing the important work initiated under the CRCWQT.

Significant achievements in the past year were:

- The initiation of a suite of membrane technology projects, focussing on demonstrating membrane efficacy, particularly for protozoan and virus pathogen removal, with an emphasis on real time monitoring
- Providing supporting evidence for log reduction credits for activate sludge plants
- Developing a suite of tools (i.e. 'environmental toolbox') for assessment of chemical risk for human health and the environment in recycled waters and wastewaters
- Quantifying the risk of pathogens and organic contaminants in biosolids
- The commencement of one of Australia's largest ARC Linkage projects investigating odour and corrosion processes in sewers, in which WQRA is a key collaborator
- The development of two international projects in priority areas with the Global Water Research Coalition and the Water Research Foundation

Total investment committed to the Wastewater Program at 30 June 2009 – Total Budget $29,064,904



Wastewater and Recycled Water Project Updates

Existing WQRA projects

There were seven projects that were either transferred from the CRCWQT or established by the CRCWQT and contracted by WQRA. The projects underway during 2008-09 included:

WQRA Project 2001-08

Quantification of pathogen removal in activated sludge treatment

Project Leader	Therese Flapper
Organisations Involved	Water Futures, LaTrobe University, AWQC, Victorian Smart Water Fund
WQRA Funding	$10,000
Industry Funding	$20,000
Other External Funding	$350,000 (Victorian Smart Water Fund)
In-Kind Contributions	$92,373
Total Project Value	$472,373
Expenditure to 30 June 2009	$164,021
Date of Board Approval	pre Feb 2008
Start Date	22 Feb 2008
Status	Ongoing (delayed)

Background and Relevance

The project objective is to provide information to assist the prediction of pathogen removal performance of activated sludge plants and to enable the effect of 'upset' plant conditions on pathogen removal to be integrated into treatment plant management plans. The information generated will assist the implementation of recently updated national and state water recycling guidelines and minimise the costs associated with validation and management of reclamation plants.

Research Approach

The research approach comprises two tasks. The first is a desktop analysis in two parts, including:

- To conduct a literature review on pathogen and indicator reduction by activated sludge plants (ASPs)
- To collate and analyse Australian data sets for pathogen and indicator removal by ASPs. Such data will be used to establish relationships between pathogen log reductions, ASP plant type and relevant operating parameters. It will also be used to assess the usefulness of somatic or F-RNA coliphage, *Clostridium perfringens* spores or other parameters as indicators for enteric virus and *Cryptosporidium* reduction

The second task utilises a pilot scale unit to:

- Determine the usefulness of indicators for *Cryptosporidium* reduction by ASP
- To investigate the effect of atypical operating conditions on pathogen reduction

Project Outcomes

As at 30th June 2009, the project outcomes were in draft form, including the literature review and data review. These documents will be finalised in 2009/10, with the inclusion of data generated during the practical phase of this project. The literature review will be submitted to a scientific journal for publication.

Industry Uptake

As this project is still in its early stages, there has been little industry uptake to date. However, early project findings have been presented at Ozwater09 and ReUse09, generating significant discussion. This project has also presented initial findings to Health Regulators, which has generated additional work on log reductions from ASP systems in some states.

Progress During 2008-09

The literature review and data review on pathogen and indicator reduction by activated sludge plants, including the collation and analysis of Australian data sets have been drafted. The experimental work schedule was delayed due to difficulties in achieving steady state conditions at the Pilot Plant. These difficulties were overcome at the end of the financial year and thus the project will be completed during 2009/10.

WQRA Project 2002-08

A national approach to the health risk assessment, risk communication and management of chemical hazards in recycled water

Project Leader	Heather Chapman
Organisations Involved	Griffith University, UNSW, AWQC, University of Queensland, United Water, CSIRO, ACTEW, Sydney Water, Melbourne Water, National Water Commission
WQRA Funding	$150,000
Industry Funding	$346,666
Other External Funding	$1,015,000 (National Water Commission)
In-Kind Contributions	$450,000
Total Project Value	$2,135,000
Expenditure to 30 June 2009	$169,224
Date of Board Approval	Aug 2008
Start Date	Jul 2008
Status	Ongoing

Background and Relevance

This project aims to measure (using toxicity testing) the biological activity in purified recycled water (PRW) extracts using in-vitro toxicity tests to assess the effectiveness of the treatment technologies and to inform risk assessment of recycled water for potable reuse. The project research plan has been written, the first and second progress reports have been submitted and the literature reviews are complete. The outcomes of this project will be used in risk assessment and risk communication to stakeholders.

Research Approach

The research approach for this project comprises a number of activities including:

- To review (from existing methods) mechanism-based bioassays across a number of levels of biological organisation (molecular and/or cellular) to estimate the relative biological activity in water matrices
- To evaluate in the laboratory, a selected set of biological assays according to an agreed set of criteria to be developed with stakeholders. These will include:
  - (i) Acute toxicity
    - (a) Cytotoxicity = causing cell death
  - (ii) Organ specific toxicity
    - (a) Hepatotoxicity = affecting the liver
    - (b) Nephrotoxicity = affecting the kidneys
  - (iii) System specific toxicity
    - (a) Immunotoxicity = affecting the immune system
    - (b) Neurotoxicity = affecting the nervous system
    - (c) Endocrine modulation = affecting the endocrine system (estrogenicity, androgenicity & thyroid)
  - (iv) Developmental toxicity
    - (a) Teratogenicity = causing birth defects
  - (v) Genetic toxicity
    - (a) Genotoxicity = causing harm by damaging DNA
    - (b) Mutagenicity = inducing DNA mutations

- To carry out an evaluation of the water/samples by chemical analysis as validation for biological assays, and identification of the cause of change in biological assays including the list of priority chemicals as per the draft National Water Recycling Guidelines
- To provide guidelines (toolbox) of appropriate and robust methods for measuring biological activity for different water matrices to inform development of Hazard Assessment Critical Control Point (HACCP) risk management and strongly support monitoring programs for direct use in recycling projects

Project Outcomes

The following documents were generated during 2008/09:

- Review of potential toxicological outcomes associated with exposure of chemical contaminants to drinking water
- Risk assessment and risk management of chemicals in recycled water: current practice and future needs
- Progress reports 1 and 2

Industry Uptake

The Project Steering Committee and investors have strong industry representation, ensuring expedient knowledge transfer to industry.

Progress During 2008-09

Milestones 5, 6 & 7 were completed during 2008/09. These included:

- The first project progress report was completed and submitted to the project steering committee and the National Water Commission
- A literature review of bioassay methods was completed
- The second project progress report was completed and submitted to the project steering committee and the National Water Commission

WQRA Project 2003-08

Ecotoxicity toolbox to evaluate water quality for recycling

Project Leader	Heather Chapman
Organisations Involved	Griffith University, Curtin University, University of Queensland, Department of Water (WA), Water Corporation (WA)
WQRA Funding	$0
Industry Funding	$353,000
Other External Funding	$0
In-Kind Contributions	$0
Total Project Value	$353,000
Expenditure to 30 June 2009	$280.000
Date of Board Approval	Jun 2008
Start Date	May 2008
Status	Ongoing through Project 2005

Background and Relevance

This project aims to develop an innovative toolbox of ecotoxicity tests that can be used to characterise water that is intended for recycling or discharge into the environment. In vitro tests for estrogenicity, androgenicity, phytotoxicity, cytotoxicity and genotoxicity will be undertaken towards this aim. The findings will be delivered through a preliminary and final report that incorporates in-vivo and chemical analysis data provided by Curtin University and UNSW respectively. Due to a successful funding bid to the National Water Commission after the commencement of this project, the final stages of this project will be continued through Project 2005 (i.e. the successor to this project).

Research Approach

Sampling will take place at three WWTPs on a seasonal basis over the period of a year (four sampling events for each plant). The plants in this project include:

- Gordon Rd WWTP: with raw, primary and final treated effluent stage samples
- Waroona WWTP: with raw, primary and final treated effluent stage samples
- Harvey WWTP: with raw, primary and final treated effluent stage samples

Each sample will be split into natural and spiked samples, with each of those in replicate. Department of Water (WA) will undertake sample preparation and send samples to WQRA for toxicity testing.

Toxicity tests to be used include:

- The EScreen assay for estrogenicity
- The AScreen assay for androgenicity
- The SOS umu-test for genotoxicity
- The iPAM test for phytotoxicity
- The Microtox test for cytotoxicity

Project Outcomes

During 2008-09, the following outputs were achieved:

- A preliminary report on results from the first sampling event, advising the success of the sampling and toxicity testing methodology
- A project update with summary data from the first three sampling events

Industry Uptake

The outcomes of this project have been directly applied by Department of Water (WA) and Water Corporation (WA). The initiation of this project has resulted in a much larger project funded by the National Water Commission to extend the outcomes of this project.

Progress During 2008-09

The project was on schedule during 2008-09. The third and last milestone for this project (i.e. the generation of the project final report) will now be included into Project 2005, which is the much larger successor for this 'Ecotoxicology Toolbox' project.

WQRA Project 2004-08

Optimal management of corrosion and odour problems in sewer systems

Project Leader	Zhiguo Yuan
Organisations Involved	University of Queensland, Barwon Water, CH2M Hill, Gold Coast Water, Hunter Water, Melbourne Water, SA Water, South East Water Limited, Sydney Water Corporation, United Water, Water Corporation (WA), University of Newcastle, University of NSW, Curtin University, Sydney University
WQRA Funding	$225,000
Industry Funding	$3,250,000
Other External Funding	$4,656,803 (ARC)
In-Kind Contributions	$11,671,809
Total Project Value	$19,813,602
Expenditure to 30 June 2009	$1,011,370
Date of Board Approval	Oct 2008
Start Date	Nov 2008

Status On track

Background and Relevance

Pollutants in wastewater undergo complex changes in sewers. The corrosion and odour emissions that result from these processes lead to massive costs to water utilities in Australia. Despite major effort and expense, odour emissions are still commonly occurring from sewers in urban areas. Furthermore, the value of public assets is being significantly diminished as a result of corrosion problems, with concrete sewer pipes being estimated to corrode at an average rate of 1-3 mm a year, and in the worst cases up to 7 mm annually; this results in costs of hundreds of millions of dollars in Australia alone. The optimal management of these problems is hindered by knowledge and technology limitations; this project is a major joint effort by the Australian water industry and world-leading scientists to generate advanced knowledge and develop innovative technologies in order to achieve efficient and cost-effective sewer management.

Research Approach

The project is structures around four areas, each managed by a Technical Advisory Group (TAC). There are nine subproject areas that sit within each of the TAC's, according to the following structure:

- TAC 1 Corrosion
  - Corrosion – laboratory testing
  - Corrosion – field testing
  - Corrosion – coatings
- TAC 2 Gas Phase Technology
  - Odour assessment and abatement
  - Ventilation technologies
- TAC 3 Liquid Phase Technology
  - Optimisation of dosing systems
  - Emerging chemical dosing systems
  - Bio-electrochemical sulphide control
  - Model based decision support
- TAC 4 Knowledge Management
  - Web-based knowledge management

The experimental work program is conducted at the subproject level.

Project Outcomes

During 2008-09, the following outputs were achieved:

- Confirmation of subproject workplans
- Additional industry / investors coming on board from Barwon Regional Water ($75,000 cash) and Hunter Water Corporation ($200,000 cash)
- Research teams including PhD students have been established for all subprojects except three additional PhD students and one research assistant which are required in early 2010

Industry Uptake

The project is in start-up mode and so they are no results to communicate at this stage. A National road show to raise awareness and communicate findings from a previous project conducted by the project team on this topic is planned for 2009/2010.

Progress During 2008-09

The project officially started in November 2008, and thus is just beginning. The focus for the last eight months has been to confirm the work plans for each subproject, including the subproject budgets. This has been achieved and the experimental work is now underway.

WQRA Project 2005-08

Development of ecotoxicity toolbox to evaluate water quality for recycling

Project Leader	Heather Chapman
Organisations Involved	Griffith University, Curtin University, University of Queensland, Department of Water (WA), Water Corporation (WA)
WQRA Funding	$0
Industry Funding	$0
Other External Funding	$353,000 (NWC funding via Department of Water, WA)
In-Kind Contributions	$171,120
Total Project Value	$524,120
Expenditure to 30 June 2009	$293,816
Date of Board Approval	Sep 2008
Start Date	Jul 2008
Status	On track

Background and Relevance

Endocrine disrupting compounds (EDC's) are of importance in water management because of potential adverse effects on wildlife and humans. Most prior work has focussed on estrogenicity. Bioanalytical methods are becoming increasingly popular as primary screening tools because they don't require prior knowledge of the contaminants, they integrate potency and concentration to provide a measure of biological activity and they provide a measure of mixture toxicity effects. No single bioassay can accurately predict the total hormonal activity of complex samples to all organisms.

This project will assess the suitability of an 'ecotoxicity toolbox' approach to characterise water intended for recycling, using the Beenyup Wastewater Treatment Plant trial as a case study.

Research Approach

The project will include sampling of raw, primary, secondary and tertiary treated wastewater seasonally over the period of a year (June = Winter, September = Spring, December = Summer, March = Autumn). Samples will be in triplicate, in addition to a spiked sample (so 16 samples per sampling occasion). A selection of tests will be conducted on each sample, including:

- Endocrine Disruptors: EScreen: Estrogenic proliferation of breast Cancer cells (full Estrogenic effect) AScreen: test for Androgenicity
- Mutagens/Genotoxicants: SOS Umu: DNA damage response (to rule out false positives of Ames Test)
- Cytotoxicity: Microtox: standard test that measures inhibition of cellular activity (luminescence of bacteria in this case)
- Phytotoxicity: IPAM: photosynthetic yield and thus effects on primary production

Project Outcomes

During 2008-09, the following outputs were achieved in collaboration with Project 2003:

- A preliminary report on results from the first sampling event, advising the success of the sampling and toxicity testing methodology
- A project update with summary data from the first three sampling events

Industry Uptake

The outcomes of this project have been directly applied by Department of Water (WA) and Water Corporation (WA). The National Water Commission to extend the outcomes of this project.

Progress During 2008-09

The initial work for this project was started through Project 2003. The project work for this project is on schedule. A significant amount of field data has now been collected and is in the process of being analysed.

WQRA Project 2006-08

Membrane integrity testing for virus particle removal - Stage 1 Literature Review

Project Leader	Greg Leslie
Organisations Involved	UNSW, Melbourne Water, SEWL, Department of Human Services (Vic), Department of Health (NSW), SA Water
WQRA Funding	$40,000
Industry Funding	$0
Other External Funding	$0
In-Kind Contributions	$0
Total Project Value	$40,000
Expenditure to 30 June 2009	$0
Date of Board Approval	Nov 2008
Start Date	Pending
Status	Contract under review

Background and Relevance

Membrane technology is used in the water industry in a variety of applications including the filtration of surface water, the desalination of brackish and seawater and the filtration of water for a variety of fit for purpose application. Integration of membrane filtration in to water treatment systems offer a range of various advantages including, small footprint, ability to treat challenged waters, ability to treat disinfectant resistant pathogens and potential to meet the stringent water quality regulations.

An important aspect of membrane filtration is reliability of the process, ensuring the complete removal of target contaminants. Membrane elements require testing prior to installation and during operation to confirm their integrity. Similarly operational plants should be monitored to ensure membrane efficacy for the intended level of contaminant removal. The reliability or intactness at various stages, before and during the operation is accomplished by conducting Membrane Integrity Tests (MITs).

This project reviews the literature to propose novel integrity testing methodologies that could be employed to test membrane efficacy, preferably in real time or on line.

Research Approach

The literature review will follow the format of the National Health and Medical Research Council Reports. The NH&MRC method will help in canvassing all reports on pathogen removal and integrity testing that are contained in peer reviewed publications, institutional reports, project documents and manufacturers literature. The format for the literature review will include:

- Research questions
- Literature search
- Hierarchy of evidence
- Literature synthesis
- Data extraction
- Data presentation and synthesis

Project Outcomes

Pending. This project has yet to commence. The anticipated outcome is a literature review.

Industry Uptake

Industry engagement during the development of the project scope has been high, with relevant feedback incorporated into the research scope. Therefore, the results from this work are anticipated to be readily utilised by industry.

Progress During 2008-09

The project is anticipated to commence in the first quarter of the 2009/10 year. The contract is currently under review.

WQRA Project 2007-08

Risk assessment for pathogens and organic contaminants in biosolids

Project Leader	Michael Warne
Organisations Involved	CSIRO, Curtin University, RMIT University, Adelaide University, Water Corporation (WA), Department of Human Services (Vic), National Measurement Institute
WQRA Funding	$303,065
Industry Funding	$160,000
Other External Funding	$0
In-Kind Contributions	$422,600
Total Project Value	$885,665
Expenditure to 30 June 2009	$605,835
Date of Board Approval	Carried forward CRC WQT Project (666005)
Start Date	September 2005
Status	This project will conclude by June 2010

Background and Relevance

The broad objective of the project is to better understand the risks of contaminants and pathogens associated with biosolids to ecosystem and human health. Specific objectives are:

- To establish the persistence of pathogens and possible re-growth in land applied biosolids.
- To establish the persistence and mobility of organic contaminants in land applied biosolids.
- Both sets of data will be used to carry out a risk assessment resulting in management guidelines.
- To identify areas where further research is required.

Research Approach

The project has been broadly divided into two areas, including pathogens and biosolids. The approach has included a literature review, laboratory studies and field studies, investigating a wide range of both pathogens and organic contaminants. The majority of the research has been conducted through three PhD students, including Brad Clarke (RMIT University), Kate Langdon (University of Adelaide) and Karen Crute-Schwartz (Curtin University).

Project Outcomes

The overall project outcome is better management guidelines for reducing the risk from organic contaminants and pathogens in biosolids applied to land.

The specific outcomes for the organic contaminants program include:

- Information on the concentration of a representative range of organic contaminants present in Australian biosolids.
- Information on the potential release of a selected suite of organic contaminants under temperate climatic conditions in Australia.
- Information on the degradation rate or persistence of this suite of organic contaminants when applied to soils.
- Information on the toxicity of runoff from biosolids incorporated into soil on aquatic organisms.
- Recommendations for further research.

The specific outcomes for the pathogens program include:

- Information on pathogen types and densities in Australian biosolids.
- Information on the die-off of pathogens under temperate Australian conditions.
- Information on conditions encouraging survival and regrowth of pathogens under temperate Australian conditions.
- Identification of pathogens likely to be a hazardous to those using biosolids.
- Management recommendations to reduce the risk from pathogens in biosolids applied to land.
- Recommendations for further research.

Industry Uptake

There has been significant industry engagement in both the design and execution of this project and project results have been presented at national and international conferences and seminars. The entire project findings including recommendations for industry will be available when the project is completed around the middle of 2010.

Progress During 2008-09

The project work progressed well during 2008-09, with Brad Clarke completing his PhD. The remaining two PhD students are making good progress, although some of the project work was temporarily delayed due to maternity leave. Both Kate and Karen are completing the final stages of their experimental work, and are expected to complete their PhD's during 2009-10.

New WQRA projects

Progress has been made in developing the project proposals for the seven short-listed WW project concepts.

As of 30 June 2009, two projects have been approved by the WQRA Board. Of the remaining projects, one has been externally funded by the Victorian Smart Water Fund, two are currently under review by the PRT and two have yet to be fully developed by the respective research organisation. Additionally, there were three ARC Linkage projects submitted with WQRA support to ARC in May 2009, one project developed jointly with the Water Research Foundation (currently pending the Foundation's Board approval) and one further project developed with CSIRO as an extension of a previous CRC project (666019).

WQRA Project 2008-09

Development of predictive tools for membrane ageing

Project Leader	Pierre LeClech
Organisations Involved	UNSW
WQRA Funding	$120,072
Industry Funding	$0
Other External Funding	$0
In-Kind Contributions	$27,246
Total Project Value	$147,318
Expenditure to 30 June 2009	$0
Date of Board Approval	Feb 2009
Start Date	Nov 2009 (proposed)
Status	Contract under review

Background and Relevance

Microfiltration (MF) and ultrafiltration (UF) have been increasingly used to remove pathogens, concentrate foods, remove salts and treat water and wastewaters. Whether using flat sheet or hollow fibres, many membrane filtration processes are subject to a repetitive cycle of chemical cleaning, shear and mechanical agitation to remove material retained on the membrane surface during operation. Notwithstanding their widespread applications, little is known on the changes occurring at the molecular and structural level when membranes are subject to the individual or combined effects of chemical attack and mechanical strain prior to failure. These changes (resulting potentially in membrane failure) can be due to a progressive build up of residual deposition, but loss of integrity (i.e. failure to separate critical components such as pathogens) is another cause driving membrane replacement. Among the main organic foulants, proteineous materials, polysaccharides, and humic substances are commonly found in both water and wastewater treatment. Chemical treatment such as acids, bases, and oxidising agents has been commonly used for these foulants, but assessment of long-term progressive degradation of performance due to accumulated residual deposition has not been studied in parallel with membrane aging and morphological changes. Cyclical cleaning may result in slow changes in the pore size distribution as well as more heterogeneous surfaces due to residual macromolecules.

This project focuses on the ageing effect of chemical agents (both oxidising and non-oxidising) commonly used in microporous membrane plants. By using a wide range of analytical techniques - mechanical, morphological and chemical – the complete assessment of the membrane state will be carried out before and after ageing. Moreover, challenge tests run with model particles will be conducted to assess the potential loss of membrane integrity. In a complementary series of experiments, the combined effect of fouling and cleaning will be assessed during consecutive cyclical runs. This study will particularly focus on the application of a rigorous methodology to allow comparison between the different membranes and cleaning agents tested. This will allow a better understanding of the long-term performances of membrane systems.

Research Approach

The research approach comprises four stages including:

- Assessment of membrane degradation, including mechanical assessment, morphological assessment and chemical assessment. Based on the initial results obtained, the most accurate and relevant techniques will be short-listed for the next series of tests
- Accelerated chemical ageing study using three commercially available symmetric hollow fibre membranes and two flat sheet membranes of different materials. Ageing tests will be carried out initially using HCl, NaOH, sodium dodecyl sulfate (SDS), and hypochlorite solutions (diluted in DI water) and the membranes autopsied in terms of integrity. Temperature and concentration of the cleaning solutions will also be changed to accelerate the ageing process. The hydraulic and rejection performances of the aged membranes will be assessed and correlated with the degradation parameters
- Consecutive cyclical runs using a filtration/cleaning rig that can perform numerous runs with minimum human interaction. Longer term, cyclical cleaning experiments will be carried out using the fully automated chemical dosing system on the same set of membranes mentioned before. Model solutions (mixture of inert colloidal materials with organic compounds (humic, fulvic, proteins and carbohydrates), all diluted with DI water, will be used to foul the membrane. At a later stage, yeast solutions may be also used as a more complex mixture. These substances have been widely used in our labs to simulate water and wastewater streams in well-controlled environment
- Analysis of industrially-aged membranes from local plants will be compared with virgin and lab-aged membranes

Project Outcomes

This project has not commenced.

Industry Uptake

This project has not commenced.

Progress During 2008-09

The project is anticipated to commence in November 2009. The contract is currently under review.

WQRA Project 2009-09

Protocol for developing chemical pretreatment for high pressure membranes

Project Leader	Greg Leslie
Organisations Involved	UNSW, Water Research Foundation, Victoria University, University of California
WQRA Funding	$168,739 (US $155,240)
Industry Funding	$0
Other External Funding	$118,478 (US $109,000)
In-Kind Contributions	$75,139 (US $69,128)
Total Project Value	$362,356 (US $333,368)
Expenditure to 30 June 2009	$0
Date of Board Approval	Feb 2009
Start Date	Pending

Status	Contract under review

Background and Relevance

Antiscalants form an important component of the pretreatment needs for many high-pressure membrane systems. They allow these systems to operate at recoveries significantly higher than they otherwise would by preventing the onset and growth of inorganic scale. However, the proprietary nature of many of the commercially available antiscalants makes them difficult to assess, model and predict.

This project aims to evaluate the current methods for determining the needs of anti-scalants for nanofiltration and reverse osmosis at the bench-, pilot- and full-scales and develop a protocol for the specific evaluation of antiscalants and scale-inhibitors.

Research Approach

The research approach has been divided into three tasks:

- A literature review of the current state of the art for chemical pretreatment, in particular the use of antiscalants and scale mitigation approaches. The review will examine the common types of scale present in membrane systems and the range of traditional and novel antiscalants and their physical and chemical properties
- The development of a protocol to optimise the use of anti-scalants and their dose rate at a bench scale for a range of source waters. This work will utilise Quantitative Structure Activity Relationships (QSAR) to relate specific properties of the antiscalant molecules to the prevention of scale
- Validation of the protocol developed in the second task on a series of current reverse osmosis and/or nanofiltration plants

Project Outcomes

The outcome of this project will be an Anti-scalant Evaluation Protocol (AEP) that can be adopted for future applications and development of water plants with high-pressure membrane systems and the benchmarking of newly developed antiscalant chemicals.

Industry Uptake

This project has not commenced.

Progress During 2008-09

The project is anticipated to commence in early 2010. The contract is currently under review.

WQRA Project 2010-09

Investigation of endocrine disruption in Australian aquatic environments

Project Leader	Frederic Leusch
Organisations Involved	Griffith University, UTS, Curtin University, RMIT University, UNSW, Smartwater (Qld), Landcare Research (NZ), Water Corporation (WA), Sydney Water, Sydney Catchment Authority, SEQ Water, QEPA, Melbourne Water, Department of Water (WA)
WQRA Funding	$120,000
Industry Funding	$180,000
Other External Funding	$432,103 (ARC)
In-Kind Contributions	$479,187
Total Project Value	$1,211,290
Expenditure to 30 June 2009	$0
Date of Board Approval	Apr 2009
Start Date	Jan 2010 (pending ARC decision)
Status	ARC funding decision pending

Background and Relevance

With many states currently on high level water restrictions and with dwindling environmental flows, there is a need to ensure good quality environmental waters for the health of aquatic ecosystems and humans that depend on those. The proposed research will provide a national account of endocrine disruption in the Australian aquatic environment and help to further protect river systems already stressed by climate change and historical water management practices. Although this project will address specific needs of the partner organisations, the outcomes will have high national significance.

Research Approach

Discrete (grab) water samples will be collected quarterly for a year at sites covering a range of land use scenarios in four states (Qld, VIC, NSW and WA). Water samples will be extracted on-site and sent to the analytical laboratories for in vitro bioassay analysis (at GU) and chemical analysis (at UNSW). The measured concentrations of chemicals at selected sites will be replicated and short-term in vivo laboratory exposures will be performed using two established model fish species, a native fish (rainbowfish, at RMIT) and a commonly found pest species (mosquitofish, at UTS). At the end of the exposures, vitellogenin induction will be measured using RT-PCR and ELISA methods. Vitellogenin is a biomarker of exposure to estrogenic compounds. The results from this research will be collated and used to perform a risk assessment of EDCs in Australian waters.

Project Outcomes

The anticipated outcomes from this project include:

- An understanding of EDC effects at individual and population levels for two fish species
- Identification of mixtures of chemicals causing estrogenic endocrine disrupting effects
- Development of an integrated approach for assessing EDC effects, which can be used by researchers and by commercial ecotoxicological testing laboratories
- That Australian water service providers will be able to make capital investment and operational planning decisions; and that regulatory authorities will be able to make policy and regulatory decisions, underpinned by sound science
- That other organisations will be able to make decisions that are consistent with ecologically sustainable development principles.

Industry Uptake

Project has not commenced.

Progress During 2008-09

Project has not commenced.

WQRA Project 2011-09

Optimisation of nutrient removal, membrane fouling and excess sludge dewatering in hybrid coagulation/submerged membrane bioreactor (SMBR) treatment of wastewaters

Project Leader	David Waite
Organisations Involved	UNSW, Tsinghua University (China), Sydney Water, Origin Water (China)
WQRA Funding	$120,000
Industry Funding	$180,000
Other External Funding	$1,050,000 (ARC)
In-Kind Contributions	$1,350,000
Total Project Value	$2,700,000
Expenditure to 30 June 2009	$0
Date of Board Approval	Apr 2009
Start Date	Jan 2010 (pending ARC decision)
Status	ARC funding decision pending

Background and Relevance

Coagulant addition is used widely in both conventional and membrane-based water treatment as an essential aid to floc formation and contaminant removal and is also recognised to assist greatly in reducing the extent of transmembrane pressure (TMP) build-up in submerged membrane bioreactor treatment of wastewaters. Coagulant addition may also assist in removal of phosphorus in treatment of wastewaters and is also recognised to aid the dewatering of the highly gelatinous sludge that is typically produced in submerged membrane bioreactor wastewater treatment. Despite the apparent advantages, there has been only limited investigation of the impact of coagulant choice and dosing conditions on nutrient removal, membrane fouling and excess sludge dewatering in SMBR treatment of wastewaters.

One reason for the limited research undertaken to date in this area relates to the complexity of the MBR system and the multitude of reactions that can occur on addition of a coagulant to a membrane bioreactor. An indication of some of the remaining knowledge gaps is provided below:

- Given the high concentration of soluble microbial products (SMP) present in SMBRs, what proportion of the coagulant (which is typically an iron or aluminium salt, polymer or oxyhydroxide particle) forms dissolved complexes with the SMP? Does the major cation (particularly Ca) binding of SMP influence its interaction with added coagulants such as Fe? Is it preferable to add partially polymerised inorganic coagulants in order to minimise the extent of complexation by SMP?
- Does the added coagulant assist in preventing gelation of the SMP or in modifying the permeability and compressibility of the SMP gel once it has accumulated on the membrane? Is the reduction in TMP accumulation resulting from coagulant addition significant (and cost effective)?
- What choice of coagulant is preferable if the goal is to maximise phosphorus removal? Does the presence of phosphate result in formation of minerals such as vivianite or is adsorption to freshly formed metal oxyhydroxides the major mechanism of removal of phosphorus from solution? Is addition of FeII rather than FeII preferable?
- How does coagulant addition affect nitrogen removal?
- Should coagulant be added continuously or intermittently? If intermittently, how frequently? Do transformations in the coagulant-mediated assemblages following coagulant addition alter the resulting filtration behaviour?
- Is dewatering of excess sludge improved significantly by coagulant addition? What type of coagulant provides maximum sludge dewaterability?
- Can the goals of maximising nutrient removal, minimising membrane fouling and maximising sludge dewaterability be achieved with the same coagulant choice and dose? What type of dosing regime is most cost effective?

Research Approach

Investigations of the impact of coagulant addition on nutrient removal, membrane fouling and excess sludge dewatering will be undertaken i) in bench scale submerged membrane bioreactors that have been recently constructed at UNSW (see Figure 1), ii) in bench scale reactors that will be constructed at Tsinghua University, iii) at North Head MBR plant (which is configured in a very similar manner to the bench scale units at UNSW, and iv) at the Miyun Recycled Water Treatment Plant in Beijing which utilises a SMBR system installed by Origin Water.

Studies utilising bench scale, pilot and full scale submerged membrane bioreactor systems will be complemented by i) laboratory studies of coagulant-SMP interactions, ii) studies of the filterability of the assemblages that form on membranes in the absence and presence of added coagulants, iii) characterisation of the structure and reactivity of the assemblages formed on coagulant addition, and iv) investigations of the dewaterability of excess sludge in the absence and presence of added coagulants.

Project Outcomes

The anticipated outcome of this project is improved nutrient removal, minimised membrane fouling and improved sludge dewatering through an improved understanding of the behaviour of coagulants in the submerged membrane bioreactor treatment of wastewaters.

Industry Uptake

Project has not commenced.

Progress During 2008-09

Project has not commenced.

WQRA Project 2012-09

Enhancing the performance of reverse osmosis desalination membranes by understanding the mechanisms of degradation and wear

Project Leader	Stephen Gray
Organisations Involved	Victoria University, University of Texas, GWM Water, Coliban Water
WQRA Funding	$183,504
Industry Funding	$60,000
Other External Funding	$240,000 (ARC)
In-Kind Contributions	$120,000
Total Project Value	$603,504
Expenditure to 30 June 2009	$0
Date of Board Approval	Apr 2009
Start Date	Jan 2010 (pending ARC decision)
Status	ARC funding decision pending

Background and Relevance

In response to increasing demands for the treatment of brackish and seawater and the recovery of wastewater for domestic use, treatment systems using reverse osmosis (RO) membranes are commonplace. A typical RO system is comprised of thin film composite membranes consisting of the following layers: a polyester support, an inner layer of microporous polysulfone, and an ultra thin aromatic polyamide (PA) barrier layer on the top surface. The PA layer is only ca. 0.2 µm thick and although this material is inherently strong and stable, degradation and wear can age the membrane. Under normal operating conditions and in accordance with manufacturer's recommendations for pre-treatment and cleaning, a typical membrane unit can have a life expectancy of up to five years. Cleaning and disinfection of RO membranes can expose the membrane surface to harmful chemical agents. These agents can potentially damage or degrade the PA membrane layer resulting in a loss of integrity and ultimately shorten the working life of the membrane element.

Current research has focused on degradation due to chemical agents such as hypochlorite which is particularly harmful to PA membranes. The mechanism of degradation is not well known but a number of degradation pathways have been proposed. There is presently no comprehensive data available on the effects of these chemicals on the performance and longevity of PA membranes. Moreover, the effects of short-term versus long-term exposure, combinations of agents, and potential catalytic effects due to metal ions are relatively unexplored. In addition to exposure to these potentially harmful cleaning and sanitising chemical agents, membranes may be exposed to undissolved particles in feed water that may scratch the PA surface. The development of scratches and holes cannot easily be detected or monitored and the first indication of a hole in a membrane may be failure of an integrity test. Other mechanisms of failure such as delamination of the PA layer from the PSO support are relatively unexplored.

Research Approach

This project will develop and refine methods to investigate the degradation mechanisms and kinetics of PA membranes in the presence of chemical agents under various conditions of pH and under isothermal and non-isothermal conditions. Factors affecting the delamination of PA from the PSO support will also be investigated under similar conditions. This project will also develop techniques to model scratching/abrasion of PA membranes and to kinetically monitor the development of holes that can result in membrane failure. The outcomes of this project will include the provision of a comprehensive database of recommendations on exposure to chemical agents both individually and in combination with other agents. A thorough understanding of the mechanisms of wear, degradation, delamination, and the influence of chemical agents will be obtained. This has the potential to enable users of PA RO membranes to maximise the operational life of the membrane by preventing or at least minimising degradation due to chemical agents.

Project Outcomes

Pending. This project has yet to commence.

Industry Uptake

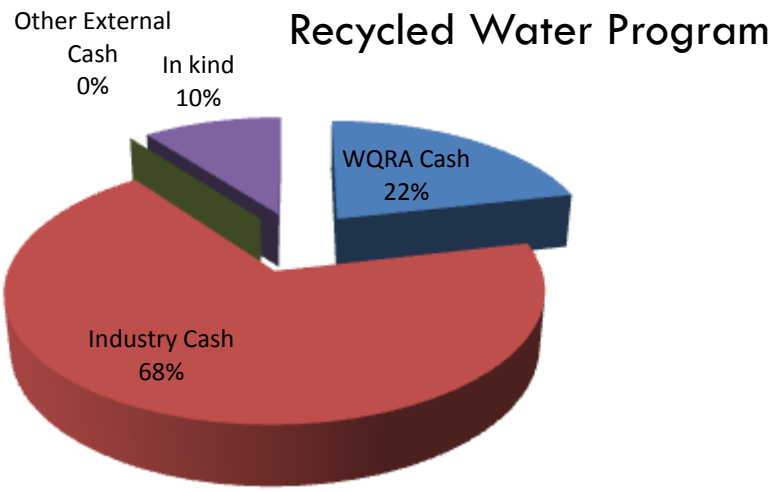
Project has not commenced.

Progress During 2008-09

Project has not commenced.

Recycled Water Program

Total investment committed to the Recycled Water Program at 30 June 2009 – Total Budget $85,790



WQRA Project 3001

Detection of cross connections in potable water distribution systems - Stage 2: Field trials of candidate detection parameters	
Project Leader	Roger O'Halloran
Organisations Involved	CSIRO, Melbourne Water, Sydney Water, SEWL, CWW, YVW
WQRA Funding	$0
Industry Funding	$58,566
Other External Funding	$0
In-Kind Contributions	$5,000
Total Project Value	$63,566
Expenditure to 30 June 2009	$0
Date of Board Approval	Jun 2009
Start Date	Pending
Status	Contract under review

Background and Relevance

In dual-reticulation schemes there is always the possibility of cross-connection of recycled water into the potable system, either by faulty plumbing or backflow preventers, or even deliberately if there is a potential cost saving. A number of cross connections have already occurred. Stage 1 of this project conducted proof-of-concept laboratory trials in 2008. Several parameters (e.g. conductivity, UV, fluorescence) were found to detect cross connections at the 95% confidence level when there was 10% contamination with recycled water. This project looks to extend the outcomes of the Stage 1 study by investigating the feasibility in the field of a low maintenance cross-connection detection device based on robust sensors for two or more parameters that can reliably detect the presence of recycled water in potable water with a low level of false positives. Devices based on one parameter often suffer from high levels of false alarms.

Research Approach

A range of candidate parameters will be measured online in Melbourne (Hunt Club) and Sydney (Rouse Hill) to

determine diurnal and weekly variations. The Report will include an analysis of these results, and the probability of detecting 10% contamination in the real world environment. If results are promising, recommendations for development of a prototype XC detector will also be included, as well as possible strategies to minimise false alarms. Application of a device in the distribution system or in the households will be considered, and these may require different approaches.

Project Outcomes

This project has yet to commence.

Industry Uptake

Project has not commenced.

Progress During 2008-09

The project is anticipated to commence in November 2009. The contract is currently under review.

WQRA Project 3002

Exposure assessment using tracer chemicals - Stage 1	
Project Leader	Martha Sinclair
Organisations Involved	Monash University, RMIT University
WQRA Funding	$18,400
Industry Funding	$0
Other External Funding	$0
In-Kind Contributions	$3,824
Total Project Value	$22,224
Expenditure to 30 June 2009	$0
Date of Board Approval	Jun 2009
Start Date	Pending
Status	Contract under review

Background and Relevance

Requirements for the microbial quality of recycled water intended for non-potable uses are defined in the Australian Guidelines for Water Recycling on the basis of log-reductions from pathogen levels in sewage. These log-reductions have been set using the process of quantitative microbial risk assessment to estimate disease risks from inadvertent ingestion of small quantities of recycled water during non-potable uses.

Researchers Sinclair, Leder and Deere were involved in the development of these guidelines, and during this process it was evident that few of the published ingestion estimates have any experimental basis to support them - most are simply expert opinion of quantities thought to be plausible. There is a need to provide real data on water ingestion to ensure that guidelines are not overly conservative (overestimating health risks and therefore requiring a higher degree of pathogen removal than is really needed), or not conservative enough (underestimating health risks and therefore not providing enough protection to water users). This project will determine whether it is feasible to measure actual water ingestion by spiking the water with a non-toxic chemical (cyanuric acid) and measuring the amount of the chemical subsequently excreted in urine. Cyanuric acid is widely used in outdoor swimming pools to "stabilise" chlorine by protecting it from UV degradation. When ingested, this compound is not metabolised but is 100% excreted in the urine within 24 hours. Measurement of cyanuric acid in urine has been successfully used to estimate water ingestion during swimming.

Research Approach

This preliminary project will investigate the feasibility of the cyanuric acid assay methodology in an Australian laboratory and explore means to enhance detection such as:

- use of higher concentrations of cyanuric acid in water
- improving the limit of detection of the published HPLC assay method
- developing a method to concentrate urine samples before HPLC analysis

On preliminary assessment of the properties of cyanuric acid, the use of anion exchange columns appears to be a promising approach.

Progress During 2008-09

The contract is currently under review.

Project Outcomes

This project has yet to commence.

Industry Uptake

Project has not commenced.

Education Program

PhD Student Project Updates

WQRA PhD Scholarships are awarded to students with excellent research potential undertaking a higher degree by research. WQRA provides students with the opportunity to enhance their research skills and professional development to a point that makes them a valuable and employable asset to the water industry.

WQRA is monitoring the progress of twelve students who were the final CRCWQT PhD intake in 2006. These students were in year two or three of their candidature at the end of the CRCWQT. The remaining stipends were transferred to the host universities, and there has been less requirement for active involvement in administration of these students.

WQRA also took over responsibility for three PhD students appointed to the Wastewater Program that was run in parallel to the CRCWQT. These students are now officially part of WQRA.

Health Effects Of Drinking Water From Rainwater Tanks

Student	Shelly Rodrigo
Project Leader	Associate Professor Karin Leder
Organisations Involved	Monash University
Start Date	March 2006
Status	Submitting in December 2009

Background and Relevance

Australia has been facing drought conditions for the past decades and water sources are becoming increasingly depleted. Measures have been taken to reduce water consumption and consider using alternative sources of water such as rainwater. Rainwater is used extensively for drinking in rural Australia. Current recommendations state that rainwater can be safely used for purposes other than drinking, but because of potential contamination and limited evidence regarding safety, drinking untreated rainwater is not approved by state health departments. Uncertainty over the degree of risk has also made some water utilities and developers reluctant to provide untreated rainwater for purposes that may be associated with inadvertent consumption such as showering or brushing teeth. This project will provide a quantitative estimate of acute health risks associated with deliberate consumption of untreated rainwater.

Research Approach

This study will determine whether drinking untreated rainwater poses a significant risk of gastrointestinal illness. A randomised, controlled, double blinded intervention study was conducted amongst families who drink unboiled rainwater. A total of 300 households each comprising at least four eligible individuals were recruited and randomly assigned to receive either a real (150 households) or a sham (150 households) water treatment unit (WTU). Individuals used the water from these units as their main supply of drinking water during the study. Participants recorded details of gastrointestinal illness on a standard questionnaire over the twelve month study period. Rates of gastrointestinal illness in the two groups will be compared to determine whether removal of microorganisms from rainwater reduces illness rates in the group with the real WTU compared to those with the sham WTU.

Outcomes

The outcome of this project will be invaluable in shaping policy on acceptable uses of rainwater in an urban setting serviced by an existing reticulated supply, and will be used by public health regulators to base their recommendations for the use of tank water for direct human consumption.

Industry Uptake

It will contribute to the ability of water suppliers to conserve conventional drinking water supplies by providing alternative water sources that are fit for purpose.

The Fate of Human Enteric Pathogens following the Land Application of Biosolids in Agriculture

PhD Student	Karen Schwarz (Curtin University of Technology)
Project Leader	D Pritchard
Organisations Involved	CSIRO Land and Water (based at University of Queensland); Curtin University of Technology, Water Corporation Western Australia; CRCWQT; Department of Human Services Victoria.
Start Date	February 2005
Status	Currently on 12 months maternity leave (July 2009 to July 2010)

Background and Relevance

The practice of applying biosolids to agricultural land offers dual benefits, to the water industry as a means of waste disposal and to the agricultural industry as a source of fertiliser. With the increase in world population and the ongoing need for fertilisers to produce food crops, biosolids offer an alternative fertiliser. Biosolids, however, may contain human enteric pathogens, despite undergoing stabilisation, and there is a risk that pathogens may transfer to humans through food products or other pathways.
Scientific data is needed as to the behaviour and persistence of enteric pathogens in biosolids-amended soil. In this study, the persistence of human enteric pathogens from two of the four major groups: viruses, bacteria, protozoa and helminthes have been measured on cereal crops in Western Australia and South Australia. The research has focused on bacterial and viral decay rates and regrowth over time in the soil, on plant leaves, on grains and in bioaerosols (dust) at harvest. The research will provide the water industry with information as to the current level of risk that enteric pathogens pose to public health following the land application of biosolids. The grain industry, growers, consumers and handlers will be able to utilise this data to ensure that enteric pathogens pose little risk to the public as a form of contaminant.

Research Approach

A series of experiments were conducted to study the survival of enteric pathogens across the growing season of a cereal crop. This approach was used so that the levels of risk associated with each stage of exposure to public health could be determined. In studying areas of risk, high levels of enteric pathogens were inoculated into the soil, onto wheat leaves and grain heads and onto grains and the decay rates determined over a time-series for a worse-case scenario. Background bacteria levels present in dust particles (bioaerosols) at harvest were also tested from biosolids-amended paddocks and non-amended paddocks at a broadacre cereal crop site in the wheatbelt of Western Australia.

Outcomes

Information on decay rates of *E. coli*, *Salmonella typhimurium*, bacteriophage and adenovirus in both soil amended with biosolids and non-amended soils is now available. Decay rates and die-off patterns in the soil were obtained from field trials conducted across two seasons in a broadacre cropping region of Western Australia and South Australia where biosolids are currently applied. Decay rates for bacteria and viruses on wheat leaves, grain heads and grains were also obtained from glasshouse trials along with the levels of bacteria present in dust at harvest time from biosolids-applied sites. The project has enabled methods for the detection of enteric pathogens in biosolids to be further developed. The results of the study may be able to be reviewed according to the Guidelines for Direct Land Application of Biosolids and Biosolids products to protect consumers, agribusiness markets, public health, the animal industry and the environment where withholding periods, application rates and usage classifications are defined.

Industry Uptake

This project has been a marked step forward in Australian environmental scientific research in determining the behaviour of select human enteric pathogens in biosolids-amended soils given their variation in initial numbers at application. The results indicate the effect that varying soil types, temperatures and other climatic factors may have on the survival of pathogens in the field, where they are currently being applied. The results from the study will enable public health agents to improve management practices across the water and grains industries. Several aspects of the study also bear relevance to other international studies and guidelines.

Assessment of the Endocrine Disrupting Effects of Sewage Contaminated Waters on Aquatic Biota and Identification of the Causative Compounds.

PhD Student	Heather Brown (UTS)
Project Leader	Associate Professor Richard Lim
Organisations Involved	University of Technology, Sydney and Sydney Water
Start Date	February 2006
Status	Thesis due to be completed in January 2012

Background and Relevance

There is considerable (and increasing) evidence for endocrine disruption in freshwater fish populations exposed to synthetic and natural compounds present in treated sewage effluent discharges in Europe, Canada, America and more recently Japan. Ethinyl estradiol from oral contraceptives, 17β-estradiol, and estrone, excreted by women, and alkylphenols are the compounds which have been identified as the primary endocrine disrupting compounds responsible for the feminisation observed in these fish populations. Feminisation such as intersex (a pathological condition in which gonads of gonochoristic fish contain both male and female sex cells) and induction of vitellogenin (Vtg; the protein precursor of egg yolk production in female fish) in male fish have been the most frequently observed abnormalities linked to these hormonally active chemicals. Although it is still unclear whether these organism-level abnormalities as a result of exposure to EDCs are translated into population effects, abnormal gonadal and hormonal changes in wild fish are undeniably a significant environmental issue. To date the reproductive capabilities of aquatic fauna exposed to endocrine disrupting compounds (EDCs) have not been adequately evaluated here in Australia, particularly the effect of low-level chemical mixtures on populations in waterways contaminated with sewage effluent. This study will aim to add to and improve our understanding of low level mixtures of EDCs in final effluent from sewage treatment plants (STPs) in South-East Queensland and Sydney using a combination of *in vitro* and *in vivo* techniques.

Research Approach

The Research Approach is based on a series of questions:

- To identify and quantify potential estrogenic chemicals present in final effluent discharged into rivers in Sydney and Southeast Qld
- Determine the relationship between the dilution of sewage effluent and the measured chemical and biological endpoints
- Determine effects on fish of estrogenic compound mixtures identified as environmentally relevant using laboratory flow through exposures

A series of laboratory and field experiments have been designed to supply the solutions to these research questions.

Outcomes

Project still in progress, no outcomes at present.

Industry Uptake

It is hoped that the Outcomes of this project will give wastewater managers a better understanding of the effectiveness of present treatment of EDCs in effluent and help in future management decisions.

Risk Assessment for Pathogens and Organic Contaminants in Biosolids –Selected Organic Contaminants in Biosolids

PhD Student	Kate Langdon
Project Leader	Michael Warne and Simon Toze
Organisations Involved	University of Adelaide CSIRO Land and Water
Start Date	June 2006
Status	Proposed to submit April 2010

Background and Relevance

The reuse of biosolids as a supplement or replacement for agricultural fertilisers is a sustainable practice that increases nutrients and organic carbon to soils. There is however, some potential environmental risk associated with this practice due to the wide range of contaminants that can be contained within biosolids. The levels of heavy metals in biosolids and their associated risks following land application of biosolids have been studied in great depth both within Australia and abroad. The risks of organic contaminants are understood to a lesser degree and have therefore been the focus of this research project.

Research Approach

A broad range of organic contaminants (including polycyclic aromatic hydrocarbons, surfactants, pharmaceuticals, personal care products and estrogens) were initially highlighted as being of potential concern. A literature search, aquatic hazard assessment and terrestrial toxicity testing then identified specific compounds from the above groups to be the focus of the overall study. The specific compounds selected were: 4-t-octylphenol, 4-n-nonylphenol, 4-nonylphenol, triclosan, bisphenol A, 17β-estradiol, estrone, estriol

and 17α-ethinylestradiol.

Following the selection of the specific compounds for the study, the initial task was to develop analytical methods for the detection of these compounds in biosolids and soils that were reliable and reproducible. The Research Approach following this was to conduct a survey on biosolids samples from each state and territory in Australia to determine levels of the selected compounds. The degradation of the specific compounds was also observed both in the laboratory under controlled and optimal conditions as well as in the field during a cereal growing season in South Australia.

The final component of this study is to use all the data compiled to conduct a risk assessment for the selected organic compounds in Australian biosolids.

Outcomes

The aquatic hazard assessment completed at the commencement indicated that there was limited potential, for the majority of organic compounds, to migrate off site with water and cause adverse effects in adjacent waterways, however, some specific compounds were highlighted and discussed. This hazard assessment was submitted to Ecotoxicology and Environmental Safety and is currently being reviewed.

An analytical method for the selected organic compounds was successfully developed using ultrasonic extraction, followed by a solid phase extraction clean up and analysis using GCMS. The biosolids survey has now been completed providing data on the concentrations of the selected compounds in 14 different Australian biosolids. 4-t-octylphenol, 4-nonylphenol, triclosan and bisphenol A were detected in all samples with Australian averages relatively consistent with the global averages that were obtained as part of the aquatic hazard assessment. The field trial and all chemical analysis of the samples from this have also been completed. The controlled laboratory degradation study has commenced. The six month duration of this study means that this will not be completed until October 2009. The completion and comparison of these components will provide information on the degradation of the selected compounds specifically under environmental conditions in Australian soils but also on the relative degradation rates of freshly added contaminants (spiked) versus contaminants that naturally occur in biosolids.

Industry Uptake

This research will outline specific organic compounds that are of concern following land application of biosolids and the concentrations of these compounds in Australian biosolids. The study will also provide information on the varying rates of degradation of the selected compounds under controlled laboratory and field conditions found in Southern Australia. Ultimately, this study will provide relevant information that may assist in the development of management guidelines to ensure the safe reuse of biosolids in this country.

Water Use in Urban Households: Perceptions, Attitudes and Values in Gosford City Households

PhD Student	Nicole Thornton (UTS)
Project Leader	Dr Chris Riedy
Organisations Involved	Institute for Sustainable Futures at UTS; Gosford City Council; Department for Environment and Climate Change.
Start Date	February 2006
Status	Data collection completed in early July 2009. Data analysis begins in August. Thesis complete in December 2010.

Background and Relevance

A number of end-use studies across Australia and overseas have provided detailed data about how urban households use water in the home. There is much less in-depth data about why these households use water the way they do. This PhD aims to fill this gap by identifying the reasons behind a householder's everyday water use, identifying their values and attitudes to water use in the home and in their community, as well as comparing their perceptions of how they *think* they use water with how they *actually* use water in the home. The research was also interested in how effective water-saving devices were in changing a person's water-using behaviour and saving water in the home.

Most studies have collected data from single residential dwellings in major cities which are owned by the people who live in them. This research focuses on single and multi-residential dwellings which are owner and renter occupied and are based in a growing regional coastal community.

Gosford City, which is located on the southern end of the Central Coast, is one hour north of Sydney. Gosford City has been in a drought since 2001, with severe drought conditions and very low water supply during 2007 and 2008. Household demographics include group rental households, single mums with school age children, pensioners, single and family households, gay couples and extended family households.

Research Approach

A total of 48 households from five Gosford suburbs were involved in the study for approximately four months each, beginning May 2008 through to July 2009.

Smart metering technology was used to collect everyday household water use. High resolution water meters registered flow rate at 72 pulses per litre (approximately 14ml per click) while data loggers recorded daily water use in ten second snapshots over a two month period. Face-to-face interviews were conducted with as many members from each household as possible in order to learn about their attitudes, values and perceptions of water use in the home and in the Gosford community.

All toilets with a flush volume of 9L or more were removed and replaced with a 4.5/3L toilet for free. Data was collected via the data loggers for two weeks before and two weeks after installation to determine water savings and behaviour changes.

Shower monitors were installed for free in each shower to determine how effective audio and visual prompts were in helping people save water while showering. An LCD screen showed the user the time of day, the temperature of the shower and how much time was left before their time was up (via black bars). A loud beeping noise ran continuously until the user turned the shower off, or a minute had passed, whichever was first.

Outcomes

The data will help answer the following research questions:

- What are the water end-use patterns in Gosford City households?
- How do behavioural, normative and control beliefs vary in Gosford households and how does this affect residential water use?
- What are the perceptions of Gosford residents to the Central Coast's current water situation and what are the expectations about their access and use of water in their home? How does this influence their beliefs and attitudes to household water consumption?
- How do lifestyle choices impact on the beliefs and attitudes to Gosford residents' water consumption?
- What are the barriers and incentives for Gosford householders to become sustainable in their household water use? What are the barriers and incentives for those residents who have the behavioural intention of using water sustainably compared with those who are actually behaving as they intended?
- How do some specific household water-saving devices perform in practice and how do they impact on water behaviour?

Industry Uptake

The data will be of use in improving behaviour change programmes and policies by providing a better understanding of the reasons behind residential water use. This will help water utilities and other organisations to target the correct audience, behaviours, barriers and incentives to ensure successful uptake of sustainable water use.

Water Treatment and Fate of Contaminants in Permeable Pavements with Underlying Storage

PhD Student	Baden Myers
Project Leader	Professor Simon Beecham
Organisations Involved	Centre for Water Management and Reuse, University of South Australia
Start Date	March 2006
Status	Submitting January 2010

Background and Relevance

Permeable pavements are a well established water sensitive urban design technology that has been around since the 1970s. Unlike other WSUD devices, they can be applied as an infiltration technique to manage stormwater onsite without compromising the amenity of land, making them a particularly attractive option for developers. In this project, the use of permeable pavements for water harvesting and reuse is being investigated, particularly with respect to the changes in physical, chemical and biological water quality through storage in permeable pavements with an underlying storage.

Research Approach

Research into water treatment and fate of contaminants has been approached by considering physical, chemical and biological contaminants. The retention and fate of a series of indicator contaminants in these sub-categories are examined in the permeable pavement structures that have been applied in the field and the laboratory.

Outcomes

Outcomes of this project have shown that permeable pavement structures can retain pollutants from stormwater runoff, particularly heavy metal contaminants. The removal of physical contaminants has also been shown with respect to clogging at the permeable pavement surface in field systems. Several other changes in water quality can be expected when permeable pavements are used to store stormwater and these can be related to the type of materials used in the permeable pavement construction. In particular, impacts on the conductivity, pH, and alkalinity have been noted. The depletion of microorganisms in the rock aggregate filled reservoirs has been investigated to indicate that limestone based minerals have a tendency to show higher rates of depletion for the pathogen indicator *E. coli*, and that the presence of natural organic matter sourced from grass runoff can support microorganisms in the reservoir more effectively than natural organic matter sourced from leaves.

Industry Uptake

Outcomes of the project will provide information to developers with an interest in the design and construction process of permeable pavements, particularly where they may be applied for water harvesting and reuse.

Genotoxicity Investigation of Disinfection by-products, Organic N-chloramines

Student	Somprasong Laingam
Project Leader	Dr Andrew Humpage
Organisations Involved	The Australian Water Quality Centre The University of Adelaide
Start Date	August 2005
Status	PhD thesis submitted August 2009

Background and Relevance

Organic N-chloramines are a group of disinfection by-products that could be found in both chlorinated and chloraminated water. While there has been a lack of studies in water-related research, organic N-chloramines have received attention in biomedical community as potential causes of aging, chronic diseases and cancers. Literature has suggested that organic N-chloramines are reactive molecules with sufficient stability to be absorbed and delivered to target organs, where they can attack macromolecules possibly by multiple mechanisms i.e. oxidative stress, alkylation or N-chlorine transfer. To date, there is a lack of toxicological information on individual organic N-chloramines. In order to fill this critical information gap regarding which exogenous organic N-chloramines (i.e. from disinfected drinking water) might contribute to these diseases, *in vivo* toxicological studies of individual compounds are required. It is, however, not possible to test all compounds *in vivo* and hence selection of those most likely to be potential health risks is a priority. Only a few studies have shown that some organic N-chloramines are mutagenic in bacteria while there is no available information on genotoxicity of the compounds in this group in mammalian cells. This research was to provide further information on genotoxicity of individual organic N-chloramines in human cells. It was expected that the information obtained would help determine which compound(s) should be subjected to *in vivo* studies in future research.

Research Approach

Phase 1: Mammalian cell based assay establishment

The flow cytometry based micronucleus (FCMMN) assay using mammalian cell lines was established at the AWQC for use as a rapid genotoxicity screening of DBPs. The assay validation was performed using model genotoxicants and a negative control. Two mammalian cell lines were compared in order to select the most appropriate cell line for use in the study of organic N-chloramines.

Phase 2: Genotoxicity studies of organic N-chloramines

Organic N-chloramines have been suggested as potential health risks in biomedical research, but there is a lack of toxicological information on individual compounds. Organic N-chloramines predicted by experts in the field were screened for genotoxicity using the FCMMN assay, and the results were confirmed by microscopy-based micronucleus assay. The compounds demonstrating genotoxic effects in the cells were subjected to genotoxic mechanism investigation.

Phase 3: Genotoxicity studies of DBPs produced in Australian water

The final phase of this study was to use the validated FCMMN assay for determining genotoxicity of DBPs produced from chlorination of MW fractions isolated from an Australian water sample. This part of the study was conducted in collaboration with researchers from Curtin University. Nine MW fractions were isolated from a highly coloured Western Australian water sample and sent to the AWQC. All samples were chlorinated and tested for genotoxicity using the FCMMN assay. Results between pre- and post- chlorination were compared.

Outcomes

- The WIL2-NS (human lymphoblastoid cell lines) FCMMN assay has been successfully established at the AWQC. The assay was used to determine genotoxicity of 16 organic N-chloramines predicted to be potential health risks. An article has been published in Mutation Research (Laingam et al., *Mutation Research* 656(1-2): 19-26).
- Four N-chloramines (at µM concentration range) demonstrated genotoxicity (both by the FCMMN and microscopic MN assays) in the human cells. Cellular oxidative stress in the cells (following exposure to the four genotoxic chloramines) was determined by measurements of glutathione depletion and the formation of a lipid peroxidation product. A slight reduction (but not significant) of cellular glutathione with no lipid peroxidation product seen indicated that oxidative stress is not likely to be a mechanism involved in genotoxicity of these four organic N-chloramines. A manuscript reporting the results obtained from this section is now being prepared.
- None of the pre-chlorinated MW fractions showed genotoxicity in the mammalian cells, while some chlorinated MW fractions (containing medium to high MW content) demonstrated genotoxic effects in the cells. This suggested that these fractions contained substances that, once chlorinated, can induce genetic damage in mammalian cells. This initial study leads to further collaboration with the researchers in Curtin University.

Industry Uptake

The WIL2-NS FCMMN assays established at the AWQC is being used in a number of research projects designed to assess genotoxicity of novel DBPs and of reuse waters. Data from this study has also been used in a submission to US National Toxicology Program recommending that animal studies be undertaken on selected N-chloramines. Such work may eventually lead to guidelines for these compounds.

The Effects of Cylindrospermopsin on Human Granulosa Cells and Spermatozoa

Student	Dina Zebian
Project Leader	Dr Andrew Humpage, Dr Fiona Young, Dr Suzanne Froscio
Organisations Involved	Water Quality Research Australia/ Flinders University/ Flinders Research Centre for Coastal Catchment Environment
Start Date	March 2006
Status	Submitting January 2010

Background and Relevance:

In 1979 a severe outbreak of hepatoenteritis occurred in Palm Island off Northern Queensland, which was attributed to the cyanobacterial alkaloid cyanotoxin cylindrospermopsin (CYN), from *Cylindrospermopsis raciborskii*. C. *raciborskii* is now commonly found in human drinking water supplies of tropical and subtropical regions (Falconer *et al*., 1999). CYN is primarily hepatotoxic (Froscio et al., 2003), although genotoxic effects have been reported (Humpage *et al*., 2000, Humpage *et al*., 2005). Murine *in vivo* studies found non-specific cytotoxic effects of CYN on kidneys, adrenal, small intestine and lung (Hawkins et al., 1985).

Little is known about the reproductive toxicology of CYN, and thus the objective of the research is to examine the effects of CYN on both human granulosa cells and human spermatozoa's functionality and cytotoxicity *in vitro* as markers of female and male reproductive toxicology respectively.

Research Approach

Research on the possible toxic effects on primary derived human reproductive cells was undertaken using an *in vitro* cell culture approach. Human granulosa cells and human spermatozoa were obtained from patients undergoing assisted reproductive technology (ART). These cells were then exposed to cylindrospermopsin (0.1-5µM) *in vitro* and cell viability, protein synthesis inhibition and functionality (hormone production by granulosa cells) was examined after set exposure periods (15 minutes - 72 hours).

Outcomes

Granulosa cell death occurred after similar CYN concentrations and exposure that caused liver damage in mice, which supports the proposed 1µg/L guideline. In contrast initial experiments found that CYN did not kill human spermatozoa. Functionality of the granulosa cells was assessed by measuring the production of progesterone and estradiol and we found that low CYN concentrations adversely affected steroid hormone production after 72 hours. Protein synthesis was significantly inhibited after 6 h exposure to high CYN concentrations.

Industry Uptake

Further research is required to determine the effects of low doses of CYN (1µg/L) over long term exposure on human fertility and reproduction prior to industry adoption of these results.

Spatial and Temporal Features of Hydrodynamics and Biogeochemistry in Myponga Reservoir, South Australia

Student	Wai sum (Grace) Chan
Project Leader	A/Prof Justin Brookes
Organisations Involved	The University of Adelaide
Start Date	1st September 2006
Status	Proposed to submit August 2010

Background and Relevance

Myponga reservoir in South Australia is entirely fed by catchment runoff during winter rains. Large amounts of allochthonous nutrients along with the runoff water often support excessive growth of phytoplankton in the reservoir when other conditions are suitable. The available nutrients slowly deplete in the water and often fall below the equipment detection limit (<0.005 mg/L) in summer and autumn, however the undetectable nutrients continuously sustain the high primary productivity in the reservoir. Recycling of planktonic nutrients and internal loading of sediment nutrients may be important factors during this period.
This project aims to determine the physiochemical processes that give rise to the nutrient dynamics, and to investigate the nutrient interactions amongst water, sediment and phytoplankton.

Research Approach

There are four components in the project involving a series of field and laboratory works:

- study the seasonal trend of water chemistry and hydrodynamics
- analyse the nutrient and metal contents of sediments and their potential releases
- examine the physiological responses of *in situ* phytoplankton community with regards to different light and nutrient conditions
- determine the nutrient contents in phytoplankton cells over a growing season

Outcomes

These findings help to understand the variability and complexity of nutrient recycling in the lake ecosystem, and also provide baseline study for the importance of recycling of planktonic and sediment nutrients.

Industry Uptake

The industry will receive the following information, which helps to improve the source water quality.

- The likelihood of the occurrence of thermal stratification in the water column, which may lead to the release of nutrients and metals under anaerobic condition
- The compositions of nutrients (e.g. C, N, P) and metals (e.g. Cu, Mn, Fe) across the lake sediments
- The response of natural phytoplankton population to ambient light and nutrient status

Radiological Impact of Technologically Enhanced Radioactive Wastes Derived from Water Use Applications in Australia.

Student	Ross Kleinschmidt (QUT)
Project Leader	Associate Professor Heather Chapman (Griffith University)
Organisations Involved	Griffith University Queensland Health Forensic & Scientific Services Queensland University of Technology, Brisbane Queensland Local Government Shires & Councils Queensland Government Departments
Start Date	Candidature - September 2006
Status	Expected completion of PhD program 2009/2010

Background and Relevance

While a significant body of information exists on the effects of the radiological quality of water used for drinking, limited information is available on the impact of the natural or artificial radioactive agents removed during water treatment, distribution, use and ultimate disposal. The fate of these waste products and their impact on future generations and the environment requires investigation.

Research Approach

The Research plan is designed around the publication of four primary, peer-reviewed papers, each one covering a critical component of the study topic. Each publication will research analysis methods, critical dose pathways where applicable, and ultimately provide a unique Australian data set relating radioactivity in water to residual radioactive materials in waste streams associated with treatment, use and ultimate disposal to the environment. The proposed papers are:

Study Area #1

Characterisation and Disposal of Water Borne Radioactive Materials During Urban Treatment and Distribution Processes.

Study Area #2

The Fate of Radiopharmaceuticals in Wastewater Systems and the Environment. This research project will also assess the use of a common macroalgae as a sensitive monitor for the determination of low concentrations of radiopharmaceutical wastes (I-131 and Tc-99/99m) in the estuarine environment.

Study Area #3

The use of 'radioactivity in water' data as an indicator of community exposure to naturally occurring radioactive material in Queensland. This program will utilise a Queensland-wide network of groundwater bores to sample water and then perform screening radiological analysis for Rn-222 and Ra-224/226/228. The data will be compiled into a 'Queensland Radiological Water Quality Map'.

Study Area #4

Assessment of Radioactivity Associated with Water Resource Exploitation in Remote Australian Communities.

Outcomes

Publications to date:

Kleinschmidt R. (2009) Uptake and depuration of ^{131}I by the macroalgae *Catenella nipae* – potential use as an environmental monitor for radiopharmaceutical waste. *Marine Pollution Bulletin*. 58(10) 1539-1543.

Kleinschmidt R and Akber R. (2008) The impact of naturally occurring radioactive materials derived from urban water treatment plants in southeast Queensland, Australia. *Journal of Environmental Radioactivity*. 99 607-620.

Kleinschmidt R. (2006) Residual radioactivity from the treatment of water for urban domestic applications. Environmental Health Risk III. *Transactions on Biomedicine and Health*. 9. 373-382.

Industry Uptake

Nil to date as PhD is not yet completed.

A Quantitative Approach to Assessing the Effectiveness of Catchment Management for the Improvement of Drinking Water Quality.

Student	Kathy Cinque (RMIT)
Project Leader	Dr Nira Jayasuriya (RMIT) and Dr Melita Stevens (Melbourne Water)
Organisations Involved	Melbourne Water, RMIT
Start Date	September 2009
Status	Planning to submit final thesis before the end of 2009

Background and Relevance

Buffer or riparian strips are known to be effective at minimising waterway pollution by reducing the momentum and magnitude of surface and sub-surface runoff thereby aiding infiltration into the soil column and promoting entrapment of pollutants. This process is well researched in terms of constituents such as sediments and nutrients. In a drinking water catchment, however, the ability of these buffer strips to trap or remove human infectious pathogenic organisms is of most interest. Having the capability to quantify the effectiveness of buffer strips for pathogen removal may give drinking water quality managers a validated barrier to contamination.

The aim of this research is to determine a way of predicting the decrease in risk to public health due to the implementation of buffer strips in an agricultural catchment.

Research Approach

The Tarago Reservoir catchment, about 100kms east of Melbourne, was chosen as the study catchment as it currently supplies drinking water to greater Melbourne. There is also a history of catchment management and an extensive water quality data set. Statistical analyses were employed to determine if there was any measurable impact on water quality that could be contributed to catchment management.

A model that specifically simulates pathogen fate and transport in a catchment is necessary. Additionally the model must be continuous to allow for the impact of events and non-point source inputs to be assessed. A simple lumped conceptual model, EG, was chosen. This model uses the partitioned flows from a hydrological model as inputs, which is vital as pathogens will be transported, lost and predated differently depending on their flow path. EG was not specifically developed for determining the effectiveness of buffer strips and therefore some modifications to the pathogen transport processes were necessary. Calibration, validation and uncertainty analysis was carried out on the modified model. The overall effect of having a buffer as compared to not having one was determined using the modified model.

Relationships were formed between the buffered and non-buffered catchments which are useful in determining the amount of pathogen reduction likely in certain circumstances given a particular increase in buffer. Catchment managers could for example use the expected decrease in pathogen numbers from the implementation of a buffer strip and the cost of those works and compare it to the cost of an increase in the treatment plant capability. By quantifying the benefits in this way on-ground works may be comparable to other treatment options and therefore justifiable.

Outcomes

The ability to quantify the benefits that implementing buffer strips along streams will give to final water quality will allow the comparison of investing in catchment management to treatment costs and an assessment of the risk reduction benefits of both.

Industry Uptake

Quantification of the benefits of buffer strips will assist catchment managers and water quality managers in planning works in the catchment and in securing funding for such works. The ability to show that the on-ground works can have a positive and measurable effect on drinking water quality is important for various stakeholders including regulators and the community. For the protection of public health drinking water quality managers need to validate the barrier's effectiveness by proving that they are achieving a specific pathogen log-reduction. Having confidence in catchment management initiatives to provide reduction and having the ability to quantify that reduction may lead to more on-ground works and less conventional treatment. This has benefits for the community on a number of different levels including, but not limited to; a reduced cost of treating their drinking water, a more aesthetic landscape and healthier waterways.

Techniques to Manage the Impacts of Salinity and Suspended Solids in Freshwater Aquatic Ecosystems

Student	Jason Dunlop (UQ)
Project Leader	Assoc Prof Heather Chapman (Griffith University)
Organisations Involved	Department of Environment and Resource Management
Start Date	March 2005
Status	In progress, expected completion Sep 2010

Background and Relevance

Salinity and sediments represent two of the most common river contaminants that can affect the habitat and biota of rivers and in the case of sediment, impacts can extend to receiving estuaries and bays. Although there is a clear need to manage their impacts it has proven notoriously difficult to establish safe concentrations to manage these contaminants. It is possible to apply a risk assessment methodology to assess the impacts of salinity and turbidity impacts on aquatic ecosystems though approaches using the available data are not established in the national water quality guidelines due to a paucity of effect data. This project is aimed at addressing this information gap through the collection of toxicity data for 102 macroinvertebrates collected from 11 locations from across Queensland. The results provide a basis for assessing salinity risk and determining trigger values for salinity in freshwater ecosystems at local and regional scales in Eastern Australia.

Future work not yet completed will investigate further the issue of variable anion and cation compositions on the toxicity of salinity with a special focus on the toxicity of sulphate dominant saline waters to macroinvertebrates. Sulphate is of particular interest because it is produced in high concentrations relative to background concentrations in mining water discharge in central Queensland. Information will be collected on sulphate toxicity through a series of laboratory ecotoxicology experiments. Predictive models of variable anion and cation composition will also be developed using the data collected as part of this project and the available toxicological literature.

Research Approach

The research approach has been to:

- Review the impacts of salinity and suspended solids
- Develop techniques for water quality guidelines for salinity and suspended solids
- Establish the toxicity of salinity to freshwater macroinvertebrates
- Investigate potential application of field data sets to develop water quality guidelines for salinity improved statistical approaches to developing water quality guidelines with rapid test data
- Investigate the effect of ionic composition on the toxicity of saline waters

Future work will focus on the toxicity of sulphate dominant saline waters to macroinvertebrates and it is anticipated that a Quantitative Structure Analysis Relationship will be developed for anion and cation toxicity.

Outcomes

There have been a number of outcomes from the project to date. The research contributing to the PhD project has been undertaken as a series of scientific publications, the details of which are provided below.

Dunlop J.E., McGregor, G., and Horrigan, N. 2005. Potential impacts of salinity and turbidity in riverine ecosystems: Characterisation of impacts and a discussion of regional target setting for riverine ecosystems in Queensland. National Action Plan for Salinity and Water Quality technical report series, QNRM05523, ISBN 1741720788. http://www.wqonline.info/Documents/Report_WQ06_Review_reduced.pdf

Dunlop J.E., and McGregor, G. 2007. Setting water quality guidelines for salinity and sediment in freshwater streams in Queensland: An applied approach within a natural resource context. National Action Plan for Salinity and Water Quality technical report series. ISBN 9781741725681. http://www.wqonline.info/Documents/Report_GuidelinesSalinitySediment.pdf

Dunlop, J.E., Kefford, B.J., McNeil, V.H., McGregor, G.B., Choy, S., and Nugegoda, D. (in press). A review of guideline development for suspended solids and salinity in tropical rivers of Queensland, Australia. *Australasian Journal of Ecotoxicology (special issue on Tropical Ecotoxicology in Australasia*) Vol 14, issue 2.

Dunlop, J.E., Horrigan, N., McGregor, G., Kefford, B.J., Choy, S., Prasad, R., 2008. Effect of spatial variation on salinity tolerance of macroinvertebrates in Eastern Australia and implications for ecosystem protection trigger values. *Environmental Pollution*. 151, 621-630.

Horrigan, N., **Dunlop J.E.**, Kefford, B.J., and Zavahir, F. 2007. Acute toxicity largely reflects the salinity sensitivity of stream macroinvertebrates derived using field distributions, *Marine and Freshwater Research*, 2007, vol 58, 178–186.

Hickey, G.L., Kefford, B.J., **Dunlop, J.E.**, and Craig P.S. 2008. Making Species Salinity Distributions reflective of naturally occurring communities: Using Rapid Testing and Bayesian Statistics. *Environmental Toxicology and Chemistry*, Vol. 27, No. 11, pp. 2403–2411.

Kefford, B., **Dunlop, J.E.**, Nugegoda, D., and Choy, C. 2007. Understanding salinity thresholds in freshwater biodiversity: freshwater to saline transition. Chapter 2, page 9-28 in: Lovett, S., Price, P. & Edgar, B. (eds); Salt, Nutrient, Sediment and Interactions: Findings from the National River Contaminants Program, Land & Water Australia, Canberra.

Kefford, B.J., Zalizniak, L. **Dunlop, J.E.** and Nugegoda, D. and Choy. S. (submitted May 2009) How are macroinvertebrates of slow flowing lotic systems directly affected by suspended and deposited sediments? *Environmental Pollution.*

Industry Uptake

Numerous consulting projects have applied the data generated by this project in determining guidelines for salinity.

The use of Compound Specific Isotope Analysis for studying the Origins of Natural Organic Matter in Aquatic Systems

Student	Dawn White
Project Leader	Professor Kliti Grice (Curtin) & Dr Paul Greenwood (UWA) Associate Supervisor: Dr Rino Trolio (Water Corporation)
Organisations Involved	Curtin University, UWA, Water Corporation of WA
Start Date	November 2006
Status	Progressing, Lab work almost complete, intended thesis submission date July 2010

Background and Relevance

Analytical characterisation studies of NOM are necessary to gain a better understanding of the sources, structural elements, transport, reactivity and fate of NOM and to identify the precursors of NOM. Due to the complex nature of NOM an integrated approach to chemical analysis is required for successful characterisation. The aim of this research project is to assess the potential of a new technique based on stable isotope composition that may complement the existing suite of analysis to improve the overall characterisation of NOM.

This PhD investigates the development and optimisation of stable isotope analysis methods for analysing the compositional and structural character of NOM, with a particular focus on establishing the isotopic signature of biomarkers of bacterial and algae active in membrane fouling.

Compound Specific Isotope Analysis (CSIA), largely developed for petroleum geochemistry studies, is now being more widely applied, including in the field of microbiology. However, the technique has not yet been widely applied to drinking water source studies. Stable isotope analysis offers considerable source and process diagnostic potential, thus encouraging its use in NOM characterisation studies.

Phospholipid Fatty Acids biomarkers (PLFAs), in combination with their stable isotope analysis is a rapidly growing approach in microbial ecology. Natural isotope ratios of biomarkers can be used to study organic matter sources utilised by microorganisms in complex ecosystems and for identifying specific groups of bacteria. A component of this PhD research will involve the PLFA analysis of biofilm/biofoulant NOM material. Its capability for relating community profile and water quality information will be investigated.

Research Approach

The approach will be to obtain stable isotopic data of NOM on both a whole sample and a compound specific basis in order to investigate the utility of stable isotope analysis for studying the source input, temporal and spatial dynamics, transportation and fate of organic material in source water systems.

CSIA requires a high degree of baseline resolution, so NOM will be isolated, fractionated and simplified using established techniques developed in other analytical fields to yield relatively simple fractions appropriate for CSIA. The fractionation techniques used can be divided into the broad categories of chemical (PLFA) and thermal (pyrolysis, microscale-sealed vessel, offline pyrolysis) degradation.

Successful fractionation and degradation methods developed will be applied to a range of selected samples representative of the entire water system from catchment to tap (e.g. dam water high in humic NOM, dam water high in algogenic NOM, membrane biofoulant and distribution system biofilm).

Outcomes

NOM affects potable water quality in a number of ways including; promotion of disinfection by-product (DBP) formation, provision of a substrate for biological growth and lowering the efficiency of treatment processes. The removal of NOM therefore presents one of the major challenges to the drinking water industry. Whilst the complete removal of NOM from drinking water sources is not viable, innovative techniques and strategies to

optimise the effective, targeted removal of NOM are much sought after. Removal strategies will benefit from a detailed understanding of the characteristics and composition of NOM and its precursors.

Industry Uptake

Interest has been shown from the Water corporation of WA with regard the CSIA of PLFA profiles from biofilm communities in drinking water distribution systems. It is as though this combination of techniques could be particularly useful in looking at bacterial communities in chloraminated systems – of particular interest is Ammanox bacteria.

New WQRA PhD students

In the past year two new students were awarded WQRA PhD scholarships. Clara Loi and Arron Lethorn will be supervised at Curtin University.

Treating Wastewater for Potable Reuse: Removal of Chemicals of Concern using Advanced Oxidation Processes

Student	Clara Loi
Project Leader	A/Prof Cynthia Joll, A/Prof Anna Heitz, Dr Kathryn Linge
Organisations Involved	Curtin University, Water Corporation of Western Australia, GHD,
Start Date	March 2009
Status	Thesis submission date end May 2012

Background and Relevance

Climate shifts, expanding populations and drought have resulted in scarcity of water in many parts of Australia and most States are now investigating alternative water sources. Perth, in particular, has experienced sustained drought conditions for the past three decades, with inflows into dams now less than one third of long-term averages. Currently water reuse is limited to supplying industry with recycled wastewater treated with microfiltration and reverse osmosis (MF/RO). However from 2010, the Beenyup Groundwater Replenishment (GWR) trial will inject MF/RO-treated wastewater into Perth's most important source of drinking water, the Gnangara Mound. This 3-year trial of indirect potable reuse (IPR) by aquifer replenishment will be one of the first major IPR schemes in Australia.

Analysis of both secondary and MF/RO-treated WW from Perth's wastewater treatment plants (WWTPs) has demonstrated that some micropollutants (MPs) are not removed by MF/RO and may even form during MF/RO treatment. These MPs present health and regulatory concerns and additional treatment processes such as advanced oxidation (AO) are required to achieve permeate that will consistently meet health and environmental guidelines. This project will aim to minimise emerging contaminants, such as benzotriazole, tolytriazole and other MPs, in treated wastewaters such as that to be injected in the GWR trial. This will be achieved by trialling a number of novel approaches, including treatment of the MF/RO permeate with advanced oxidation processes (AOPs).

Research Approach

- This PhD project will study the reaction mechanisms, kinetics and processes involved in the formation and destruction of benzotriazole, tolytriazole, and possibly other MPs (to be determined)
- The kinetics of formation and destruction of MPs by various AOPs will be studied in laboratory trials using standard compounds, and the effectiveness of pre-treatment of the secondary effluent and post-treatment of MF/RO permeate will be determined using AOPs (e.g. UV, peroxide, ozone, ferrate) both individually and in combination

Outcomes

- Literature review underway
- Planning of project with guidance with Prof Urs von Gunten (EAWAG, Switzerland)
- Chemicals and equipment (low-pressure UV lamp and reactor) have been purchased and should arrive soon
- Preliminary method development for the analysis of benzotriazoles by liquid chromatography-mass spectrometry-mass spectrometry (LC-MS/MS) has commenced

Industry Uptake

- Future results will be of great interest for water utilities considering IPR and for health authorities reviewing water quality guidelines

Emerging Disinfection By-Products and their Precursors	
Student	Arron Lethorn
Project Leader	Assoc. Prof. Cynthia Joll, Assoc. Prof. Anna Heitz
Organisations Involved	Curtin University, Curtin Water Quality Research Centre, Water Corporation of WA
Start Date	March 2009
Status	Thesis submission date end March 2012

Background and Relevance

In chlorinated water, disinfection by-products (DBPs) are formed via reaction of chlorine with bromide and aquatic natural organic matter (NOM) to form a complex mixture of mainly halogenated organic compounds. While maintenance of pathogen barriers through disinfection is a priority for drinking water safety, minimisation of DBPs is also of major importance for water utilities and regulators. Epidemiological studies have shown that consumption of chlorinated water may be linked with a number of adverse human health effects, e.g., cancers of the urinary and digestive tracts and bladder and colon cancers, low birth weight, intrauterine growth retardation and spontaneous abortion. Historically, the focus has been on the DBPs that are present in greatest abundance, the trihalomethanes (THMs) and haloacetic acids (HAAs), but more recently, interest has shifted to other, emerging DBPs, that are suspected to be more important from a human health perspective. Several groups of compound classes that have substantially higher mammalian toxicities than the THMs and HAAs have been identified, including haloquinones, halocyclopentenoic acids, organic *N*-haloamines, *N*-nitrosamines and nitrosamides, halonitriles and haloamides. It is also important to note that brominated and, in particular, iodinated DBPs have substantially higher toxicity than their chlorinated analogues. In addition, the non-volatile, higher molecular weight fraction of DBPs, which has not been extensively studied due to the challenging analytical chemistry requirements, is likely to contribute significantly to the toxicity of disinfected water. It is therefore important to study the characteristics of NOM and the kinetics and mechanisms of the formation of these emerging DBPs from NOM in order to develop strategies to minimise the formation of emerging DBPs in drinking waters.

Research Approach

Characterisation of NOM will be based on some existing techniques at CWQRC, as well as implementation of some new techniques, e.g. for characterisation of the polarity, acidic functional groups and dissolved organic nitrogen content within the NOM sample. Molecular weight fractions, collected via preparative size exclusion chromatography of the NOM within a Western Australian source water sample, will be characterised. Analytical methods for some emerging DBPs will be developed. Disinfection studies, using both chlorination and chloramination, will be conducted on the molecular weight fractions, and regulated and emerging DBPs will be analysed. Detailed kinetic and mechanistic studies of some emerging DBPs will then be conducted. The structural characteristics of the NOM in the fractions and the DBP, particularly emerging DBP, formation will be correlated in order to increase the fundamental understanding of DBP formation and develop strategies for DBP minimisation.

Outcomes

- Literature review underway
- Candidacy commenced
- Study of the effect of quenching agents on DBP concentrations underway. Poster presentation accepted for Gordon Research Conference on Disinfection By-Products August 2009
- Analytical method development for halonitriles commenced
- Project planning underway and ongoing

Industry Uptake

Future results on emerging DBP formation and minimisation will be of wide interest to industry.

2008-09 PhD Student Presentations

Dawn White gave an oral presentation on "A Stable Isotopic Study of the Origins of Aquatic Natural Organic Matter" at the Australian Organic Geochemistry Conference, Adelaide, September 2008.

Kate Langdon gave an oral presentation on "*Aquatic Hazard Assessment for Pharmaceuticals, Personal Care Products and Estrogenic Compounds from Biosolids Amended Land*" Langdon KL, Warne MStJ and Kookana R at the Biosolids Specialty Conference IV, Adelaide, June 11-12 2008. Kate also gave the same oral presentation at the 5th SETAC World Congress, Sydney, August 3-7 2008.

Dina Zebian gave an oral presentation on "CYN-FULL SPERM?" at The Flinders Research Centre for Coastal and Catchment Environment & Flinders Bioknowledge Postgraduate Research Conference in Adelaide, Australia and on "*Blooming Problems In Water, And Possible Effects On Future Baby Booms*" at the Australian Water Association Regional Conference in the Barossa Valley, South Australia.

Wai sum Chan gave a presentation on the "*Lake Physical Factors Contributed to Spatial Variability of Phytoplankton in Myponga Reservoir*" at the 13th International Conference on Harmful Algae 2008.

Ross Kleinschmidt was Guest speaker and gave a presentation at Entox (University of Queensland) Seminar Series on "*Radionuclides in Urban Wastewater Treatment*".

Kathy Cinque presented on "*Investigating the Public Health Impacts of Deer in a Protected Drinking Water Supply Watershed*" at IWA World Water Congress, Vienna, September 2008 and attended OzWater09, Melbourne, March 2009.

Jason Dunlop presented the paper "*Effect of Spatial Variation on the Salinity Tolerance of Macroinvertebrates in Eastern Australia: Implications for Ecosystem Protection Trigger Values*" at the 5th SETAC World Congress, 3 - 7 August 2008, Sydney Convention and Exhibition Centre, Sydney Australia.

Nicole Thornton gave an oral presentation on progress in her PhD at the WQRA Members' Meeting in May 2009.

Heather Brown gave an oral presentation on progress in her PhD at the WQRA Members' Meeting in May 2009.

Somprasong Laingam submitted a Poster presentation at the Society of Environmental Toxicology and Chemistry (SETAC) World Congress, Sydney in August 2008.

Shelly Rodrigo attended the 18th International Epidemiology Association World Congress of Epidemiology, Porto Alegre, Brazil, September 2008 and the Epidemiological Research and New Directions, September 20 - 21, Porto Alegre, Brazil.

Baden Myers submitted the following papers Myers S B, Van Leeuwen J & Beecham S (2009) "*An Experimental Study on the Long-Term Water Quality Impacts of Gravel Media in Storage Underlying Permeable Pavements*" at the 6th International Water Sensitive Urban Design Conference and Hydropolis #3 in Perth, Australia.

Shackel B, Beecham P S, Pezzaniti D & Myers B (2008) "Design of Permeable Pavements for Australian Conditions" at the 23rd Australian Road Research Board Conference in Adelaide, Australia.

Smith E, Myers B, Scanlon A & Mills J E (2008) "Online Learning Techniques: Using Wikis and Blogs in First Year Engineering. ATN Assessment 08: Engaging Students with Assessment". Adelaide, Australia.

2008-09 Summer Scholarship Initiative

In 2008-09 WQRA hosted its first round of Summer Scholarship students since the official launch. This initiative gives undergraduate students an opportunity to undertake a ten week project, over the summer university break, in an area of relevance to the water industry.

For the students it provides a taste of R&D in an industry-relevant project and also the opportunity to develop advanced skills in presenting to audiences and report writing. For WQRA industry members the Summer Scholarship initiative provides the opportunity to meet a group of high calibre students who have been exposed to the water industry.

In this year's Summer Scholarship initiative ten students from various academic backgrounds undertook investigations in a diverse range of projects – see Table 7.

The students gave presentations on the outcomes of their research to WQRA Members and others at the summer scholarship reporting seminar in Melbourne on February 17th. Judging the presentations were Emeritus Professor Nancy Millis (former Chair of the CRC for Water Quality and Treatment), Dr Kathryn Linge from Curtin University and Jodieann Dawe, the CEO of WQRA.

Prizes were awarded to three outstanding students - Tom O'Rielly, Jane-Louise Lampard and Dylan Irvine.

• Tom's project, investigating industry water recovery using membranes and waste heat, was conducted under the supervision of Associate Professor Mikel Duke (Victoria University) and Nigel Corby from City West Water.

• Jane-Louise Lampard's project focussed on reviewing contaminants in recycled water identified as being of concern to the water industry and general public. Her supervisors were Associate Professor Heather Chapman and Dr Fred Leusch at Griffith University.

• Dylan Irvine's project investigated the potential of using modified zeolite to prevent biological clogging of artificial recharge structures. He was supervised by Dr Huade Guan, Dr John Hutson and Professor Craig Simmons at Flinders University.

Summer Scholarship Student Report summaries

Using Modified Zeolite to Prevent Biological Clogging of Artificial Recharge Structures

Dylan Irvine

Supervisors: Dr Huade Guan, Dr John Hutson and Prof Craig Simmons

Flinders University, Adelaide, SA.

Summary

Artificial recharge (or aquifer storage and recovery, ASR) using storm water or treated wastewater is increasing in many areas facing water shortages. Artificial injection wells often suffer from microbiologically-induced clogging. Previous studies at Flinders University have demonstrated that clogging is caused by microbial growth, stimulated by nutrients in the source water.

Surfactant-modified zeolite (SMZ) has shown to be effective in removing microbiological organisms in field experiments over a five month period in a constructed wetland receiving septic tank outflow, demonstrating that a 10 cm-thick SMZ barrier, with 2 minute Contact time, effectively removed 100% *Escherichia coli*. Other studies have shown that SMZ removes 20 mmol.kg-1 of nitrate and 3 mmol.kg-1 of phosphate in batch experiments performed over 24 hours. These properties of SMZ demonstrate that a SMZ column could potentially be used prior to treated wastewater being injected into aquifers.

SMZ was shown to remove both nutrients and a bacterial surrogate in column experiments using synthetic wastewater, however, the magnitude of nutrient and bacterial (surrogate) removal of similar studies could not be replicated. It appears that contact time is an important factor in the efficiency of the removal of nutrients and bacteria from wastewater.

Use of Mouse Embryonic Stem Cells and Sheep Reproductive Cells to Detect Endocrine Disrupting Compounds (EDC) Bioactivity in Environmental Water Samples

Allan Bond

Supervisors: Dr. Fiona Young and Dr. Kenneth Lang

Department of Medical Biotechnology, Flinders University, Adelaide, SA.

Summary

Drinking water supplies in Australia are being outstripped by demand, with recycled wastewater being proposed as a feasible supplement option. Even after treatment, wastewater may contain compounds with endocrine disrupting activity, known as endocrine disrupting compounds, or EDC's.

EDC's have the capacity to mimic hormones such as progesterone and 17β-Estradiol and compounds involved in regulating their action. These steroids are vital for normal homeostasis as well as the regulation of normal hormonal function and the maintenance of pregnancy.

Although the full extent of risks these compounds present to humans is not yet fully understood, regulatory authorities are seeking further investigation into the actions of these compounds to provide more relevant information to determine safe guideline levels.

The blue green algal toxin cylindrospermopsin (CYN) has been shown to inhibit progesterone production in human granulosa cells at concentrations of 0.15μM, and cytotoxic at 1.2μM. However insufficient supply of human granulosa cells requires suitable alternative cells to be found. Ovine luteal cells provide this alternative and have been well characterised *in vitro*, however due to seasonal breeding are only available during sheep breeding season, therefore cryopreservation is required.

Three freezing protocols were trialled in this study, being 5 and 10% DMSO and 22-propandiol, and at the time of this report 10% DMSO has been determined to be the most appropriate method, as these frozen cells were more similar to fresh cells in their response to luteinising hormone (LH), di butyryl cyclic adenosine monophosphate (dbcAMP), and the two EDC's cylindrospermopsin and ethinyl estradiol (EE2) a metabolite of the synthetic estrogen used in the female contraceptive pill.

Mouse embryonic stem (mES) cells provide a suitable model of embryo development, and as such can be used to model the effect of EDC's on embryonic development. In this study the effect of the EDC's cylindrospermopsin and ethinyl estradiol on the ability of mES cells to differentiate into the mesoderm (cardiomyocyte) or ectoderm cell lineage (neural). Mesoderm differentiation was observed in embryoid bodies treated with 0.1μM CYN, however cytotoxicity was observed at 1μM CYN, comparatively mesoderm differentiation was observed in bodies treated with 10-8M EE2, while cytotoxicity was observed at 10-8M.

Managing Water Demand in Remote Australian Indigenous Communities for Improved Livelihoods

Bonnie Marshall

Supervisors: Helen Salvestrin, CAT, Alice Springs, NT.

Summary

Water scarcity is often a direct response to both human population growth and climatic change, although rising demand remains the primary strain on water resources. Australia's overall indigenous population has doubled in the past twenty years, most living in either 'remote' or 'very remote' areas. With climate change in the future it is predicted that water supplies are to become less predictable and dry regions will become even drier. Already, Central Australia shows some of the most rapid climate warming rates in Australia.

The arid region of Australia is stated to be among the world's largest non-renewable groundwater systems. Already, groundwater recharge is typically episodic and highly variable. Groundwater services 58% of all indigenous communities Australia-wide, often with no practicable alternative. A high proportion of remote indigenous communities are located in Central Australia, a region of limited groundwater recharge potential. Water Demand Management here is of high importance.

Although still in its infancy, Water Demand Management is a fast emerging approach dealing with the issue of water scarcity. It aims to maintain water resource sustainability by management of the demand for water or conserving water. This study explores the application of Water Demand Management in remote indigenous communities in order to sustain water resources for improved livelihoods. To make suitable assessments for WDM planning, knowledge of physical, social and political environments are explored.

Water Demand Management in remote indigenous communities is uniquely challenging and this report highlights these challenges. Determination of groundwater sustainability is difficult, involving complex climatic, hydrogeological and consumptive interactions. Uncertainty of whether a groundwater supply is sustainable often results in frequent exploitation. Water supply infrastructure is often poorly constructed and maintained resulting

in unnecessary water loss. Highly different consumptive influences exist in indigenous towns and communities and therefore water consumption and uses should not be compared to those of non-indigenous settlements.

Water Demand Management strategies are reviewed. Water resource managers are recognising the benefits of more sociological approaches such as 'integrated water resources management' and the 'sustainable livelihoods approach'. Models and ideas were obtained for assessment and incorporation into Water Demand Management planning for remote indigenous communities. Assessment of appropriateness of strategies as a standard approach to Water Demand Management in remote indigenous communities is carried out. There is no standard method appropriate to all communities.

For long term sustainable Water Demand Management, strategies must be appropriate to each individual community and consider a community's uniqueness. It is proposed that the way forward is a strong focus on community education with a combination of community-appropriate Water Demand Management strategies. A framework for Water Demand Management planning was developed. The framework includes six steps and aims to provide a community with information, knowledge and education regarding Water Demand Management; a Water Demand Management plan appropriate for the individual community; capacity for ongoing Water Demand Management; movement toward community self-sufficiency; water resource security; and improved livelihood. A 'risk assessment and management' structure was proposed for creation of an appropriate Water Demand Management plan.

The study identified areas for development on the subject and recommended further study be conducted to rectify the lack of data available; investment in detailed hydrologic and hydrogeologic studies; development of appropriate water sustainability analysis/calculation methods for remote indigenous communities; water policy and legislation relating to water supply and management (specifically Water Demand Management); consideration of high water consumption uses and appropriate alternatives for those; and finally, future development of infrastructure design to simultaneously consider health, culture and resource sustainability. Further recommendation is given to consider the highly social nature of Water Demand Management and that water resource managers should work alongside social scientists or possess background in such a field in order to create optimal management planning and education.

Analysis of Contaminants of Concern in Wastewater Treatment Processes

Yasmine van Leur

Supervisors: Dr. Heather Coleman and Prof. Richard Stuetz

UNSW Water Research Centre, UNSW, Sydney, NSW.

Summary

As the demand for water increases, interest has increased in water reuse such as the use of treated wastewater for irrigation or discharge to the environment. Concern has arisen with regards to the fate and removal of certain trace chemical contaminants during the wastewater treatment process. The treated wastewater could potentially have an impact on human health if the contaminants are not completely removed and may also impact aquatic life when the treated water is released into a river system.

This project involved investigating the fate of chemical contaminants, in particular steroids (both natural and synthetic) and antibiotics (sulfonamide antibiotics and trimethoprim), in wastewater treatment processes. The wastewater treatment processes that were investigated were the widely implemented conventional activated sludge (CAS) and a decentralised membrane bioreactor (MBR). The various treatment processes were compared in regards to their effectiveness in removing these chemicals of concern.

This work was in collaboration with MidCoast Water. Samples were taken from a wastewater treatment plant in the Mid-North coast of New South Wales which employs a full scale activated sludge treatment process with UV disinfection and a pilot scale membrane bioreactor. Samples were taken at different stages of the treatment process - raw sewage (influent), effluent after the clarifier, effluent after UV disinfection and membrane bioreactor effluent.

Sample preparation was carried out by filtration and solid phase extraction prior to analysis with Liquid Chromatography-tandem Mass Spectrometry (LC-MS/MS) using isotopic dilution.

The results highlighted that the decentralised MBR process is comparable and in some cases, superior over the CAS process in removing the steroids and antibiotics from the influent.

Contaminants of Concern in Recycled Water – Alternate Sources of Exposure

Jane-Louise Lampard

Supervisors: Assoc Prof. Heather Chapman, Dr Frederic Leusch

Smart Water Research Facility, Griffith University, Brisbane, Qld.

Summary

In the early 2000s many Australian state governments began considering wastewater reclamation as a means of combating water scarcity issues associated with drought, climate change and population growth. This has generated significant debate in parliament, the media and at the community level over the potential of human health effects associated with potable re-use water. In 2007 the Co-operative Research Centre for Water Quality and Treatment (CRCWQT, 2008) conducted a survey across five Australian capital cities examining community views on recycled water. Half of the 3000 respondents expressed an unwillingness to drink recycled water. Encouragingly, 74% of all respondents said they would be willing to drink recycled water if they could be assured of its safety.

To provide a clearer understanding of the potential exposures consumers face from recycled water, this paper reviews the most significant research pertaining to exposure sources for five contaminants known to be in wastewater and therefore potentially present in recycled water. The paper does not purport to provide a comprehensive meta-analysis of the existing literature for each contaminant, but provides a snapshot of the most significant exposure sources for each contaminant comparing these exposures with the predicted exposure resulting from consumption of recycled water. The compounds were selected from four categories of contaminants identified as being of concern by the scientific community, water industry providers and/or the general public:

- pharmaceutical and personal care products - this paper focuses on 17α-ethinylestradiol (EE2), a known endocrine disruptor, and galaxolide (HHCB) a musk fragrance detected in human breast milk
- phthalates - di-2-ethylhexyl phthalate (DEHP), a compound used extensively in household, medical and food packaging products is reviewed
- herbicides - atrazine which is used extensively in Australia
- disinfection by-products - N-nitrosodimethylamine (NDMA) which is produced during drinking water treatment

Demonstration of Industry Water Recovery Using Membranes & Waste Heat

Tom O'Rielly

Supervisors: A/Prof. Mikel Duke and Nigel Corby (City West Water)
Institute of Sustainability and Innovation, Victoria University, Melbourne, VIC.

Summary

The industry sector accounts for 12% of Australia's total water use. Steps need to be taken to start focusing on reducing the amount of water consumed in industry; this in turn will result in more potable water being available for drinking and domestic needs. Membrane distillation (MD) is an emerging separation technique that takes advantage of waste heat to treat water; this process can be applied to industry processes using on site waste heat to recover high quality water. MD works by allowing only volatile water vapour to pass through the pores of the membrane to the permeate side. Collection of the vapour as useful treated water varies depending on the setup. Direct contact MD (DCMD) was applied to treat wastewater from industry on a lab scale with the overall objective of exploring its possibility at a large scale to reduce the amount of fresh water consumed in industrial processes.

Using trade waste (TW) samples and data from Coogee Chemicals and Ensign Services experiments were conducted with parameters such as flow rate and temperature set approximately to replicate the conditions on site at the production plants. The experimental aim was to get maximum flux and observe the optimal recovery, while also observing the effect of fouling and scaling on the membrane.

The results from the Ensign Service tests showed that it was not possible to treat the wash water with current membrane technology. Wash water contained detergents and surfactants which inhibited the membranes hydrophobicity, causing it to become wetted allowing the membrane to act as a bridge allowing the feed to pass through to the permeate side. An alternative proposal would be to use a SGMD system to replace the cooling towers with the role of cooling the water from the heat exchanger loop and save on water evaporation losses. Some preliminary calculations were done showing SGMD a flux of 1 L/m2.h and could achieve 3.5% recovery. These calculations also estimated membrane area to be 255 m2. More lab testing and research would need to be done to determine if the SGMD alternative would be feasible.

The Coogee tests showed promising results producing high flux around 40 L/m2.hr with 4.4% recovery. This showed a DCMD unit could be used to replace the heat exchanger. The results also showed by sourcing on site

waste heat, water recovery could be increased by adding the feed recycle loop and increasing the size of the membrane. The PTFE membrane remained stable throughout the testing achieving 98% salt rejection. Ammonia from the feed was found to pass through the membrane, so further work would be needed to better understand the implication of ammonia passage through the membrane in regards to the ultimate use of the treated water.

Membrane distillation is therefore a viable process for treating TW using readily available heat, but requires studies such as this to guide it to its most appropriate use.

Modelling IntelliRain – A Digital Ecosystem to Maximize the Utilisation of Harvested Rainwater

Jack P Toke

Supervisors: Assoc. Prof. Nalin Sharda, Victoria University, Melbourne, Victoria.

Summary

Gardening is an integral part of the Australian way of life. But maintaining a green garden while water restrictions are being enforced is a real challenge.

This research project focuses on the following question: How can we maintain green gardens and avoid wasting precious drinking water at the same time? One of the most promising ways to solve this problem is to use harvested rainwater.

However, with manual watering we may not derive the maximum benefit from this harvested rainwater. By knowing the watering needs of the various plants, base on the species, planting density and microclimate of the plants, the amount of water really needed for each plant can be calculated. By combining this with the information about the predicted rainfall and current soil moisture level, optimum decision can be made to increase the benefit derived from the harvester rainwater stored in a backyard tank.

The aim of this research project is to investigate techniques for maximising the utilisation of harvested rainwater by using a computer based digital ecosystem called IntelliRain. The IntelliRain system will do this by using a reticulated watering system that is controlled by intelligent software that uses the knowledge of the watering needs of the various plants in the garden, current soil moisture levels, and the predicted rainfall, so that only optimum amount of water is used for watering the plants. For example, if rain is predicted in the near future, the system can skip watering the garden, or water most demanding plants just enough to keep the plants going until it rains, and thus avoid wasting the harvested rainwater.

One of the core intelligence to be included in the IntelliRain system is the ability to decide how much water to apply to keep plants optimally irrigated. Formulae for calculating the amount of water needed are provided based on factors such as: Evapotranspiration, Landscape Coefficient, Species Factor, Density Factor, Microclimate Factor, and Irrigation Efficiency.

The outcomes of this research project will be used to develop, implement, and test the IntelliRain system in future research projects.

Relating Fluorescence and Size Fractionation for Recycled Water Analysis

Yi Zhu

Supervisors: Dr Rita Henderson, Dr Stuart Khan and Assoc Prof Richard Stuetz, UNSW, Sydney, NSW.

Summary

Dissolved organic matter (DOM) is derived from plant residues as well as in situ via biological activities in water. Research has found that DOM character will affect the performance of treatment processes as well as water quality in grey water, recycled water, wastewater and portable water systems. It is therefore vital to understand the characteristics of DOM. The aim of this research is to investigate DOM character of recycled water systems using two characterisation techniques: size fractionation and fluorescence spectroscopy. The most relevant fluorescence excitation-emission wavelengths for monitoring recycled water during size fractionation will be determined. Additionally, this research will improve understanding of information provided by fluorescence excitation-emission matrix (EEM) characterisation of recycled water.

Size fractionation was undertaken using size exclusion chromatography (SEC) with UV, Organic Carbon and Nitrogen Detection using a Liquid Chromatography – Organic Carbon and Nitrogen Detection (LC-OCD) system. Fluorescence EEM spectroscopy was employed to investigate the fluorescence character of each size fraction. Different size fractions were collected from the LC-OCD and analysed by fluorescence EEM spectroscopy, as this is not possible by online detection. Both techniques give information regarding the presence of humic-derived and protein-derived DOM fractions and therefore the relationship between fluorescence EEM spectra and size fractions was determined.

In this research, fluorescence EEMs were successfully fractionated to show the relationship between size and fluorescence. The majority of the peaks observed were protein-like (Peak T1) and humic-like (Peak C). Most biopolymer peaks were protein derived where humic-like fluorescence was present in the humic, building block and low molecular weight humic and acid fractions. Two wavelength pairs were then recommended for online fluorescence detection.

Pesticide Residues within a Drinking Water Catchment

Andrew Dinh

Supervisors: Dr Nichola Porter

Summary

Hexazinone, a residual herbicide was used on herbaceous and woody weeds in a *Pinus radiata* plantation in an area close to a major water drinking water catchment from 2004 until April/May 2005. Although the application of the herbicide has ceased, repeat testing of the catchment since 2005, has confirmed the presence of Hexazinone at low levels. While these levels are below the Australian Drinking Water Guidelines (ADWG), the continued presence of the herbicide is puzzling.

The application of the herbicide before heavy rain resulted in contaminated runoff into the catchment reservoir. Hence there is a need for a user friendly and sensitive method to detect the pesticide. The use of an on-site Flow Injection (FI) system was planned to be used for the detection of Hexazinone for this project. The direct injection High Performance Liquid Chromatography was used to confirm the FI results but due to the time constraints this was unavailable. This was unfortunate as the FI system is fast, sensitive and can be made portable.

Direct injection HPLC system is precise with a limit of quantitation (LOQ) of 0.33 ppb and a detection limit of 0.02 ppb. To remove the natural organic matters (NOM) present in water and soil samples, a solid phase extraction (SPE) was included into the procedure before injecting samples through the HPLC. The recovery of Hexazinone from this cleanup process was high 97% and gave superb sensitivity for very low concentrations of Hexazinone.

Since 2004, Hexazinone levels have decreased, but once in a while an elevated detection was observed which means heavy rains have possibly led to a contaminated runoff into the reservoir. Another possibility is soils being contaminated by the runoff during the rainy periods. Samples of water and sediments were taken from around the catchment to provide an indication of the source of the Hexazinone in the Moorabool catchment.

Regarding the water samples there was detection of Hexazinone but still below the ADWG and is mostly detected at the Water Treatment Plant and Korweinguboora Reservoir. From the soil sediments experiment, Korweinguboora and Stony Creek reservoir contains low levels of Hexazinone. This suggests the pesticide could be travelling through the soil and entering the surface of the water which contributes to the flux in results for the water samples.

Towards the end of this project there were still many unanswered questions. One of the questions is "How can we get rid of the Hexazinone completely?" This is where researchers and other interested groups need to continue the study. Hexazinone could still be detected in the future because it appears to exist in the reservoir sediments, providing a constant source of the pesticide.

The Regulation of Cyanobacterial Alkaloid Toxins in Drinking Water Supplies

Ivan Wong

Supervisors: Brett Neilan

Summary

An important member of marine and freshwater ecosystems is cyanobacteria, also known as blue-green algae. They can produce a variety of biologically active compounds including cyclic peptides and alkaloid toxins. Cyclic peptides such as the heptatoxin, microcystin, and alkaloid toxins such as the cytotoxin, cylindrospermopsin, occur most frequently in cyanobacterial blooms. Cylindrospermopsin is produced non-ribosomally by a mixed non-ribosomal peptide synthetase and polyketide synthase enzyme complex.

Cyanobacteria may multiply to high densities to form a bloom under nutrient rich conditions and exposure to sunlight. The major nutrients responsible for the occurrence of cyanobacterial blooms are phosphorus and nitrogen. This study investigates the effect of environmental factors on the regulation of cylindrospermopsin production in the cyanobacterium, *Cylindrospermopsis raciborskii* AWT205. Understanding the conditions in which toxic cyanobacterial strains may increase toxin production is critical in the control of harmful effects of *Cylindrospermopsis* blooms in Australian drinking water supplies.

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Clarke, B (2008) Persistent organic pollutants in Australian sewage sludge. RMIT University.

Kaucner C (2008) MSc (P/T) Surface Properties and Transport of Pathogens in Runoff. University of NSW.

O'Toole J (2008) Water Reuse and Alternative Water Sources : Attitudes, Practices, Risk Assessment and Human Health Outcomes. Monash University.

Pengelly J (Mar 2008) Effects Induced by pH, Ionic and Osmotic Stress on PSP Toxin Production in Cyanobacteria. University of NSW.

Ruebhart D (Sep 2008) Investigation, Optimisation and Validation of a Range of Bioassays Using Lower Trophic Level Organisms for the Testing of Aquatic Toxins. Griffith University.

Berwick L (2009) PhD Thermal Maturation Studies of Natural Organic Matter to Release Macro-Molecularly Bound Biomarkers and Investigate the Diagenetic Pathway of Major Organic Precursors (submitted). Curtin University.

Dong J (2009) PhD Urban Planning and Integrated Water Management : Towards an Alternative Institutional Model (submitted). Griffith University.

Huston R (2009) PhD An Assessment of Chemical Contamination of Rainwater Tanks in Urban/Industrial Areas of Australia (submitted). Griffith University.

Book Chapters

Kefford B, Dunlop JE, Nugegoda D and Choy C (2007) Understanding salinity thresholds in freshwater biodiversity: freshwater to saline transition. Chapter 2, page 9-28 in: Lovett, S., Price, P. & Edgar, B. (eds); Salt, Nutrient, Sediment and Interactions: Findings from the National River Contaminants Program, Land & Water Australia, Canberra.

NEPC (2008) Recycled water quality: A guide to determining, monitoring and achieving safe concentrations of chemicals in recycled water. Prepared by Middleton H, Moore M, Chapman H, Leusch F, Tan B, Drew R, Frangos J, Khan S, Leslie G and Shaw G. National Environment Protection Council (NEPC), Adelaide, SA, Australia.182pp.

Chapman HF, Leusch FDL and Tan BLL (2008) Risk management of chemicals in recycled water. Chapter 5 *in* Purified recycled water for drinking: The technical issues. Queensland Water Commission, Brisbane, QLD, Australia. 273pp.

CRCWQT Final Reports

When the CRCWQT ended, WQRA undertook to manage the completion of a significant number of final research reports. In the past year, eighteen final CRCWQT reports and two Water Research Foundation (formerly AwwaRF) reports have been published – a significant number of reports compared with previous years. When all reports are completed more than ninety research reports, nine occasional papers, eight technical fact sheets and numerous other publications will have resulted from the thirteen year lifespan of the CRC.

Underlying the production of such a large number of reports in a relatively short time has been a major coordinated effort. WQRA has relied on the goodwill of many industry and research colleagues who provided critical assessment of reports to help maintain a high quality in the standard of output.

The CRCWQT publications will continue to be freely available in PDF form from the WQRA website.

Reports published in 2008-09

Bain P, Burcham P, Falconer I, Fontaine F, Froscio S, Humpage A, Neumann C, Patel B, Shaw G, and Wickramasinghe W (2008) *Cylindrospermopsin Mechanisms of Toxicity and Genotoxicity*. WQRA/CRC for Water Quality and Treatment Research Report 61.

This project aimed to further investigate the mechanisms underlying toxicity and genotoxicity of Cylindrospermopsin (CYN) and how these may relate to potential carcinogenicity. The data obtained should aid in the risk assessment process. Another issue to be determined was the potential toxicity of the CYN analogue deoxycylindrospermopsin (deoxyCYN) that occurs in source waters with CYN.

Specifically the aims of the project were to gain an insight into the mechanisms of CYN toxicity and genotoxicity, assess the toxicity of the CYN analogue, deoxycylindrospermopsin, evaluate toxicological or genotoxicological endpoints for use as biomarkers of human exposure to CYN, use the toxicology data to undertake human health risk assessment and to provide this information for use in guidelines for CYN in drinking water.

Beard N (2009) *Small water system reliability in remote Indigenous communities in the Kimberley*. WQRA/CRC for Water Quality and Treatment Research Report 49.

This research investigated the reasons for the high frequencies of equipment breakdown in the Kimberley region, the effect on settlements with populations of less than 50 people and recommends ways to address the issues in the region.

The study focussed on 24 homeland communities in the Derby West-Kimberley Shire. The aim was to gain a detailed understanding of the management and operation of water supplies in these communities and how residents were affected. Sanitary surveys, infrastructure inventories, resident interviews, contractor maintenance visit reports and water quality tests were utilised in conjunction with historical water resource data to obtain an understanding of these water supplies.

Brookes J, Burch M, Hipsey M, Linden L, Antenucci J, Steffensen D, Hobson P, Thorne O, Lewis D, Rinck-Pfeiffer S, Kaeding U, Rasmussen P (2009) *A practical guide to reservoir management*. WQRA/CRC for Water Quality and Treatment Research Report 67.

This report summarises a range of studies and consolidated practical knowledge related to reservoir management in the Australian context, which also have wider international application. The guide provides an overview of processes that impact upon drinking water quality in reservoirs and also a range of selected procedures and tools for reservoir management. This is supported by a series of case study investigations that were largely carried out within the Source Water Program of the CRC for Water Quality & Treatment.

Brookes JD, Burch MD, Lewis DM, Regel RH, Linden L, Sherman B (2008) *Artificial mixing for destratification and control of cyanobacterial growth in reservoirs*. WQRA/CRC for Water Quality and Treatment Research Report 59

The primary aim of this project was to investigate control of cyanobacteria by creating mixing regimes that are unfavourable to cyanobacteria and which limit the release of nutrients from the sediments. The project evaluated a hybrid artificial mixing system, which included raft-mounted mechanical mixers and a bubble plume aerator as a means of controlling cyanobacteria and low dissolved oxygen levels in Myponga Reservoir, South Australia. A major component of the evaluation involved monitoring and understanding the behaviour of the reservoirs in terms of physical, chemical and biological processes and to demonstrate how monitoring data could be used to predict the onset of water quality hazards

Chow C, Fitzgerald F, Kuntke P, Davey D, McLeod S, Badalyan A, Zhao H and Zhang ES (2008) *Development of Low Cost Online Monitoring Package to Improve Chloramination Control*. WQRA/CRC for Water Quality and Treatment Research Report 44.

On-line ammonia monitoring is an important tool to optimise chloramination (reduce nitrification), however, the commercially available systems generally suffer from high capital and maintenance costs. These restrictions make the systems unattractive to the water industry, particularly downstream of distribution systems. The application of conductance measurement after the micro-distillation process to determine free ammonia in chloraminated drinking water distribution systems was successfully demonstrated using the new instrument - micro-distillation conductance measurement instrument (Micro-DCMI). The developed and optimised Micro-DCMI uses less toxic chemicals, compared to the colorimetric method, and provides a low limit of detection and limit of quantification for ammonia determination.

Dow N, Zhang J, Duke M, Li J, Gray SR, Ostarcevic E (2008) *Membrane Distillation of Brine Wastes*. WQRA/CRC for Water Quality and Treatment Research Report 63.

A significant proportion of potable water for rural communities is produced from brackish water sources by localised reverse osmosis (RO) operations. However, these inland RO plants typically recover only 70-75% of the feed water, the remaining 25-30% of the resource being discarded as saline RO concentrate. One possible remedy to this situation is to increase water recovery by passing the RO concentrate through an additional process like membrane distillation (MD).

The goal of this study was to compare a selection of newly available polytetrafluoroethene (PTFE) membranes in a small MD apparatus against typical performance data reported in the scientific literature. Assessment of membrane performance takes the form of desalted water production rate produced from brackish or saline water. Laboratory scale equipment with a membrane size of 0.014 m^2, along with a 0.35 m^2 hollow fibre element, were evaluated for overall water production rate and fouling tendency when exposed to a series of different feedwaters such as; pure sodium chloride, seawater and two different RO concentrate streams from existing plants.

Froscio S, Cannon E and Humpage A (2009) *Optimisation of Cylindrospermopsin Screening Assays*. WQRA/CRC for Water Quality and Treatment Research Report 66.

The aim of this project was to optimise a rapid assay for cylindrospermopsin (CYN) using cells that express a green fluorescent protein (GFP). The assay utilises CYN's inhibitory effects on protein synthesis as a diagnostic endpoint for detection of the toxin. Cell-lines expressing GFP were created in order to provide a continuous measure of protein synthesis in the cells.

Results in this study indicated that limited sensitivity to CYN was likely to be due to poor uptake of the toxin by the Vero-GFP cells rather than its potency at the site of action. A number of strategies were trialed in order to improve sensitivity. The improved GFP assay allowed detection of $\geq$ 1 µM CYN following 4 hr incubation of the cells with the toxin. This provides a more rapid and sensitive response than previously achieved using cytotoxic endpoints.

Froscio S, Fanok S, King B and Humpage A (2008) *Screening Assays for Water-borne Toxicants*. WQRA/CRC for Water Quality and Treatment Research Report 60
The aim of this project was to develop a panel of screening assays that have potential to replace the standard mouse bioassay for detecting toxicants in water. The focus was placed on developing assays to detect the cyanotoxins relevant to Australian drinking water sources; cylindrospermopsins (CYN), microcystins (MCYST), and saxitoxins (STX). The research outcomes identified a number of assays that may have potential use in a screening capacity.

Ho L, McDowall B, Wijesundara J, Shaw G, Saint C and Newcombe G (2008) *Biological filtration processes for the removal of algal metabolites*. WQRA/CRC for Water Quality and Treatment Research Report 64.

This project identified biological filtration as a viable water treatment option for the removal of the algal metabolites 2-methylisoborneol (MIB), geosmin, cylindrospermopsin (CYN) and the microcystins toxins. Effective biological filtration of MIB and geosmin was observed at the Morgan water treatment plant in South Australia, and this was confirmed through laboratory-scale experiments.

Cylindrospermopsis raciborskii and CYN removals were evident through a biologically-active filtration pilot plant located at North Pine Dam in Queensland, with removal of CYN shown to be through biodegradation. Microcystin toxins were shown to be effectively biodegraded through laboratory-scale columns containing sand sourced from

various water treatment plants, under both slow and rapid sand filtration conditions. Bacteria responsible for the degradation of geosmin, CYN and microcystin within biological filters were isolated and identified, and also shown to have the ability to degrade their respective metabolites in natural waters in planktonic states.

Kastl G, Sathasivan A and Fisher I (2008) *Modelling DOC Removal by Enhanced Coagulation*. WQRA/CRC for Water Quality and Treatment Research Report 57.

The objective of this project was to develop a quantitative description of the residual Dissolved Organic Carbon (DOC) in drinking water after enhanced coagulation treatment with aluminium or ferric salts. Such a description is viewed as beneficial for optimisation of the treatment process as it enables, through a limited number of the experiments, the selection of treatment conditions (coagulant aluminium or ferric based, coagulant dose and pH) and prediction of the residual DOC if the concentration of DOC in the raw water is known.

Software was developed which enables calculation of residual DOC for any selected treatment condition, assuming that parameters of the model are known.

Keegan A, Daminato D, Fauser J, Monis P, Angles M, Cox P, Bustamante H, Cheng Y, Budanovic B, Hu J, Dixon D, Anderson N and Saint C (2009) *Optimising the water treatment and disinfection train for pathogen removal*. WQRA/CRC for Water Quality and Treatment Research Report 68.

The objective of this project was to assess the effects of water treatment processes and disinfection practices on *Cryptosporidium* and virus infectivity from raw water samples using cell culture assays. In the first phase of the project, laboratory-scale experiments were conducted to determine the effects of water treatment processes.

The second phase of the project was to combine water treatment processes with disinfection by chlorine/chloramine. The final phase of the project encompassed a virus survey in South Australian weirs and creeks and demonstrated low levels of adenovirus and enterovirus at these sites. Impacts due to upstream usage of septic tanks appear to be the most likely source of contamination.

King B, Monis P, Keegan A, Harvey K and Saint C (2008) *Investigation of the survival of Cryptosporidium in environmental waters*. WQRA/CRC for Water Quality and Treatment Research Report 47.

The objective of this project was to assess the survival of *Cryptosporidium* oocysts in environmental water samples using a cell culture infectivity assay. In the first phase of the project laboratory-scale experiments were conducted to determine the effects of temperature on the long-term survival of fresh oocysts of *Cryptosporidium parvum* in reagent-grade water and environmental waters of different quality and biological activity.

The findings presented here relating to oocyst inactivation by temperature and solar UV provide valuable information for determining the relative risks associated with *Cryptosporidium* oocysts in a range of environments. They also identify solar radiation as possibly the most critical process affecting the survival of *Cryptosporidium* in the environment.

Linden L, Soh Y, Roddick F, Brookes J, Ganf G, van Leeuwen J (2008) *Impacts of De-stratification on Reservoir NOM and its Removal by Water Treatment*. WQRA/CRC for Water Quality and Treatment Research Report 72.

The objectives of the project were to determine impacts of water storage in reservoirs on the character of NOM, determine impacts of de-stratification of reservoir water on the character of NOM, relate character changes or differences of NOM due to water storage and destratification to the capacity of conventional water treatment (using the coagulant alum) to remove NOM from raw water, and model the NOM budget of the Myponga catchment-reservoir system.

McDonald S, Lethorn A, Loi C, Driessen H, Joll C, Heitz A (2009) *Causes and prevention of chlorinous off-flavours in potable water*. WQRA/CRC for Water Quality and Treatment Research Report 62.

Chlorinous off-flavours are among the most common causes of customer complaints to water utilities worldwide. The primary aim of this study was to identify the causes of chlorinous off-flavours by establishing and training an odour panel at Curtin Water Research Centre (CWQRC); establishing the odour threshold concentrations for the odour panel for various odorous compounds; identifying sites across Perth's water supply system where chlorinous odours are caused by excess free chlorine equivalents and where chlorinous odours are caused by compounds other than chlorine and identifying which fraction(s) of natural organic matter (NOM) are responsible for chlorinous off flavours that are not directly caused by free chlorine.

Miller R, Guice J and Deere D (2008) *Risk assessment for drinking water sources*. WQRA/CRC for Water Quality and Treatment Research Report 78.

This paper provides examples of ways to implement the Australian Drinking Water Framework in drinking water supply sources and discusses the use of a number of risk assessment techniques in use by water suppliers. A step-by-step catchment risk assessment methodology was proposed as an interpretation of the Framework. The interpretation was undertaken to set the management of drinking water source risks and water supply operational needs within the context of broader source water management environmental objectives.

O'Toole J, Leder K and Sinclair M (2008) *A Series of Exposure Experiments - Recycled Water and Alternative Water Sources: Part B – Microbial transfer efficiency during machine clothes washing and microbial survival turfgrass experiments*. WQRA/CRC for Water Quality and Treatment Research Report 46.

The overall aim of this project was to address data gaps to facilitate the exposure assessment component of the Quantitative Microbial Risk Assessment (QMRA) process to help set appropriate water quality criteria to protect public health. The two experimental components described in this report target health aspects of recycled water use, and specifically investigate the microbiological safety of using recycled water in washing machines and for municipal irrigation.

Results of experimental components of this project may be used for QMRA modeling to determine the human health risk associated with the use of recycled water for non-drinking water purposes in an urban context and provide an important supplement to existing information. In addition, information provided in this report can be used to inform recycled water policy and methodological aspects of future experimental studies.

O'Toole J, Leder K and Sinclair M (2008) *Study of Water Usage in Urban Areas*. WQRA/CRC for Water Quality and Treatment Research Report 53

This report includes information about: the performance of Australian water usage surveys; survey response rates and limitations of selection and recruitment methods using publicly available sampling frames; a comparison of the water-using behaviour of dual reticulation households and households supplied with drinking water only and a comparison of recycled water exposure estimates using a Computer Assisted Telephone Interview (CATI) and water-activity diary entries. This report also explicitly makes recommendations about how future Australian studies may be better performed and comments upon whether existing available data for households receiving a conventional water supply may be extrapolated to dual reticulation households.

The report is of significant value in terms of it being a repository of information about Australian household surveys about water use and the recycled water exposure profile of dual reticulation households. In addition to collection of information about water uses pertinent to dual reticulation systems (garden and other outdoor uses and toilet flushing), information was also collected about use of water in the laundry. While recycled water is currently not supplied to Rouse Hill residents for laundry purposes, it is a potential future additional use of recycled water in dual reticulation schemes.

Richards D, Shaw G, Wickramasinghe W, Holling N, Eaglesham G (2008) *Investigations of NDMA formation by chlorination of model compounds*. WQRA/CRC for Water Quality and Treatment Research Report 52.

This study demonstrated that there is the potential for formation of NDMA from the chlorination or chloramination of various nitrogenous biological molecules. The potential of a wide range of amino acids to act as precursors for NDMA formation was examined.

A limited survey of NDMA presence in Australian disinfected waters indicated that, with a few exceptions, the waters surveyed did not contain detectable levels of NDMA. These results however need to be regarded as indicative only as they utilised analytical methodology in development at the time. It is recommended that further, more extensive surveys be conducted using the latest sensitive analytical methods.

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