# Table of Contents

Table of Contents .................................................................................................................. 1

1. Director’s Report .................................................................................................................. 2

2. Aims and Functions .............................................................................................................. 4

3. Centre Management ........................................................................................................... 5
   3.1 Centre management ......................................................................................................... 5
   3.2 Management committee ................................................................................................. 5
   3.3 Advisory committee ........................................................................................................ 6

4. Key centre activities ........................................................................................................... 7
   4.1 Environmental microbiology and pathogen risk assessment ........................................... 8
   4.2 Physical-chemical processes .......................................................................................... 10
   4.3 Sustainability Assessment .............................................................................................. 12
   4.4 atmospheric emissions and odours .................................................................................. 14
   4.5 Trace Organics .............................................................................................................. 16

5. Project details ..................................................................................................................... 18
   5.1 Overview ....................................................................................................................... 18
   5.2 Project Summaries .......................................................................................................... 22

6. CWWT Supported Research Students .................................................................................. 39

7. CWWT STAFF ................................................................................................................... 54

8. CWWT Publications 2007 .................................................................................................... 55
   Books .................................................................................................................................. 55
   Book Chapters .................................................................................................................... 55
   Journal Articles (Reviewed) ............................................................................................... 55
   Conference Papers (reviewed) ........................................................................................... 57
   Conference Papers (Not Reviewed) .................................................................................... 58
   Technical Reports ................................................................................................................ 60

9. Financial Statement ............................................................................................................. 62
1. **Director's Report**

The 2007 year has been another year of significant change in terms of research staff and new research projects. The centre has continued to consolidate its research program into environmental aspect of natural and engineering systems and further develop its research activities in trace organic analysis, risk assessment and sustainable assessment. New research funding in 2007 has enabled the appointed of four new research fellows, Dr Heather Coleman, Matthias Schulz, Dr Marcus Klein and Dr Rita Henderson. The year has also seen the departure of long term staff members Dr Cheryl Davies and Prof Nick Ashbolt, however both have retained active research collaboration with CWWT through there appointment as Visiting Fellows and Visiting Professors, respectively. The year also saw the departure of Lyn Menzies as CWWT Business Manager after 9 years and the appointment of Robert Steel as the new CWWT Business Manager.

The centre again received strong support from the Australian Research Council (ARC) through a number of Discovery, Linkage and Large Infrastructure and Equipment Funding (LIEF) Grants. This includes a Linkage grant on the use of “Fluorescence as a Tool for Sensitive Detection of Failures in Recycled Water Treatment and Distribution Systems” lead by Stuart Khan, a Discovery grant on the “Impact of Metal - Reactive Oxygen Species (ROS) Interactions on Growth and Toxicity of Ichthyotoxic Algae in Australian Coastal Waters” lead by David Waite and a LIEF grant on the “Chemical Analysis of Micropollutants in Urban Water Systems” lead by Richard Stuetz. These ARC success where supported by other collaborative Discovery, Linkage and LIEF grants lead by the UNESCO Centre for Membrane Science and Technology (UNSW) on “Optimising Membrane Fouling” and the “Advanced Characterisation of Organics and Biopolymers in Water and Wastewater Treatment and a collaboration Linkage grant with the University’s of Queensland, Sydney and Newcastle on “Optimising Management of Corrosion and Odour Problems in Sewer Systems”. Additional collaborative funding was also received from the National Water Commission on “A National Approach to Risk Assessment, Risk Communication and Management of Chemical Hazards from Recycled Water” and the Development of an Ecotoxicity Toolbox to Evaluate Water Quality for Recycling”.

In July, the Centre hosted the 3rd AWA Water Reuse and Recycling Conference supported by Sydney Water, Veolia Water, CH₂MHill, Rocla, National Water Commission and WSAA. The conference was attend by 180 delegates and included keynote presentations by Associate Professor Jörg Drewes, Colorado School of Mines and Prof Takashi Asano, the 2001 Stockholm Water Prize recipient. CWWT also hosted a successful 5 day workshop on Advanced Chemometrics and Multiway Analysis lead by Professor Rasmus Bro from the University of Copenhagen for 30 delegates and a 4 month programme on Water Quality Management and Risk Assessment for 3 World Health Organisation fellows lead by David Roser.
In 2008, the Centre will see the purchasing of several new analytical instruments including a LC-QTRAP, GC-QQQ and a second TD-GC-MS-O to improve the Centre’s analytical capacity to quantify the fate of micropollutants in different water and wastewater systems and characterise odorants from odorous emissions. I thank the group for their excellent efforts during 2007 and look forward to continuing to grow the Centre’s research portfolio in the next and subsequent years.

Richard Stuetz
2. AIMS AND FUNCTIONS

The Centre for Water and Waste Technology at UNSW is an international leading University Centre that provides multidisciplinary research in water and wastewater engineering and the development of tools for environmental management and sustainability for improving the aquatic and atmospheric environments.

It operates as an externally funded University of New South Wales (UNSW) research centre within the UNSW School of Civil and Environmental Engineering.

The principal aim of CWWT is to provide a focus within the University of New South Wales for multidisciplinary collaborative research and development of tools for environmental management and sustainability with regard to water, water reuse and wastewater.

The Centre interacts and collaborates with many organisations outside this University: with industry, with both State and Federal governments, with individuals and research groups in other universities both in Australia and overseas. The Centre takes a leading role in establishing and contributing to collaborative research projects with these organisations.

The research strengths of the Centre include a range of core disciplines essential to the further development of soundly based technology. The Centre’s objectives are achieved through the efforts of a group of externally funded personnel assisted by a wide range of academic and professional colleagues from a variety of Schools, other centres and laboratories on the UNSW campus.

A key objective of the CWWT is to provide significant opportunities to postgraduate students to enable them to undertake industry related research projects. These can be on topics related directly or indirectly to CWWT projects or to the overall research program of the Centre. Supervision of these postgraduate students is provided from the most appropriate sources within and outside the School of Civil and Environmental Engineering.
3. CENTRE MANAGEMENT

3.1 CENTRE MANAGEMENT

The Centre for Water and Waste Technology is managed by an Executive Committee made up of the CWWT Director and Business Manager together with a Program Leaders within the Centre. This committee meets on an “as needs” basis to discuss strategy, performance and research opportunities.

In addition, input to CWWT management is provided by the Water Research Management Committee (WRMC) within the School of Civil and Environmental Engineering. Members of this Committee are:

Assoc. Professor Richard Stuetz, Director, CWWT (Chair),
Professor David Waite, Head, School of Civil and Environmental Engineering
Dr Bill. Peirson, Director, Water Research Laboratory
Dr Ian Turner, Deputy Director (Research), Water Research Laboratory
Professor Ian Acworth, UNSW Connected Waters, Water Research Laboratory
Mr Robert Steel, Business Manager, CWWT (by invitation)
Mr Brett Miller, Manager, WRL (by invitation)

The purpose of this Committee is to ensure that water-related research activities within the School of Civil and Environmental Engineering (involving, in addition to CWWT, the Manly Vale Water Research Laboratory) are operated in a financially sound manner with due regard for consistency between the various water-related groups.

3.2 MANAGEMENT COMMITTEE

As required for all UNSW Centres, a Management Committee for CWWT has been established by the Vice-Chancellor, on advice from the Pro-Vice-Chancellor (Research) and the Dean of Engineering. This Management Committee is responsible to the Vice-Chancellor for ensuring the objectives of the Centre are pursued and the terms of reference of the Centre are implemented. During 2007 the Management Committee for CWWT was made up of the following members:
3.3 ADVISORY COMMITTEE

An Advisory Committee has previously provided advice to the CWWT Director and Management Committee. Re-establishment of this Committee is being considered in light of developments in the research direction of CWWT.
4. **Key Centre Activities**

Centre research activities are focused into 5 programs under the direction of Associate Professor Richard Stuetz.

During 2007 the programs and their leaders were:

**Environmental microbiology and pathogen risk assessment**  
Dr David Roser

**Physical-chemical processes**  
Professor David Waite

**Sustainability assessment**  
Dr Greg Peters

**Atmospheric emissions and odours**  
Assoc Professor Richard Stuetz

**Trace organics**  
Dr Stuart Khan
4.1 ENVIRONMENTAL MICROBIOLOGY AND PATHOGEN RISK ASSESSMENT

PROGRAM LEADER: DR DAVID ROSER

Since 2003 a range of new national and international water management guidelines have been released by the World Health Organization and the National Health and Medical Research Council. These guidelines are a major break with past practice. Previously water quality assessment, including that for microbiological contaminants, focused on compliance style water monitoring. The new guidelines, however, promote a whole of system analysis leading to risk characterisation which is in turn the basis for management actions.

These new guidelines, place less emphasis on assessing end-of-treatment or point-of-contact contaminant concentrations, rather the major focus is now placed on upstream process performance within catchments/treatment systems at major control points. Quantitative microbial risk assessment (QMRA) has emerged as the principal method that provides both target values for pathogens at control points, as well as what latitude there is for their control.

This style of analysis is a formalisation of the approach the microbiology group has been undertaking in projects of past years e.g. those for the CRC for Water Quality and Treatment and the European Union MicroRisk Project.

Consequently risk assessment continued in 2007 to be the primary driver of the group’s work with a number of new projects being initiated, progressed and concluded.

Highlights and important findings were as follows:

- Two projects with Sydney Catchment Authority approved in 2006 were extensively progressed:
  - The first of these aims to understand cattle migration and their propensity to damage the riparian environment and foul water courses. Ms Christine Kaucner is using GPS collars to quantify the movement and behaviour of cattle at farms within the Sydney catchment areas. All preliminary work was completed and in mid 2007 cattle herds were provided with these devices. The experiments undertaken aim to determine whether providing shade and water away from streams can alter cattle behaviour.
  - The second project is on the Assessment of Sewage Treatment Plant Relative Risk. A literature review/survey was undertaken which indicates that data on the pathogen content of sewage is limited. With the experience of water reuse assessments in mind a procedure for undertaking QMRA’s was developed with application to the SCA project as a final outcome. Finally with SCA input a survey of the pathogen
content of southern highlands wastewater was undertaken. This provided a high quality data set on pathogen loads associated with STPs for comparison with loads from other sources.

- A new project was initiated with the University of Western Australia’s School of Population Health to develop tools for assessing how to safely reuse water in that state using new national guidelines as a starting point.

- QMRA was extended to animal waste, specifically cattle feedlot manure. As a first step a literature review was undertaken which identified 10 key pathogens needing assessment and the most likely pathways by which human populations are exposed to them. An inspection of feedlot research and operations in the USA revealed high quality science being undertaken but very little integration using risk assessment and management.

- PhD student Nanda Altavilla finalised her measurements on Cryptosporidium inactivation in cowpats (believed to be the primary source of these pathogens in Sydney’s catchments). This work showed reasonable inactivation at 37 °C but no inactivation whatever at 4 °C over a period of 500 days.

- Dr Cheryl Davies completed an assessment UV inactivation by new units installed by Sydney Water and finalise work on an AWWARF funded study. This data will be essential in QMRAs involving UV treatment.

- QMRA was applied to stormwater via a Smart Water Project. This work showed that while stormwater treatment was possible, recontamination of storage ponds compromised upstream treatment. Dr Susan Petterson and Christine Kaucner continued their assessment of stormwater treatment processes in order to obtained critical information for input into QMRA models.

- The group completed semi-quantitative risk assessment of pathogens (and chemicals in conjunction with the trace organics program) in biosolids for Sydney Water with a view to determining whether they might again be applied safely in the Sydney catchment area.

- At the end of 2007 three senior scientists from the People’s Republic of China came to the Centre for 4 months supported by WHO Fellowships to learn about Australian water quality management. A clear opportunity was identified in China for applying QMRA though the management appears challenging due to the widespread use of rivers and other contaminated water supplies.

- PhD student Rebecca Barnes continued her investigations into the barriers to provision of clean drinking waters to communities in the developing world focusing on the Philippines. She also surveyed a range of development aid workers to identify major barriers to clean water. A key limitation appears to be a lack of holistic planning which integrates technology, economics, social constraints and training.

- Research into Legionella pathogens that developed within amoeba within domestic hot water pipe biofilms continued.

For further information please contact Dr David Roser: djroser@unsw.edu.au
4.2 **PHYSICAL-CHEMICAL PROCESSES**

**Program Leader: Professor David Waite**

The Physical-Chemical Processes discipline area within the Centre for Water and Waste Technology represents a focal point for research into physical and chemical aspects of both the natural aquatic environment and engineered water and wastewater treatment systems. The areas of principal research activity through 2006 included i) membrane fouling in water and wastewater treatment, ii) redox transformations mediated by nanoparticulate zero valent iron, iii) iron and aluminium speciation and transport associated with acid sulfate soils in coastal environments, and iv) impact of reactive oxygen species generation on iron uptake by aquatic organisms.

Funding provided by the Australian Research Council has again been critical to continuing activity in the above areas with Veolia-supported ARC Linkage support being critical to the activities of APAI students Peter Kovalsky and Suvinai Santiwong, both of whom have now completed their doctoral dissertations on fouling in dead end membrane water filtration systems. This work is now being extended to investigation of fouling in membrane bioreactor wastewater treatment by research fellow Dr Xiao-mao Wang who commenced in late 2006 with support through an ARC Discovery grant. ARC support has also enabled continuation of our investigations of the behaviour of nanoparticulate zero valent iron (nZVI). Studies by APAI student Quan Sun of both the oxidative and reductive degradation of contaminants are continuing as are investigations of the behaviour of the nZVI produced using the alternate reductant, sodium dithionite. This latter technology has been patented by the group with this patent now licensed by Orica Australia.

While an understanding of iron transformations has been found to be valuable in developing alternate water treatment technologies, the understanding of similar processes in nature has been critical to elucidation of the transport and fate of contaminants from acid sulfate soils and the impact of these contaminants in coastal waters. Thus, both iron and aluminium represent key “acid carriers” in acid sulfate soil systems with these elements releasing acid on their precipitation in receiving waters. Support from both the ARC and Linkage partners the Tweed Shire Council and the Cane Growers Association has been vital to investigations undertaken by Senior Research Fellow Dr Richard Collins and APAI student Adele Jones in the Blacks Drain catchment near Murwillumbah in northern NSW. The ARC and the Moreton Bay Water Quality Partnership have also provided funding enabling Mark Bligh at UNSW and Linh Dang at UQ to undertake doctoral studies...
into the efflux of key nutrients from sediments of Moreton Bay and to assess the potential impact on growth of the toxic cyanobacterium *Lyngbya majuscula*.

Related studies by ARC Research Fellow Dr Andrew Rose, school-supported Research Fellow Dr Shikha Garg and co-tutelle scholar Aurelie Godrant into the superoxide–mediated transformation of iron by coastal cyanobacterium *Trichodesmium erythreum* and ichthyotoxic raphidophyte *Chattonella marina* is providing new insights into the functioning of these marine organisms. This information is likely to be critical to understanding the impacts of coastal development and aeolian input to growth of these organisms and, as a result, the ecology of coastal waters.

For further information please contact Professor David Waite: d.waite@unsw.edu.au
4.3 Sustainability Assessment

Program Leader: Dr Greg Peters

Sustainability assessment is a broad rubric for methods which aim to assist organisations and individuals improve their sustainability considering environmental, social and economic factors. The Sustainability Assessment Program at CWWT has the goal of deepening the scientific basis for such assessments and broadening their application into new fields and industries. This includes applied research projects in areas including:

- Sustainability assessment
- Life Cycle Assessment
- Ecological and carbon footprints
- Life Cycle Costing
- Triple-Bottom-Line reporting
- Sustainable planning frameworks
- Input-Output Analysis

The above methods have wide application in the water industry, waste management, food and manufacturing industry, and tourism sector. Projects have been carried out for clients from industry and governmental organisations.

National and international Collaborations

- Australian Life Cycle Assessment Society (ALCAS): Greg Peters is the President of ALCAS, which is working with the CSIRO to develop the next generation of LCA data for Australian practitioners and pursuing a number of other activities to enhance LCA application in Australia. This involves collaboration between a wide range of industry, government and academic bodies.
- CSIRO Timber LCI Project: Greg Peters is a member of the technical Steering Committee which is guiding CSIRO in a major national project to develop a detailed set of data for LCA practitioners working in the area of timber products.
- United Nations Environmental Program (UNEP) / Society of Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative: The UNEP/SETAC Life Cycle Initiative established 9 “Task Forces” to promote LCA globally and to improve the quality of LCA methodology. The aim of the cross-cutting activities is to address questions in relation to life cycle approaches that have been identified as relevant in the overall user needs assessment, but that have not
been further developed. Associate Professor Lundie was appointed as a Chairman of Task Force 3 – LCI methodological consistency.

- Australian Ecolabelling Association (AELA): Sven Lundie is a Scientific Advisor and accredited Assessor for AELA. Sven was involved in setting up the Association and in developing several standards of various product types.

- Energy from Waste (EfW) Division – Waste Management Association Australia: Sven Lundie is a member of the EfW Devision in New South Wales. The aim of this division is to analyse global trends in EfW technologies and assess their environmental and economic performance. The results may support strategic decision making in the Australian waste management sector.

In 2007 sure the continuation of projects on the sustainability of the Australian meat and water industries, and the addition of new applied research projects for the Victorian water sector, New Zealand’s dairy industry and the Australian plastics industry. The program also provided peer review services for the LCA in the telecommunications sector and was invited to give lectures to gatherings in Sydney, London and Colorado.

Hazel Rowley won a postgraduate scholarship to commence doctoral studies in 2008 with Greg Peters and the team expanded with the addition of Matthias Schulz as a full-time Research Associate and with Sven Lundie and Jonathan Cheng also working part-time in the Program.

For further information please contact Dr Greg Peters at: g.peters@unsw.edu.au
4.4 ATMOSPHERIC EMISSIONS AND ODOURS

Program Leader: Assoc Prof Richard Stuetz

Odorous emissions from different waste management facilities, wastewater treatment plants, and agricultural practices can cause annoyance to a local population resulting in complaints. Indoor air quality (IAQ) is also an area of increasing public awareness due to higher standards of living and concerns regarding the impact of air quality parameters such as VOCs on public health (for example, material emissions). To improve our understanding on the potential impact of these emissions, new knowledge and approaches are required for identification in order to better understand the fate of environmental emissions. The mission of the UNSW odour research group in CWWT is to provide international leading research and training through the application of different analytical techniques for the measurement of odorous emissions and the development of treatment systems for the abatement of odours and odorants.

During 2007 the group continued to develop its expertise on the application of olfactory – mass spectroscopy (GC-MS-O) through a number of research and commercial projects. GC-MS-O allows for the integration of olfactory analysis and chemical characterisation through the separation of odorants by gas chromatography and their identification as individually compounds via mass spectroscopy analysis (GC-MS) and the parallel olfactory analysis of complex odorants via an odour detector or sniffer port (ODP). Samples can be pre-concentration onto selective sorbent tubes and thermal desorbed for GC-MS-O analysis. The group acquired two new analytical systems during 2007, a Markes TC-20 conditioner for the bulk conditioning of sorbent tubes and a sulfur chemiluminescence detector (SCD) for reduced sulphur analysis. These new analytical systems will complement existing technical expertises:

- Sampling of odours from different field sources;
- Measurement of the odorants compounds such as VOCs, PAHs, ammonia and hydrogen sulphide;
- Improvement and optimisation of the equipments for determining emissions from specific industrial, agricultural sources and indoor environments;
- Odour dispersion modelling and environmental impact assessment and
- Odour abatement and treatment.

Current research areas / projects include:
- Chemical analysis of odorants from intensive livestock operations;
- Chemical treatment of liquid stream using ozone to reduce odour emissions;
- Biofiltration of methane emissions from landfill waste disposal sites using recycled waste products;
- Development of indoor air quality (IAQ) indicators and methodology and
- Assessment of odours in wastewater collection systems.

Kelso Waste Depot Trial Passive Gas Drainage and Biofiltration System

The group was involved a number of technical reviews for industry and government, which included for example a Water Environment Research Foundation (WERF) report on “Odours Formation and Corrosion in Sewer Systems” with 14 other research partners and the publication of a NSW Department of Environment and Conservation Factsheet on “Passive Drainage and Biofiltration of Landfill Gas using Recycled Materials”. The group also submitted several research proposals to the Australian Research Council (ARC) and other research bodies and was successful in a large collaborative ARC linkage project with University’s of Queensland, Newcastle and Sydney and 6 water utilities on “Optimising Management of Corrosion and Odour Problems in Sewer Systems” which will provide core funding for 5 years. CWWT will lead theme 2 of this project on odour assessment and treatment of odours in sewer systems.

For more information, please contact Assoc Prof Richard Stuetz at r.stuetz@unsw.edu.au or visit our website @ http://www.odor.unsw.edu.au
4.5 Trace Organics

Program Leader: Dr. Stuart Khan

The Trace Organics Program incorporates the analytical determination, fate analysis, and removal characterisation of organic constituents in water.

Current and recent projects have focussed on some high-profile organic contaminants including pharmaceutically active compounds (PhACs), endocrine disrupting chemicals (EDCs), disinfection byproducts (DBPs), natural organic matter (NOM) and pesticides. Investigations of these chemicals have been undertaken for environmental waters, drinking waters, municipal wastewaters, industrial processing waters and beef cattle feedlots.

A particular strength is the range of analytical capabilities. CWWT staff are proficient in the use of a diverse range of analytical instrumentation and methodologies. Examples include gas chromatography-mass spectrometry (GC-MS and GC-MS/MS), high performance liquid chromatography-mass spectrometry (HPLC-MS and HPLC-MS/MS), fluorescence excitation emission matrix (EEM) analysis, a multitude of UV-Vis Spectroscopy applications and most traditional water and wastewater analytical techniques. A successful ARC equipment grant in 2007 has enabled the purchase of a new Applied Biosystems Q-TRAP HPLC-MS/MS system, which will significantly enhance analytical capabilities for 2008.

Recent projects have investigated the removal of trace organics during conventional (primary and secondary) municipal sewage treatment, as well as a wide range of advanced treatment processes. Treatment processes of interest include membrane-based treatment (microfiltration, nanofiltration, reverse osmosis), advanced oxidation (incorporating UV, ozone, peroxide and nano zero valent iron), and advanced biological treatment processes (membrane bioreactors and biologically activated carbon).

Water reuse and recycling are particular interests with numerous current projects relating to the treatment and beneficial reuse of municipal wastewaters. Members of the Trace Organics Program have been closely involved with the development of Australian water recycling guidelines particularly focusing on risk assessment techniques for trace organic chemicals.

The Trace Organics Program is closely involved with the newly established ‘pilot hall’ at UNSW. This facility houses fully operating bench-scale units of a number of wastewater treatment operations. Current active units include membrane bioreactors and activated sludge reactors. These units are being used to assess
the effect of various parameters on the behaviour and removal of key contaminants.

The Trace Organics Program also incorporates research into modelling techniques for the description and prediction of chemical fate. Established modelling techniques have been used for a variety of chemicals (including PhACs and EDCs) for the prediction of their fate during sewage treatment and environmental exposure.

Dr Rita Henderson joined the group from Cranfield University during 2007. Rita is working on the development of fluorescence techniques for enhanced monitoring of recycled water quality.

For more information, please contact Dr Stuart Khan at: s.khan@unsw.edu.au
### 5. Project Details

#### 5.1 Overview

<table>
<thead>
<tr>
<th>Key project proponents</th>
<th>Research Topic</th>
<th>Granting Organisation</th>
<th>Funds Received in 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. D. Waite, R. Collins, A. Rose</td>
<td>Element uptake by rice – root iron plaque formation and Implications to nutrient and toxicant uptake</td>
<td>France-Australia Science and Technology Fund</td>
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<td>T. D. Waite</td>
<td>Floc characteristics in sheared systems</td>
<td>ARC Linkage LP0347117 with Vivendi Australia and Vivendi Water</td>
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<td>N.J. Ashbolt, S. Lundie</td>
<td>Development of an integrated sustainability framework for best management practice of urban water systems</td>
<td>ARC Linkage LP0455742 with WSAA and Total Environment Centre</td>
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<td>T.D. Waite, M. Melville, I. White (ANU), R. Bush (USC)</td>
<td>Reducing export of acid sulphate soil products (particularly iron, aluminium, phosphorus and organic carbon) as contaminants to coastal waters</td>
<td>ARC Linkage LP0455697 with Tweed Shire Council</td>
<td>$77,709</td>
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<td>T.D. Waite, L. Li (UQ), T. Howes (UQ)</td>
<td>Predicting Lyngbya blooms: impact of iron transformation kinetics on flux, distribution and rate of uptake of bioavailable iron and phosphorus</td>
<td>ARC Linkage LP0455697 with Moreton Bay Waterways and Catchments Partnerships</td>
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<td>R. Stuetz, N. Ashbolt</td>
<td>Removal of potential impact of pharmaceutical active compounds during wastewater treatment</td>
<td>ARC Discovery DP558029</td>
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<td>T.D. Waite, B. Neilan, M. Furnas (AIMS), M. Burford (GU), A. Rose</td>
<td>Mechanism of Iron Acquisition by the Cyanobacterium Trichodesmium in Coastal Waters</td>
<td>ARC Discovery DP0558710</td>
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<td>R. Stuetz</td>
<td>Quantification and evaluation of odorants from Poultry Sheds</td>
<td>Australian Poultry CRC</td>
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<td>N.J. Ashbolt M.J. Storey</td>
<td>Understanding the growth of opportunistic pathogens within distribution mains</td>
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<td>S. Lundie A. Feitz G. Peters H. Rowley</td>
<td>Life Cycle Analysis of the grass fed red meat industry with Feedlot Services Australia</td>
<td>Meat and Livestock Australia Ltd</td>
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<td>Pathogen risk indicators for wastewaters and biosolids</td>
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<td>D.Waite P. Le-Clech S. Chang</td>
<td>Membrane fouling in submerged hollow fibre membrane bioreactor systems: theory, modelling and fouling control</td>
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<td>N. Ashbolt, G. Peters, D. Roser, S. Khan, C. Davies R. Stuetz</td>
<td>Managing the contaminants in feedlot waste products (Flot 333) with Feedlot Services Australia</td>
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<td>C. Ferguson (Ecowise) N. Ashbolt C. Davies</td>
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<td>S. Khan P. Le-Clech</td>
<td>Absorption and removal of pharmaceutically active compounds by membrane processes used in water treatment and wastewater recycling</td>
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<td>S J Khan</td>
<td>The Use of Chiral Pharmaceutical Compounds to Characterise Sewage Treatment Processes and Sewage Contamination of Surface Waters</td>
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<td>H. Rowley</td>
<td></td>
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<td>R. Collins</td>
<td>2007 ANSTO - EXAFS Spectroscopic determination of the amorphous mineral phases controlling Iron solubility and transport in Australian acid sulfate soils</td>
<td>Australian Synchotron Research Program</td>
<td>$4,380</td>
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<td>D. Waite</td>
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<td>S. Khan</td>
<td>Fluorescence as a tool for sensitive detection of failures in recycled water treatment and distribution systems</td>
<td>ARC Linkage LP0776347 and 8 partner organisations</td>
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<tr>
<td>R. Stuetz</td>
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<td></td>
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<tr>
<td>A. Baker</td>
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<tr>
<td>M. Storey</td>
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<td>S. Khan</td>
<td>Development of an Ecotoxicity Toolbox to evaluate Water Quality for recycling</td>
<td>CRCWQT</td>
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<td>R. Stuetz</td>
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<td>G. Swarbrick</td>
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<td>R. Stuetz</td>
<td>Passive Drainage and Biolfiltration of Landfill Gas using Recycled Materials and project extension</td>
<td>NSW DECC</td>
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## Applied Research Projects 2007

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<td>CWWT - Conferences - aggregated account</td>
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<td>CWWT - Atmospheric Emissions - aggregated account</td>
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<td>CWWT - Physical Chemical Processes - aggregated account</td>
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<td>CWWT - LCA &amp; Sustainability - aggregated account</td>
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<td>CWWT - Analytical Services - aggregated account</td>
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<td>CWWT - Micropollutants - aggregated account</td>
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<td><strong>Total funding</strong></td>
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5.2 Project Summaries

Summaries of selected projects that were either completed or were active during 2007 are provided below:

**Project Mechanism of Iron Acquisition by the cyanobacterium *Trichodesmium* in Coastal Waters**

**Funding Body**
ARC Discovery Grant (DP0558710)

**Research Team**
D Waite, B Neilan, M Furnas, M Burford, A Rose (APD) and non-ARC funded PhD students S Garg (EIPRS scholar) and Aurelie Godrant (a French co-tutelle student) contributed to aspects of this project.

**Duration**
2005 – 2007

This project aimed to elucidate the mechanism of iron uptake *Trichodesmium* (a cyanobacterium) in coastal waters and, by implication, to assess the likely impact of terrestrial runoff on its growth.

**Key Activities and Outcomes**

(i) Preliminary activities to establish conceptual models and refine techniques using the model organism *Chattonella marina* while cultures of *Trichodesmium* were being established. This resulted in several papers (1-6 below) on chemical interactions of superoxide with iron, the mechanism of iron uptake by *C. marina*, and the impact of light on superoxide generation.

(ii) Development of methods to measure superoxide concentrations and production rates in the laboratory and the field. This resulted in two new methods papers and one paper reporting field measurements of superoxide with collaborators from Woods Hole Oceanographic Institution (7-9).

(iii) Establishment of batch cultures of *Trichodesmium* grown under varying iron conditions and examination of the effect of these conditions on growth rates, superoxide production rates and iron uptake rates and mechanism. Results are being analysed and will form the basis of two more papers.

(iv) Field studies (cruises) on the Great Barrier Reef to measure speciation and transformation kinetics of iron, and superoxide production and decay kinetics, yielding a further publication (10).

(v) Successful development of continuous culturing methods. Results are being finalised.

Strong evidence now exists that iron availability controls the productivity and species composition of planktonic organisms in open oceans and coastal and estuarine environments. Reduction of iron to the Fe(II) state is one strategy that is employed by marine organisms to increase its availability, but the ability of organisms to reduce iron is strongly influenced by the occurrence of natural organic complexing agents and the specific mechanism the organism uses. This project aimed to elucidate the iron uptake mechanism of *Trichodesmium* (a
cyanobacterium) in coastal waters and, by implication, to assess the likely impact of terrestrial runoff on its growth. The information so obtained is expected to be critical to modelling the growth and distribution of this toxic, nitrogen fixing organism in coastal waters such as those of the Great Barrier Reef and the Gulf of Carpentaria.

Activities in 2007 involved a range of laboratory and field studies, including work with collaborators at Woods Hole Oceanographic Institution (USA) and project investigator Miles Furnas at the Australian Institute of Marine Science (AIMS). These included development of new methods to measure the concentration and production rates of superoxide (a reactive form of oxygen) that we believe to be a critical player in the iron acquisition strategy of Trichodesmium. Postdoctoral fellow Andrew Rose, PhD student Aurélie Godrant, and Honours student Chris Miller applied these new methods during a cruise on the Great Barrier Reef with Miles Furnas on the AIMS ship R/V Lady Basten in April, resulting in intriguing new insights into the behaviour of superoxide and iron on the reef and, in particular, in blooms of Trichodesmium that were encountered.

In the laboratory, Aurélie successfully established batch cultures of Trichodesmium under varying conditions of iron nutrition. The influence of iron concentration and speciation on these cultures was examined for effects on growth rates, superoxide production rates and rates of iron acquisition by the organism. Meanwhile, Andrew established continuous culturing methods with Honours student Shane Tyrrell using a related organism, Crocosphaera watsonii (a unicellular nitrogen fixing marine cyanobacterium) that will be used to grow Trichodesmium and other organisms in the laboratory in future.

Key outcomes from the project in 2007 were the publication of four papers by PhD student Shikha Garg on related studies with another model organism, Chattonella marina, and acceptance of two papers by Andrew Rose (with collaborators from Woods Hole as co-authors) on the measurement of superoxide in the field. Several further journal articles are in preparation as a result of the field studies on the Great Barrier Reef and the laboratory work by Aurélie Godrant.

Blooms of Trichodesmium cover the water off the coast near Cairns.
With Dr Sheng Chang’s relocation to Canada early in 2006, approval was sought and given by the ARC for appointment of an alternative Research Fellow with Dr Chang (who is now employed by GE Water and Environment) becoming a PI. The position was advertised and Dr Xiaomao Wang (a Tsinghua University graduate and University of Hong Kong post-doc) was offered and accepted the position. Dr Wang commenced activities on 9 October, 2006 and has settled in very well. Major attention in the initial 4-5 months was focused on membrane bioreactor (MBR) construction with three membrane bioreactor units with different sludge retention times now operating in parallel. While these units took some time to stabilize, they have now achieved steady state and are yielding a high quality effluent. Membrane fouling behavior is being monitored by continuously recording the TMP.

In addition to MBR construction, Dr Wang has also been refining approaches to quantification of fouling layer properties. Of particular importance is the response of the fouling layer to increasing trans-membrane pressure with the need to understand the compressibility behaviour of the fouling layer and the implications of compression to hydraulic conductivity. Significant advances in this regard have been made by LP0347117 APAI PhD students Kovalsky and Santiwong but in constant pressure systems (Kovalsky et al., 2007; Santiwong et al., 2008a&b). Dr Wang has utilized the “steady state” method developed in these studies to quantitatively compare different approaches to describing fouling behavior in flat sheet systems (Wang et al, 2008a&b). He has also worked closely with Kovalsky to extend the approach to prediction of TMP increase during constant flux filtration (Kovalsky et al., 2008) and is currently extending these approaches to examination of the behavior of polymeric fouling materials in hollow fibre systems as used in the MBR units. Dr Wang (with Professor Waite’s support) has also played an important role in cosupervising a 4th year Honours student through 2007 (Gostelow, 2007).

Satisfyingly, we have also been successful in establishing a collaboration with Tsinghua University in an area related to this ARC project with travel funding provided by the DEST Australia-China Special Fund.

<table>
<thead>
<tr>
<th>Project</th>
<th>Membrane Fouling in Submerged Hollow Fibre Membrane Bioreactor Systems: Theory, Modelling and Fouling Control</th>
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</thead>
<tbody>
<tr>
<td>Funding Body</td>
<td>ARC Discovery Grant (DP0665515)</td>
</tr>
<tr>
<td>Research Team</td>
<td>D Waite, S Chang, X Wang, S Santiwong, P Kovalsky</td>
</tr>
<tr>
<td>Duration</td>
<td>2006 - 2008</td>
</tr>
</tbody>
</table>
Project | Reducing Export of Acid Sulfate Soil products (particularly iron, aluminium, phosphorus, and organic carbon) as Contaminants to Coastal Waters
---|---
Funding Body | ARC Linkage Grant (LP0455697)
Research Team | D Waite, M Melville, A White
Duration | 2004-2007

Comprehensive monitoring of drainage water quality at the Black’s Drain field site by the project team of Senior Research Associate Dr Richard Collins, APAI student Adele Jones and CI Waite have assisted in identifying the acid-generating “hotspots” in this catchment (Collins et al., 2008). In addition, installation of multi-level piezometers in transects away from the constructed drains on this sugar cane property has provided detailed insight into the response of the unconfined groundwater system to rainfall events. Investigations in the field are being complemented by detailed laboratory studies of both geochemical behaviour of iron and aluminium and geophysical behaviour of soils from different locations and depths. The latter studies have been assisted particularly by Honours student Ms Le Thi Minh Hue who has made excellent use of oedometric facilities in the UNSW School of Civil and Environmental Engineering to characterize the hydraulic properties of soils and their likely response to acidification events and seawater flooding (Le, 2006). Ms Le continued these studies through 2007 with two papers now under review based on her work (Li et al., submitted).

Isotope exchange kinetic methods have been used to test the hypothesis that isotopically exchangeable Fe(II) and/or Fe(III) are the major sinks of labile Fe in acid sulfate soils (ASS). Results have shown that the adsorption of Fe(III) is a very rapid process throughout the soil profile of ASS with > 99 % of adsorption occurring within 1 minute. However, labile Fe(III) concentrations are relatively insignificant (9 – 210 mg/kg) compared to the total concentration of Fe in these soils (> 60,000 mg/kg). Current experiments are examining labile Fe(II) concentrations with similar methodologies but is technically more challenging due to the facile oxidation reactions of Fe(II).

Complete chemical analyses of ASS soil porewaters have been conducted and, according to thermodynamic equilibrium principles, the chemical speciation of Fe and Al has been determined in ASS. These results indicate that organic-metal complexes may comprise a significant component of soluble Fe(III) and Al(III) in some ASS porewaters. However, ferrous and aluminous sulfato complexes are also predicted to be major aqueous forms in ASS. Based on these speciation calculations, initial laboratory experiments show that the presence of sulfate (at concentrations found in the field) in soil porewaters inhibits the formation of highly toxic polymeric Al upon mixing with saline drainwaters. The effects of dissolved organic carbon on polymeric Al formation and Al precipitation kinetics have also been assessed. The effects of both organic carbon and silica on the kinetics of transformation on the crystallinity and reactivity of iron oxyhydroxides present in
these ASS systems are currently being assessed with evidence that these species retard the Fe(II)-mediated crystallisation process.

### Project

**Predicting Lyngbya blooms: impact of iron transformation kinetics on flux, distribution and rate of uptake of bioavailable iron and phosphorus**

### Funding Body

ARC Linkage Grant (LP0561150)

### Research Team

M Bligh, L Dang, Howes, D Waite

### Duration

2005 - 2007

APAI students Mr Mark Bligh (UNSW) and Ms Linh Dang (UQ) are making good progress with both students nearing the end of their second year of their doctoral programs. Ms Dang is focusing on transformations and transport of iron in the subterranean estuary underlying Moreton Bay while Mr Bligh is focusing on the transformation and fate of iron and phosphorus on release to the overlying water column from underlying benthic sediments.

Major issues being addressed by Linh Dang are:

1. What are the significant geochemical processes controlling the fate of iron in the subterranean estuary at Morton Bay? What is the most important factor governing the transformation of iron in different geochemical zones, i.e., oxic and anoxic zones?
2. How does the water exchange and mixing process affect geochemical processes in the near shore region? And what is the magnitude of the influences on geochemical process?
3. Can the overall flux of iron released to the bay be quantitatively predicted through numeric simulations?
4. What is the source of iron in the subterranean estuary?

Studies are underway at two field sites; i) on the west coast of Morton Island, and ii) in Deception Bay (near Bribie Island). Pore water and sediment samples are being collected and the concentration of iron and other chemical compounds measured. The model FEFLOW is being used to simulate groundwater flow with reactive chemical transport and transformation in the intertidal and subtidal zones. The model predictions will be compared with collected field data to refine and verify the conceptual and numerical models. The calibrated model will then be applied to explore the reactive transport process under a range of conditions, e.g., impacts of sub-surface groundwater discharge in a dry year and impact on groundwater composition of alternative land-use activities.

Mr Bligh is focusing on the kinetics of oxidation of Fe(II) on release of groundwaters to the overlying water column and nature and reactivity of the iron oxyhydroxide particulate phases produced. Investigations of both the size of particles produced (as this influences their transportability) as well as their ease of
acquisition by Lyngbya (via reductive dissolution) are underway. Additionally, the impact of iron oxyhydroxide particulate formation and dissolution on the uptake and release (and, ultimately, the bioavailability) of phosphorus is also being considered. While Mr Bligh is undertaking extensive laboratory studies, he has also commenced a field investigation of Fe and P release from sediments using both in situ benthic chambers and laboratory studies with freshly acquired cores. Additionally, he also participated in a visit to the Photon Factory in Tsukuba in mid-December where he obtained EXAFS data on amorphous ferric oxyhydroxides produced both from hydrolysis of Fe(III) salts and from oxidation of Fe(II) salts (a process similar to that occurring in the Moreton Bay sediments in the vicinity of Lyngbya blooms). The data is still being interpreted but the two oxides obtained (AFOII and AFOIII) show very distinct differences in crystal structure.

Professor Waite has also provided advice through 2007 to the Queensland Healthy Waterways Program and is a member of the Lyngbya Scientific Advisory Committee with ongoing advice to this committee of outcomes of investigations funded by this ARC Linkage project. This advice is transferred to the public domain through newsletters produced by the Healthy Waterways Program (see Healthy Waterways, 2007).

<table>
<thead>
<tr>
<th>Project</th>
<th>Managing the contaminants in feedlot waste products (FLOT 333) with Feedlot Services Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding Body</td>
<td>Meat &amp; Livestock Association</td>
</tr>
<tr>
<td>Research Team</td>
<td>D Roser, C Davies, G Peters, S Khan, R Stuetz and N Ashbolt (R Tucker and P Watts from FSA consulting)</td>
</tr>
<tr>
<td>Duration</td>
<td>2006 - 2008</td>
</tr>
</tbody>
</table>

This project represents a significant boost to world-leading research at UNSW in the area of risk assessment. Meat and Livestock Australia has awarded a research grant to improve the scientific knowledge underpinning the management of cattle feedlot wastes. This research is being managed by the Centre for Water and Waste Technology in the School of Civil and Environmental Engineering, in collaboration with FSA Consulting. FSA Consulting is an agricultural and environmental engineering company with extensive experience in the design and environmental management of feedlots.

Australia is currently the biggest beef exporter in the world. Australia has about 28 million cattle and the feedlot industry has a capacity of about 1.1 million. Around 2.5 million cattle pass through feedlots every year, making a significant proportion of our beef exports. Effective management and the future growth of the feedlot industry will depend on the sustainable management of the manure and effluent it produces.

This project will improve our understanding of the potential risks associated with microbes and other contaminants in manure and effluent and the best management practices to minimise these risks. During 2007, the project team submitted a comprehensive review of chemical contaminants in feedlot wastes based on work begun in 2006. This was accepted for publication by Environment
International. Project progress was delayed by the departure of our experienced microbiologist Dr Cheryl Davies, but the arrival of Dr Marcus Klein (microbial geneticist) and Dr Heather Coleman (chemical contaminants) saw the project return to speed. Dr Klein worked with Drs Roser, Khan and Coleman to prove sample preparation methods and contaminant detection techniques which will be used in a quantitative survey of contaminants in feedlot wastes. The data will facilitate quantitative risk assessment and the development improved management guidelines for the reuse of feedlot byproducts.

**Project**  
**Life Cycle Analysis of the grass fed red meat industry with Feedlot Services Australia**

**Funding Body**  
Meat and Livestock Association

**Research Team**  
G Peters, H Rowley, M Schulz  
(R Tucker and S Wiedemann from FSA Consulting)

**Duration**  
2005-2008

The application of life cycle assessment (LCA) to the agricultural sector is a major step forward in the evaluation of the environmental impacts of products and services. Traditionally a tool for the analysis of consumer products and industrial processes, much of the methodological development of LCA has been based on steady-state concepts which do not directly apply to production systems impacted by factors as random as Australia’s climate. Even in locations where the climate is more reliable, agricultural LCA is a field which is developing rapidly. This project is part of that development, and has two overall aims: to provide strategic intelligence to the red-meat industry on the environmental profile of its operations, from the production of inputs to farming to the products leaving the meat processing works; and to improve LCA for red-meat production, taking natural resource management issues into account.

CWWT teamed with Feedlot Services Australia for this contract. In 2007, the project team used data collected in 2006 to develop a comprehensive life cycle assessment model of red meat supply chains in three states. We also reviewed the methods for reporting water use in relation to agricultural production.

**Project**  
**Review of the Sustainability Framework with respect to the Gold Coast Waterfuture Process**

**Funding Body**  
Water Services Association of Australia

**Research Team**  
S Lundie, G Peters, N Ashbolt

**Duration**  
2007

In 2005, a consortium of researchers from the Centre for Water and Waste Technology, the School of Civil and Environmental Engineering (UNSW, Sydney), the Sustainable Water Division of the NSW Department of Commerce (Sydney) and Chalmers Industriteknik (Chalmers Technical University, Sweden) was funded
by an ARC Linkage Grant to develop a sustainability framework for evaluating urban water systems. The industry partners were the Water Services Association of Australia (WSAA) and the Total Environment Centre. The objective of the project was to develop a common methodology for evaluating the overall sustainability of alternative options for urban water systems. This includes large scale options for cities as well as configurations of water-sensitive urban development’s or single high rise developments. In particular the project aimed for a common methodology for evaluating overall sustainability of alternative options for urban water systems, noting the range in alternative tools and approaches currently being used.

In 2007, this “Sustainability Framework” was announced at the national Ozwater conference and endorsed by the Board of WSAA. It was also the subject of an extension research project on the Gold Coast Waterfuture (GCWF) process, a program of consultation and planning that lead to long-term directions being set for the future of the water supply in south-east Queensland. The review compared and contrasted the Framework with the GCWF process, and showed that while some details of the methodologies differed, there was a significant level of commonality which suggests that the Sustainability Framework provides a practical procedure that allows the evaluation of the overall sustainability of urban water systems. The comparison of the WSAA Sustainability Framework and the approach taken in the GCWF project showed a high degree of concordance between the two approaches and has given us confidence that the WSAA Framework works. This case-study demonstrates the WSAA Framework in the context of large-scale decision-making, but we see no reason why it would not work when tailored to smaller projects.

GCW should be recognised as having undertaken a very comprehensive sustainability assessment process and incorporating an advanced form of community engagement which leads the way in the Australian water industry. This engagement has lead to a high degree of community support for GCW’s plans. The GCWF project gives us substantial confidence that the stakeholder empowerment process is both practical and valuable for its ability to generate public endorsement for a planning process.

<table>
<thead>
<tr>
<th>Project</th>
<th>Removal of Potential Impact of Pharmaceutical Active Compounds during Wastewater Treatment</th>
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<tbody>
<tr>
<td>Funding Body</td>
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<td>Research Team</td>
<td>R Stuetz, N Ashbolt, S Khan, K Jury (PhD student) and N Le (PhD student)</td>
</tr>
<tr>
<td>Duration</td>
<td>2005 – 2008</td>
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</table>

Municipal wastewater effluents typically contain low concentrations (ng l-1) of pharmaceutically active compounds (PhACs). Some PhACs are known to have both acute and chronic health effects as well as environmental implications. This
The project is investigating the fate of PhAC in wastewater treatment processes and spread of bacterial resistance.

During 2007, baseline studies continued with the two laboratory scale bioreactors (Activated Sludge and MBR) after which a spiking trial was commenced in the two bioreactors with the addition of a low concentration of sulphonamide from mid 2007 to study the impact of the PhAC on the operation of the bioreactors in terms of operational parameters and to do preliminary studies on the fate of the micropollutant and its impact on the microbial community.

Development of analytical techniques using HPLC-MS-MS for quantifying sulphonamide and daughter compounds where undertaken by Nhat Le whereas Karen Jury focused on studying the impact of sulphonamide dosing on changes to the bioreactor microbiota and commenced initial screening of microbial bacterial resistance for sulphonamide resistance genes, SUL 1 & 2. This information was presented at two national conferences.

Further optimisation of molecular methods for the detection of sulphonamide genes transfer between different bioreactors microbiota and the development of analytical methods for solid phase extraction of PhAC were also undertaken during 2007 with support from a practicum exchange student (Martin Troster). In addition two new pilot scale MBR bioreactors were established at the Malabar STP in collaboration with ARC DP0556980 (Chen & Stuetz) which will be used to study the fate of sulphonamide in real wastewater during 2008.

**Project**  Dust and Odour Emissions from Poultry Sheds  
**Funding Body**  Australian Poultry CRC  
**Research Team**  R Stuetz, X Wang, M Manefield (BABS), Gavin Parcs (PhD student) and Sania Wadud (PhD student, BABS)  
**Duration**  2005 – 2008
Intensive livestock operations are often the source of odour complaints from neighbouring residential. In Australia, population expansion has resulted in rural encroachment, increasing the potential for odour related complaints. The varied Australian climate almost exclusively dictates the use of mechanically ventilated poultry sheds to sustain profitable agricultural practices. These sheds produce significant odour and dust emissions, impacting upon the surrounding environment.

A collaborative project with QDPI, VicQPD and QUT funded from the Australian Poultry CRC is investigating the emission of dust and odours from tunnel ventilated sheds. The CWWT component aims to determine the composition of these odorous emissions using olfactory-GC-MS (GC-MS-O) analysis and better understand the formation of odours within the litter material. Emission samples have been collected from poultry sheds in Queensland and Victoria and are characterised in terms of their chemical composition and odorant characteristics via sorbent tube pre-concentrations, thermal desorption and GC-MS-O analysis. Litter samples are also collected from within the poultry shed and characterised in terms of their microbial community structure following DNA extraction and denaturing gradient gel electrophoresis (DGGE) analysis of the PCR products in order to generate fingerprints of microbial communities in chicken litter sheds.

The characterisation of emissions from poultry sheds over its 9 week production cycle have shown that the emission profiles changes with time and that a number of key odorants can be prioritised and tracked against changes in odour concentrations and microbial DNA yields. These studies indicated an intrinsic correlation between variations in odorant composition with time and strongly suggested that odorant formation can be linked to the metabolism of the biochemical process. Further studies during 2008 aim to better understand the relationship between the microbial composition and the formation and emission of odorants from chicken litter.

Olfactory – GC-MS system
Project: Fluorescence as a Tool for Sensitive Detection of Failures in Recycled Water Treatment and Distribution Systems

Funding Body:
Australian Research Council Industry Linkage (LP0776347) with City West Water Ltd., Gold Coast City Council, Melbourne Water, South East Water Ltd., Sydney Olympic Park Authority, Sydney Water Corporation and Water Corporation

Research Team:
S Khan and R Stuetz, A Baker (University of Birmingham, UK), Michael Storey (Sydney Water Corporation), Rita Henderson and Adam Hambly (PhD Student)

Duration: 2007 - 2010

Pressure on water sources Australia-wide has led to an increased uptake of municipal water recycling schemes. This typically involves the treatment of secondary effluent to an advanced standard using technology including membrane and disinfection processes. This high grade water can then be recycled to households via dual reticulation systems (Figure 1) for low risk uses such as irrigation and toilet flushing. Potential risks for such schemes include underperformance or failure of treatment technologies, in particular membrane processes and also cross-connections between recycled and drinking water pipes. For example, fifty direct cross-connections were identified during a random audit of properties. On-going, careful management of water recycling schemes is therefore essential to ensure public health and maintain public confidence. It has been identified that existing water quality monitoring techniques, such as conductivity and total organic carbon (TOC), do not provide the sensitivity or speed required to manage such eventualities.

Fluorescence spectroscopy has received attention in the water industry recently due to the sensitivity of the method for detecting dissolved organic matter, ease of sample preparation and rapidity of analysis. It is therefore a most promising approach in the identification of very low concentrations of sewage-derived organic matter.

This project aims to devise a rapid, sensitive monitor of water quality using fluorescence spectroscopy. The intended outcomes include a technique that can be used for online monitoring of underperformance or failure of treatment processes and also as a portable system for rapid identification of cross-connections in dual reticulation systems.
<table>
<thead>
<tr>
<th>Project</th>
<th>Development of an Ecotoxicity Toolbox to evaluate water quality for recycling</th>
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</thead>
<tbody>
<tr>
<td>Funding Body</td>
<td>National Water Commission (NWC) under the Raising National Water Standards Program and industry partners including The West Australian Department of Water and Water Corporation.</td>
</tr>
<tr>
<td>Research Team</td>
<td>H Khan, H Coleman (and other collaborators).</td>
</tr>
<tr>
<td>Duration</td>
<td>2007 - 2010</td>
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</table>

The project aims to develop an innovative toolbox of ecotoxicity tests that can be used to assess and ensure the environmental safety of water intended for recycling or discharge into the environment. It has been clearly established that chemical measurements alone are not sufficient basis on which to base risk assessment for trace chemicals; this project will provide a major advance towards addressing this shortcoming. Knowledge gained will be of great value for the guidance of policy development and management of water recycling projects throughout Australia.

To assess the potential ecotoxicity of wastewater, the ANZECC/ARMCANZ (2000) guidelines recommend whole of effluent toxicity (WET) testing. In the case of wastewater, specific tests for endocrine disruption, cytotoxicity, mutagenicity and genotoxicity are also required. Such a toolbox of tests does not currently exist for freshwater biota in Australia. In order to address this, the proposed project has 2 components:
1. Measure hormonal activity, as a measure of endocrine disruption potential, in raw wastewater and in waters treated to various qualities for water recycling.

Hormonal activity will be measured in raw wastewater, and at 2-3 stages through the wastewater treatment process for a number of wastewater treatment plants. Hormonal activity will be measured by in-vitro bioassays, which provide a measure of the potential for endocrine disruption. These tests have not been performed previously in WA, and will allow comparison with the levels measured elsewhere in Australia and around the world. It is known that this is dependent on the wastewater treatment process and climatic conditions.

2. Evaluate the use of an ecotoxicity toolbox approach to assess the environmental impact of treated wastewater in the freshwater environment. This component will build upon an existing toolbox of ecotoxicity tests developed at the CRC for Water Quality and Treatment, and evaluate this toolbox for use in Western Australia. The development of this toolbox will provide the capacity to assess the potential for environmental impacts resulting from wastewater recycling and discharge. The toolbox will consist of in-vitro tests for endocrine disruption, cytotoxicity, mutagenicity and the development of a new test for genotoxicity. Additionally, in-vivo tests on the indicator fish species Gambusia will be performed, results of which will be verified with field work. It is anticipated that both components of this work will provide data able to demonstrate a reduction in the endocrine disruption potential and ecotoxicity of wastewater through the wastewater treatment process. This will be valuable both to inform the regulation of wastewater discharge and recycling, and to inform community understanding of water quality.

The Research Team at Beenup WWTP (Perth)
<table>
<thead>
<tr>
<th>Project</th>
<th>A National Approach to Risk Assessment, Risk Communication and Management of Chemical Hazards from Recycled Water</th>
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<tr>
<td>Funding</td>
<td>National Water Commission (NWC) under the Raising National Water Standards Program and industry partners including</td>
</tr>
<tr>
<td>Body</td>
<td>S Khan, H Coleman and other collaborators from ACTEW, Melbourne Water, Sydney Water, United Water, and SA Water</td>
</tr>
<tr>
<td>Duration</td>
<td>2007 - 2010</td>
</tr>
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</table>

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. This project involves collaboration between established researchers and industry partners representing major stakeholders in health issues surrounding recycled water use. However toxicity testing also has a number of limitations that must be recognised. One is that no matter how complex a bioassay system (or organism) may be, it will never be identical to a human being and thus some uncertainty will remain in terms of extrapolation of results to public health implications.

This work involves using biological methods (= bioassays or bioanalytical techniques) in addition to chemical monitoring, to directly measure the biological activity of a water sample, provide more complete information on potential adverse health effects than chemical data alone. This will assist the development of more accurate methods for monitoring and assessment as required in a management approach to protection of ecological and public health. Some of the same bioassays can also be used to monitor discharged wastewater and/or treatment prior to discharge, thus preserving the quality of both Australia’s environment and the health of the human population. A significant strength in this approach is that because we are dealing with effects at a sub organism level the information can be applied to potential ecosystem effects and human health impacts.

The broad aim of the study is to adopt and validate methods or tools for assessing the potential for ecosystem and/or human health impacts from drinking water that contains a significant proportion of recycled water.
<table>
<thead>
<tr>
<th>Project</th>
<th>The Use of Chiral Pharmaceutical Compounds to Characterise Sewage Treatment Processes and Sewage Contamination of Surface Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding Body</td>
<td>ARC Discovery Grant (DP0772864)</td>
</tr>
<tr>
<td>Research Team</td>
<td>S Khan, Nor Haslina (PhD student)</td>
</tr>
<tr>
<td>Duration</td>
<td>2007 - 2009</td>
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</tbody>
</table>

The aim of this research is to investigate a promising, but poorly characterised chemical marker for exposure to biological sewage degradation. Such a marker will enable improved characterisation of secondary sewage treatment processes as well as the differentiation of raw sewage contamination from treated sewage contamination of surface waters.

Many studies of secondary sewage treatment processes report the ‘removal’ of chemicals from the effluent compared to the influent. However, in most cases, it is not possible to confidently distinguish biodegradative removal mechanisms from other non-biodegradative methods such as adsorption to solids or partitioning to surface scum. This has been a major limitation in the detailed characterisation of secondary treatment processes required for effective modelling of the systems. Accurate characterisation and modelling is needed for improved optimisation of design and operating parameters of sewage treatment plants. The proposed research will investigate a means of clearly distinguishing relative degrees of biodegradative and non-biodegradative removal of some chemicals during treatment processes.

Surface waters are occasionally exposed to untreated sewage as a result of leaking sewers or combined sewer overflows. This is significant since untreated sewage contains a greater diversity and significantly greater concentrations of environmentally significant chemicals and micro-organisms compared to properly treated and discharged sewage. Unfortunately, pollution by untreated sewage is generally not distinguishable (in discrete aqueous samples) from properly discharged treated sewage effluent. This research will provide a novel chemical marker for identifying and characterising untreated sewage pollution. This, in turn, will help to identify the sources of such pollution so that they may be corrected.

The approach proposed to address these issues is to gain insights to the phenomenon of enantiomeric ratio enhancement of some chiral chemicals during biodegradative sewage treatment processes. It is anticipated that this phenomenon will provide strong and reliable indications of the nature and degree of biodegradative sewage treatment to which the compounds have been subjected. The approach has the advantage of not being affected by sample volume, short-term concentration fluctuations or variable extraction recoveries for different chemicals.
Molecular structures of some stereogenic 2-APA NSAI agents

**Project**  
**Adsorption and Removal of Trace Organic Compounds by Membrane Processes used in Water Treatment and Wastewater Recycling**

**Funding**  
ARC Discovery Grant (DP0557085)

**Research Team**  
S Khan, J McDonald, J Drewes (Colorado School of Mines), P Le-Clech (UNESCO Centre for Membrane Science and Technology).

**Duration**  
2005 - 2008

Trace organic compounds adsorb to polymeric membranes, which are used in water treatment and wastewater recycling. The mechanisms of retention, adsorption and desorption as well as the interaction with fouling layers are poorly understood. The accumulation and sudden release of hazardous compounds may
pose a significant risk in water treatment and recycling applications. This project aims to identify sorption and retention mechanisms of trace organic contaminants, mechanistically describe the release of trace organic compounds during desorption scenarios as well as develop a model to predict performance.

Analytical methods have been developed with the adaptation, expansion and optimisation of a gas chromatography-mass spectrometry method with solid phase extraction. A method is now optimised for the simultaneous analysis of 21 trace chemical contaminants. Initial investigations have demonstrated that the solution pH, ionic strength, as well as the presence of divalent cations and anions, can markedly influence the removal of ionisable trace organic compounds by high pressure membrane processes. These observations were explained by electrostatic interactions between the solutes and the membrane surface and by the speciation of the ionisable compounds. Membrane fouling has been shown to exert considerable impact on the retention of trace organics from nanofiltration membranes. The observed rejection behaviour of some key chemicals has been shown to be valuable for elucidating the specific mechanisms by which fouling alters membrane properties with implications to a wider range of contaminants.
6 **CWWT Supported Research Students**

The following research students received scholarship, project funding and/or support through CWWT activities during 2006.

<table>
<thead>
<tr>
<th>Student</th>
<th>Thesis topic</th>
<th>Degree</th>
<th>Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebecca Barnes</td>
<td>Decision-making for sustainable water and sanitation interventions in rural developing communities</td>
<td>PhD</td>
<td>D. Roser R Stuetz</td>
</tr>
<tr>
<td>Mark Bligh</td>
<td>Fate and transformation of Iron and Phosphorus in Coastal Waters – Implications for Bloom Forming Benthic Cyanobacterium,</td>
<td>PhD</td>
<td>D. Waite</td>
</tr>
<tr>
<td>Christopher Duesterberg</td>
<td>Kinetic modelling of advanced oxidation processes involving Fenton’s reagent</td>
<td>PhD</td>
<td>D. Waite</td>
</tr>
<tr>
<td>Aurelie Godrant</td>
<td>Iron uptake by Trichodesmium: impact of superoxide production.</td>
<td>PhD</td>
<td>D Waite A Rose</td>
</tr>
<tr>
<td>Adele Jones</td>
<td>The Transport and Transformation of Aluminium (Al) and Iron (Fe) from Acid Sulfate Soils (ASS)</td>
<td>PhD</td>
<td>D. Waite</td>
</tr>
<tr>
<td>Christine Kaucner</td>
<td>Surface properties of Cryptosporidium oocysts.</td>
<td>MSc</td>
<td>N. Ashbolt</td>
</tr>
<tr>
<td>Sashikala Maruthai Pillai</td>
<td>Headspace analysis of chemical odorants from broiler chicken litter</td>
<td>MSc</td>
<td>R Stuetz</td>
</tr>
<tr>
<td>Elizabeth Lai</td>
<td>Development of an integrated sustainability assessment framework for best practice management of urban water systems.</td>
<td>PhD</td>
<td>S. Lundie N. Ashbolt</td>
</tr>
<tr>
<td>Nhat Le Minh</td>
<td>Removal of antibiotics in Wastewater using activated sludge and membrane bioreactor</td>
<td>PhD</td>
<td>R. Stuetz S Khan</td>
</tr>
<tr>
<td>Kate Murphy</td>
<td>Seawater tracers and their application to verifying mid-ocean ballast water exchange</td>
<td>PhD</td>
<td>D. Waite W.Dunsmuir</td>
</tr>
<tr>
<td>Nor Haslina Hashim</td>
<td>The Use of Chiral Pharmaceutical Compounds to Characterize Sewage Treatment Processes and Sewage Contamination of Surface Waters</td>
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<td>S. Khan R. Stuetz</td>
</tr>
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</tr>
<tr>
<td>Nanda Altavilla</td>
<td>Factors affect the fate of <em>Cryptosporidium parvum</em> oocysts in catchments</td>
<td>PhD</td>
<td>D Roser, R Stuetz</td>
</tr>
<tr>
<td>Gavin Parcsi</td>
<td>Chemical analysis of Odorants from Poultry Facilities</td>
<td>PhD</td>
<td>R. Stuetz</td>
</tr>
<tr>
<td>An Ninh Pham</td>
<td>Generation and Transformation of Iron and Manganese in Lake Burratorang</td>
<td>PhD</td>
<td>D. Waite</td>
</tr>
<tr>
<td>Suvinai Santiwong</td>
<td>Characterisation of compressible cake and control of cake permeability in submerged membrane filtration: implications to low pressure membrane filtration in water treatment</td>
<td>PhD</td>
<td>D. Waite</td>
</tr>
<tr>
<td>Nida Seelsaen</td>
<td>Stability of Recycled Organic Material in Urban Water Treatment.</td>
<td>PhD</td>
<td>R. Stuetz</td>
</tr>
<tr>
<td>Eric Sivret</td>
<td>Nitrous Oxide Monitoring for Nitrification Process Control</td>
<td>PhD</td>
<td>R. Stuetz</td>
</tr>
<tr>
<td>Adam Hambly</td>
<td>Fluorescence as a Portable Tool for Cross-Connection Detection</td>
<td>PhD</td>
<td>S. Khan, R. Stuetz</td>
</tr>
<tr>
<td>Hazel Rowley</td>
<td>Enhanced weighting techniques for multi-criteria decision making in sustainability assessment</td>
<td>PhD</td>
<td>G Peters, R Stuetz</td>
</tr>
<tr>
<td>Jacquie Thomas</td>
<td>Free-living amoebae as reservoirs of microbial pathogens in municipal (reuse and potable) water distribution systems</td>
<td>PhD</td>
<td>R Stuetz, N Ashbolt</td>
</tr>
<tr>
<td>Quan Sun</td>
<td>Application of nano-sized zero valent iron particles to agrochemicals degradation through Fenton's reagent oxidation</td>
<td>PhD</td>
<td>D. Waite, A. Feitz</td>
</tr>
</tbody>
</table>
Rebecca Barnes

**Project:** Planning for sustainable water and sanitation interventions in rural, developing communities

**Supervisors:** Dr David Roser, Dr Paul Brown and Assoc Prof Richard Stuetz

**Funding:** Women in Engineering Research Scholarship

**Project Outline:** Recent decades have seen a growing emphasis by theorists on the importance of environmental and social sustainability in the water and sanitation development industry. Despite this, there is evidence that development practice is not catching up. Premature failure or abandonment of rural water and sanitation development projects is a common phenomenon, and one which is preventing potential benefits from being fully realised. In searching for the cause, researchers have implicated poor initial planning processes. Proposed planning tools have not been, and often cannot be, adopted by development agencies.

For these reasons, the research aims to explore the relationship between planning processes and long-term sustainability, and to investigate feasible ways in which local-level project planning can be modified in order to improve the longevity of water and sanitation benefits for the poor.

The methodology has been twofold in order to obtain the advantages of depth and breadth of research. A case study in the Philippines tested the above aims using community focus groups in four remote Filipino communities, interviews with development workers, and observational techniques. It also involved trialling a planning framework in a workshop with 25 Filipino development workers. In order to verify the context-specific results of the Philippines case study, semi-structured interviews were conducted with 30 water and sanitation development professionals, chosen to represent all global regions and organisational types.
Adam Hambly

**Project:** Fluorescence as a Portable Tool for Cross-Connection Detection

**Supervisors:** Dr Stuart Khan and Assoc Prof Richard Stuetz

**Funding:** Australian Postgraduate Award (Industry), ARC Linkage Projects funding scheme (LP0776347).

**Background:** Adam completed a B.Sc (Hons) in Chemistry at the University of Sydney in 2006. He then worked as a Research Assistant within the Chemistry department at the University of Sydney (2006-2007) prior to commencing a PhD at UNSW in September 2007.

**Project Summary:** Municipal water recycling has become a key component of water management in the modern world, and recycling schemes are increasingly relying on membrane processes such as reverse osmosis to regenerate high quality water. Dual reticulation systems are being used in a number of housing areas for the redistribution of recycled water back to households by a separate pipe. As with all water systems they risk underperformance and hence require careful monitoring to prevent potential events such as cross-connections of non-potable water with potable water supplies. Cross-connection incidents can seriously undermine public confidence in a dual reticulation scheme and water recycling in general so a rapid, online method of detection is needed to ensure proper management of these networks.

Water sciences have implemented a vast number of techniques to assess water qualities, such as total organic carbon (TOC), conductivity, pH, biochemical oxygen demand (BOD) and turbidity, however research into fluorescence-based techniques are becoming increasingly prevalent within the field. Fluorescence-based spectroscopy has been implemented in water sciences for over 50 years to investigate the composition, concentration, distribution and dynamics of organic matter, however improvements in technology such as, instrument speed, range and stability as well as data storage and processing speeds has allowed fluorescence spectroscopy to evolve into a much more advanced analytical tool. This project aims to use excitation-emission fluorescence spectroscopy to develop an efficient, online diagnostic tool for detecting recycled water within potable water supplies.

The experimental section of this project involves the close development of a fluorescence EEM database, the comparison of various mixtures of waters, the undertaking of extensive mapping at dual reticulation system sites, the comparison of the usefulness against other methods such as conductivity, and the testing of the possibility of dosing into the system to enhance sensitivity. The project is currently within a large sampling and analysis stage, showing promising results in line with the pilot study carried out.
Nor Haslina Hashim

**Project:** The Use of Chiral Pharmaceutical Compounds to Characterize Sewage Treatment Processes and Sewage Contamination of Surface Waters

**Supervisors:** Dr Stuart Khan and Assoc Prof Richard Stuetz

**Funding:** ARC Discovery Project and Malaysian Government (under Academic Training Scheme for Public Higher Education Institute (SLAI), Ministry of Higher Education).

**Background:** MEng in Environmental Engineering from University of Technology Malaysia and BSc in Chemistry from University of Malaya, Malaysia. Before starting a PhD in the end of October, 2006, I worked as a Junior Lecturer at Tun Hussian Onn University of Malaysia.

**Project Summary:** Surface waters are occasionally exposed to untreated sewage as a result of leaking sewers or combined sewer overflows. This is significant since untreated sewage contains a greater diversity and significantly greater concentrations of environmentally significant chemicals and microorganisms compared to properly treated and discharged sewage. Unfortunately, pollution by untreated sewage is generally not distinguishable (in discrete aqueous samples) from properly discharged treated sewage effluent.

The non steroidal anti inflammatory (NSAI) agents that have now been identified many times in sewage and surface water offer an ideal set of model anthropogenic compounds with which to undertake this study. NSAIs are used to relieve some symptoms caused by arthritis, gout attacks, menstrual cramps, fever, bursitis, tendinitis, sprains, strains and other injuries. The molecular structures of each of the 2-APAs feature a stereogenic centre in the form of a chiral carbon atom makes these molecules exist in either of two enantiometric forms (R- and S-). Investigations will be focus on ibuprofen, ketoprofen, naproxen and tiaprofenic acid since there are the only 2-APAs dispensed in significant quantities in Australia. In this study, their stereoselective activities normally administered as racemic mixtures will be investigate as the previous studies showed that the enantiomer of these substances degraded at different degrees due to the phenomenon of environmental stereoselective enhancement. By measuring their enantiomeric fraction (EF), the proposed research will provide a novel chemical marker for identifying and characterising untreated sewage pollution. This, in turn, will help to identify the sources of such pollution so that they may be corrected.

Since both of extracted enantiomers have similar physical properties, separation and identification are only possible by converting them into volatile diastereomeric forms by using derivatization method. Samples are derivatized in two steps; activation and amidation by using phenylethilalanine (PEA) in the presence of ethylchloroformate (ECF) and triethylamine (TEA) prior to analyze using Gas Chromatography-Mass Spectrometer (GCMS).

This study will involve a thorough investigation of enantiomeric ratio enhancement of 2-APAs during sewage treatment processes as well as during residence in surface waters. The effects of a variety of environmental conditions and residence times will be investigated in laboratory-scale bioreactor systems, full-scale treatment systems and natural environmental systems.
Adele Jones

**Project:** The Transformation and Transport of Fe and Al from Acid Sulfate Soils to Estuarine Environments

**Supervisors:** Prof T. David Waite and Dr Richard Collins

**Funding:** Australian Postgraduate Award (Industry) / ARC Linkage: ARC, Tweed Shire Council and NSW Canegrowers Association

**Background:** Adele completed a BSc(Hons1) majoring in Chemistry at the University of Sydney in 2001. She then worked as in various roles as an analytical chemist for Energy Australia and an industrial wastewater treatment plant, and as a laboratory manager for Colloidal Dynamics P/L prior to commencing a PhD at UNSW in March 2005.

**Project Summary:** Acid sulfate soils contain reduced iron sulfide species, which oxidise upon exposure to air, releasing toxic quantities of Fe and Al. During flooding significant quantities may be exported to the main estuary. The various transformations that Al and Fe may undergo can greatly impact on the toxicity of the metal species in addition to affecting its transport, thereby impacting on the concentration that may be released. Understanding these transformations is therefore very important particularly as acid sulfate soils tend to surround estuarine environments that provide for productive breeding grounds and a lucrative fishing economy.

This project therefore focuses on investigating the various metal species transformations that Fe and Al may undergo as they are initially released from the soil and then travel via floodwater drains into the main estuary. This involves both field studies and laboratory experiments.

Laboratory studies to date have been successful in understanding the role of natural organic matter in facilitating the transport of metal species, the impact of sunlight mediated iron species transformations, the main form and reactivity of iron mineral species within the soil profiles, the impact of pH on the release of Al from the soil profile and the likely species controlling the solubility of Al within the soil profile and within the flood drain water.

![Our Flooded Field Site on the Tweed River Floodplain](image-url)
Field studies have confirmed the results of some of these laboratory studies, in addition to determining where, at our field site in the Tweed River floodplain, most of the Al, Fe and acidity are generated. This has enabled certain landscapes in the floodplain to be targeted as likely ‘hotspots’ for contaminant production. The field studies also demonstrate that certain practices, some of which are currently in place at the field site, are useful in reducing the export of Fe, Al and acidity from the soil to the main estuary.

Overall, the results of our studies have assisted in determining what remediation plans are/would be useful to undertake on a larger, catchment scale and where resources should be targeted in order to reduce the deleterious effects during flooding.

Hazel Rowley

Project: Enhanced weighting techniques for multi-criteria decision making in sustainability assessment

Supervisors: Dr Greg Peters and Assoc Prof Sven Lundie

Funding: Australian Postgraduate Award/ UNSW/Faculty of Engineering Scholarships

Project Summary: My research is concerned with improving the applicability of environmental and sustainability impact assessment tools to decision making and policy, by enhancing weighting methods for multi-criteria decision making (MCDM).

Decision-makers at many levels - from individuals to governments - increasingly wish to base their decisions on a range of economic, social and environmental criteria, in order to address concerns about sustainability. One of the most significant barriers to more effective decision making in sustainability is the difficulty that arises when one option is not absolutely better than another in terms of multiple criteria. For example, Option A may use less water but cause more greenhouse gas emissions than Option B.

If this problem occurs, it may be addressed using an MCDM approach, for example by computing a weighted aggregate score. Even when this ‘weighting’ is not explicitly carried out by an analyst, it must be implicitly carried out by the decision-maker for one option to prevail. In practice, this may result in a default weighting of unity for all criteria, which is far from ideal. However, there are a number of barriers to the practical application of an explicit weighting process. My research will address two of the most significant of these barriers, in the context of a specific environmental impact assessment technique: life cycle assessment (LCA). My research will also have implications for various other MCDM problems in sustainability assessment.

I aim to improve the use of environmental and sustainability impact assessment tools in decision making and policy, by answering the following:

- How can criteria interaction be accounted for in MCDM problems?
How can decision-making processes be made easier with respect to improved weighting procedures?

How can these methods be applied to improve the applicability of LCA and other sustainability impact assessment tools to decision making and policy?

The environmental impacts of society are ultimately driven by the consumption of goods and services, during their production, use and disposal. Therefore, one of the most effective ways to reduce our environmental impacts and improve our sustainability is by making ‘greener’ or more sustainable purchasing decisions.

Aggregation methods for the performance of consumer goods against multiple criteria will enable more effective consumer product labelling. This is analogous to the Weight Watchers™ ‘points’ system of food labelling, which provides consumers with a single, easily-understood metric rather than a detailed nutritional information profile. This is one example of how my research may enhance sustainability, by improving the ability of decision-makers to use the results of environmental and sustainability impact assessments.

Karen Jury

Project: Investigation of the role of antibacterial drugs in municipal wastewater as a selective influence on the spread of bacterial resistance.

Supervisors: Assoc Prof Richard Stuetz, Prof Nick Ashbolt, Dr Stuart Khan, Dr Tony Vancov and Dr Paul Gill

Funding: ARC Discovery.

Project Outline: Multi-resistant bacteria, especially pathogens, are a serious worldwide health issue. Over exploitation and inappropriate use of antimicrobial agents, particularly in medical and agricultural practises, have led to a proliferation of multi-resistant bacteria. An environment loaded with bacteria carrying antibiotic resistance genes capable of lateral transfer has disastrous health consequences. Preventing the potential spread of antimicrobial resistance genes within the environment would be greatly served by a better understanding of these mechanisms, particularly studies focusing on point of source transfer in their natural habitats.

This study focuses on one ‘hotspot’ area; the waste water treatment plant (WWTP). The synthetic antimicrobial Sulfamethoxazole (smx) has three sulphonamide resistance genes; sul1, sul2 and sul3 and has been selected as a model antibiotic for this study. Low levels of smx will be added to two pilot-scale WWTP bioreactors; a traditional activated sludge (AS) reactor and a membrane bioreactor (MBR) which is an emerging technology for waste water treatment. Comparative studies (culturable and molecular) will be performed on reactor biomass samples to determine: sul gene levels within the population (real-time PCR), ascertain whether transference is clonal or lateral (DNA fingerprinting; LH-
PCR, DGGE) and phenotypic and genotypic characterisation of smx resistant isolates.

Progress to date: A low concentration (1ng/L) of sulfamethoxazole was added to the reactors over a 10 month period. Total reactor DNA was isolated and the bacterial communities profiled by DNA fingerprinting (LH-PCR). Additionally smx resistant bacterial isolates were antibiotic profiled and genotyped (DGGE, REP-PCR).

A snap-shot look at the culturable smx resistant bacteria showed an immediate response in both reactors after the smx spike. The AS smx resistant bacterial numbers initially increased 2-fold and maintained this level for 2 months before dropping back to pre-spike levels. Similar trends were noted in the MBR except that it maintained high levels of sul resistance for 5 months before dipping back to pre-spike numbers. DNA fingerprint analysis of the reactor communities (LH-PCR) revealed dramatic changes in bacterial diversity after smx spiking. Genotyping and antibiotic profiling of smx resistant isolates revealed that each bioreactor contains distinctly unique culturable bacteria. Furthermore, AS smx resistant isolates were found to carry only sul1 resistance genes, whereas the MBR isolates were observed to harbour either sul1 or sul2 genes.

Nhat Le-Minh

Project: Removal of Antibiotics in Wastewater Using Activated Sludge and Membrane Bioreactor

Supervisors: Assoc Prof Richard Stuetz and Dr. Stuart Khan

Funding: UIPA Scholarship, UNSW/Faculty of Engineering Scholarships, ARC Discovery

Background: Nhat completed a Bachelor of Environmental Engineering at the University of Southern Queensland in 2006 and commencing a PhD at UNSW after his graduation.

Project Summary: There has been an increasing concern about the presence of antibacterial agents within a sewage treatment plant (STP) and its immediate receiving environments. Antibiotics like many other pharmaceutical compounds are present in domestic sewage via either human excretion or disposal of unused drugs into the sewer. Municipal water recycling processes are potential persistent human exposure routes of low concentrations of antibiotics. While the implications of such exposure scenarios are unknown, concerns have been raised regarding the possibility that they may facilitate the development or proliferation of resistant strains of bacteria. As planned indirect potable reuse (IPR) schemes are developed, utilising significantly increased portions of reclaimed municipal effluents, it is imperative to improve our understanding of the fate antibiotics during conventional sewage treatment processes and new treatment technology.
The input of antibiotics may change the characteristics of the microbiological community in the STP reactors, in which certain bacteria that are able to assimilate antibiotics may become dominant. However, information about the potential development of antibiotic resistant strains within the STP and its impact on the performance of the treatment processes is still unknown, implying more research needed on these aspects. In addition, membrane bioreactor is a new and alternative secondary treatment process for the conventional activated sludge. Although many preceding studies have assessed the effectiveness of conventional activated sludge in eliminating antibiotics, information about the treatment capacity of membrane bioreactor is still insufficient. The objectives of this research are to compare effectiveness of the conventional activated sludge and that of membrane bioreactor in treating the selected antibiotics, to model the partitioning between aqueous and biomass phases (i.e. sorption to sludge of each antibiotics), but taking into account the potential inter-transformation between active forms and metabolites, and to assess the potential development of the antibiotics resistant strains during the treatment processes and its impacts on the treatment performance. This research uses pilot scale AS and MBR as simulation models to investigate the fate of the sulfonamide and trimethoprim antibiotics within the treatment processes. Long-term spiking with antibiotics is used to simulate the environmental input of the drugs from the wastewater stream into STP. The development of analytical method using solid phase extraction and HPLC-MS-MS techniques is also a focus of the study to improve the detection sensitivity for antibiotics in wastewater matrix.

Sashikala Maruthai Pillai

**Project:** Headspace analysis of chemical odorants from broiler chicken litter

**Supervisor:** Assoc. Prof. Richard Stuetz

**Funding:** Malaysian Government (MARDI) Scholarship and Australian Poultry CRC

**Background:** BSc(Hon)(Chemistry), University Technology of Malaysia, 1999.

**Project Outline:** Broiler chicken farm is an expanding business in Australia and Malaysia. The expansion in
population to establish cities has led to urban encroachment near farming agricultural sites. This expansion has caused an increase in the number of odour complaints especially from the broiler chicken farms, which are often located within the existing buffer distance between the sheds and surrounding rural residences. Previous poultry research at CWWT has suggested that chicken litter maybe a significant source for odorous emissions from tunnel ventilated poultry sheds. A better understand of the pathways of odour production will enable improved odour management of odours from poultry sheds.

The aims of this project are to develop a method to assess the odorants generation from the broiler chicken litter samples and to characterise the odorants from chicken litter using olfactory GC-MS or GC-MS-O. The initial experimental work will involve developing a protocol for direct headspace sampling of the litter following by thermal desorption and GC-MS-O analysis of VOC from the chicken litter. Different litter samples will be compared to determine if variations can be observed in the chicken litter due to the production cycle of the poultry shed. VOCs characterisation will also be correlated to the chemical composition of the chicken litter and the environmental conditions of the chicken shed.

Eric Sivret

Project: Nitrous Oxide Monitoring for Nitrification Process Control
Supervisors: Assoc Prof Richard Stuetz and Dr. William Peirson
Funding: Endeavour International Research Scholarship, UNSW/Faculty of Engineering Scholarships
Background: Eric completed a B.Sc.E. in Chemical Engineering at the University of New Brunswick (Canada) in 2001. He then worked as an environmental consultant with Jacques Whitford Environment Limited in Canada (2001-2005) prior to commencing a PhD at UNSW in March 2005.
**Project Summary:** The nutrient enrichment of water bodies can promote the formation of algal blooms which upset natural ecosystems, killing other forms of aquatic life and potentially introducing toxins, colours and tastes into the source water for potable water treatment plants. One of the controllable sources of nutrient emissions to water bodies is from municipal sewage. Nitrogen emissions from sewage are commonly mitigated using a two step biological nutrient removal process (aerobic nitrification and anoxic denitrification). Control of these processes has a strong influence on operating costs, and is crucial to provide an effluent of sufficient and consistent quality to meet environmental discharge regulations.

This project focuses on the development and implementation of a non-invasive aeration control system (based on off-gas nitrous oxide analysis) for the nitrification component of nutrient removal systems. While the concept of process control based on off-gas analysis exists in literature (particularly related to respirometry and anaerobic digester biogas production), the use of nitrous oxide gas emissions from nitrification plants for process control currently exists only at the conceptual level.

Experimental components of this project will be conducted using a laboratory scale activated sludge pilot plant equipped with an off-gas analysis system and process control equipment. The objectives of the experimental work will be to increase understanding of the response of nitrification systems (with emphasis on gaseous emissions) to fluctuations of selected process parameters, and to evaluate the cost-effectiveness (in terms of aeration costs and costs associated with emissions to the environment) and technical feasibility of the developed control system in the context of existing control systems. In addition to the above objectives, the experimental component will support, and be supported by, a process modelling study that will expand upon existing activated sludge models to allow the prediction of gaseous emissions of nitrous oxide.

**Nanda Altavilla**

**Project:** Factors affecting the fate Cryptosporidium parvum oocysts in catchments

**Supervisors:** Dr. David Roser, Assoc Prof Richard Stuetz, Dr. Dan Deere, Prof Nicholas Ashbolt

**Funding:** CRCWQT

**Background:** Since graduating from UNSW in 1988, Nanda has been involved with microbial ecology research at both Sydney and Macquarie Universities, working on various projects ranging from the degradation of pesticides and other
recalcitrant pollutants to the assessment of River Health. In 2000, Nanda joined a multidisciplinary research team with the CWWT as a PhD student working on project 2003/5: “Fate and Transport of Surface Water Pathogens in Watersheds”. Nanda has also been involved with teaching both post graduate and undergraduate students and continues to do so as a guest lecturer at Macquarie University and the University of Notre Dame. Currently, she is employed as a Senior Policy Advisor for NSW Health.

**Project summary:** The focus is on the effect of environmental factors, namely temperature, moisture and biota, upon the inactivation of *Cryptosporidium parvum* oocysts in faecal deposits. A rapid and simple method for the detection and quantification of potentially viable oocysts using fluorescent *in situ* hybridisation (FISH) was developed.

Using the FISH method, it was determined that there was no difference between the inactivation rates of oocysts on the surface or in the centre of artificial cow pats despite the fact that the surface of a cow pat is drier than the centre.

Further investigation was conducted into the effect of temperature, moisture and biota, upon on the inactivation of oocysts in faecal matter in multifactorial experiments. In order to design the experiments to accurately reflect the natural environment, temperature probes were inserted into freshly deposited cow pats at a dairy farm. In both summer and winter periods, temperature within the pats is buffered from the upper and lower extremes of the ambient diurnal fluctuations. The temperatures for the experiments were set up to reflect temperatures encountered by oocysts enmeshed in the centre of the pat. Temperature has emerged as the main factor that effects inactivation, such that high temperatures lead to higher rates of inactivation. The inactivation rates generated from these studies have been incorporated into a model that can predict the likely load of oocysts that are generated on the land, taking into account the inactivation that occurs at ambient temperatures. Using readily available temperature data, the model can be easily applied to aid water and catchment authorities to better manage waterborne pathogens.

**Jacquie Thomas**

**Project:** Free-living amoebae as reservoirs of microbial pathogens in municipal (reuse and potable) water distribution systems

**Supervisors:** Prof Nicholas Ashbolt, Assoc Prof Richard Stuetz, Prof. Staffan Kjellberg and Dr. Michael Storey.

**Funding:** Sydney Water Corporation, U.S. Environmental Protection Agency, Australian Postgraduate Award and Supplementary Engineering Award.

**Background:** Jacquie completed a BSc (Microbiology) with honours and BA (Politics and International relations) at the University of New South Wales in 2006. Jacquie commenced her PhD in March of 2007.
Project summary: With targets for reuse water in Sydney set at 70 billion litres a year by 2015 (Sydney Water Corporation, 2007) there is a clear need to further explore the potential microbial pathogen risks associated with this water source. The higher nutrient load of reuse water presents an environment suitable for increased microbial pathogen growth especially when combined with other favourable growth factors, such as an increase in temperature. The use of reuse water in cooling towers, truck hose downs, toilet flushing and garden watering presents unique exposure scenarios for which more extensive microbial risk assessments are required.

Cooling towers provide an ideal environment for microbial pathogens to proliferate due to the elevated temperatures and presence of biofilm. A review of Legionnaires infections revealed that 28% were associated with cooling towers. Furthermore, the replication of Legionellae in cooling tower biofilms has been shown to be due solely to intracellular growth within amoebae. Amoebae are frequently isolated from cooling towers and their ability to act as reservoirs for bacterial pathogens is well accepted. The question remains, however, if using reuse water (with its higher nutrient load) will result in a greater amoebae population and microbial pathogen risk for cooling towers? A greater understanding of the diversity of amoebae in both reuse and potable water and the biological and physical factors that lead to the uptake and release of microbial pathogens are required before attempting to answer this question.

The aim of this project is to explore the population diversity and distribution of free-living protozoa and associated with key bacterial pathogens in distribution system biofilms in an urban dual reticulation (drinking and reuse water) system. This will be achieved using the molecular identification method of quantitative polymerase chain reaction (qPCR). From these findings a risk assessment for the use of reuse water taking into consideration the opportunistic pathogens and free-living protozoa will be undertaken.

Quan Sun

Project: Contaminant Degradation Using Nanosized Zero Valent Iron Particles

Supervisor: Professor David Waite and Dr. Andrew Feitz

Funding: Australian Postgraduate Award (Industry)

Project Outline: Zero-valent iron (ZVI) has been successfully used for the degradation of a wide range of organic contaminants in groundwaters in recent years with the mechanism of transformation involving the reduction of the contaminant. This reductive application of ZVI is typically undertaken in the absence of oxygen.

Recent observations by Joo et al (2003, 2005) and Noradoum et al. (2003) have shown that if oxygen is present, a two electron pathway may also occur and products are ferrous iron and hydrogen peroxide, the reactants that constitute the
well-known Fenton reaction, the product of which is the powerful oxidising species, the hydroxyl radical.

The rate of both the oxidative and reductive transformation of contaminants by ZVI may be enhanced by use of nanosized zero valent iron (nZVI) particles which possess higher surface area than the more widely used granular materials. The most widely used method of producing nZVI involves the reduction of FeIII by sodium borohydride however this method is expensive. As a result, if nZVI technology is to be widely used, alternate less expensive methods of producing nZVI are required.

The aim of the project is to examine alternative methods of preparing nanosized zero valent iron (nZVI) particles (lowering the price from $66 to $9/kg) and to subsequently investigate their oxidative (and reductive) properties. It is expected that such investigations will i) provide insight into the mechanisms involved in the iron-mediated transformation processes, and ii) lead to the development of optimised treatment technologies.
### 7. CWWT STAFF

<table>
<thead>
<tr>
<th>Staff Member</th>
<th>Position</th>
<th>Phone</th>
<th>e-Mail</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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</tr>
</tbody>
</table>

* Academic staff of School of Civil & Environmental Engineering.
** Retired in June 2007
8. **CWWT PUBLICATIONS 2007**

**BOOKS**


**BOOK CHAPTERS**


**JOURNAL ARTICLES (REVIEWED)**


**CONFERENCE PAPERS (REVIEWED)**


**CONFERENCE PAPERS (NOT REVIEWED)**


TECHNICAL REPORTS


9. **Financial Statement**

Centre for Water and Waste Technology

**Statement of Financial Performance**
for the Year Ended 31 December 2007

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2006</th>
<th>Notes</th>
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<tbody>
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<td><strong>Income</strong></td>
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<td>External Funds*</td>
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<td>UNSW Contribution</td>
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<td>Internal Revenue</td>
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<td>Total Income</td>
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<td><strong>Expenses</strong></td>
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<td>Payroll</td>
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<td>938,070.19</td>
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<td>Equipment</td>
<td>128,060.52</td>
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<td>Materials</td>
<td>419,096.74</td>
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<td>Scholarship Stipends</td>
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<td>Travel</td>
<td>117,515.75</td>
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<td>Total Expenses</td>
<td>2,136,190.64</td>
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<td><strong>Operating result</strong></td>
<td>135,097.04</td>
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<td><strong>Surplus(Deficit) Bfwd from Prior Year</strong></td>
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<td>130,752.03</td>
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<tr>
<td><strong>Accumulated Funds Surplus(Deficit)</strong></td>
<td>726,507.14</td>
<td>591,410.10</td>
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<tr>
<td>* Excludes debtors (unpaid invoices)</td>
<td>105,337.55</td>
<td>298,538.96</td>
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</tr>
</tbody>
</table>

**Notes to the Statement of Financial Performance**
General Notes:
The method of financial reporting has been changed for the centre.
In previous years the financial reports included in the annual reports have been done on a semi accrual basis.
The method of reporting for the CWWT has been changed to comply with UNSW Policy and will now be reported on a cash basis.
Because of this change, the 2006 figures reported in this table have been reconstructed to allow for meaningful comparison with 2007.
The 2006 figures cash figures cannot be directly compared with the figures in the 2006 annual report.

Specific Notes:
1. Several projects were delayed due to the difficulty and time to find suitable replacement staff. An estimate of the sum of three of the projects affected is $300,000 to $650,000 of invoices not able to be sent during 2007.
2. The Centre does not pay any rent for the premises it occupies. It does not receive support for administrative salaries, telecommunications, internet access or other running costs, nor does it receive Research Quantum.
3. A line has been added for internal revenue.
Internal revenue for the CWWT comes from several different sources:
For 2006, internal revenue came from reimbursement for work done for another faculty, at UNSW, and from reimbursement of expenses – also within UNSW
For 2007, most internal revenue is recorded as coming from salary support from the school for lecturing work done ($35,000), and for work done for another faculty at UNSW ($7,545). Other small items comprise the remainder.
4. The increase in Payroll is due to 7 staff hired over the course of 2007. Two staff left during the year.
5. The Accumulated Funds amounts include the CWWT Staff Termination Preservation Account totals of:
   2006    $97,140.00
   2007    $112,528.00
This account was set up as a specific provision for staff where a termination payment is due.